Environmental Engineering Lab
(Lab Manual)
Civil Engineering Department
Civil 6th Sem
Preface

Environmental engineering is the application of science and engineering principles to protect and utilize natural resources, control environmental pollution, improve environmental quality to enable healthy ecosystems and comfortable habitation of humans. It is based on multiple disciplines including geology, hydrology, biology, chemistry, physics, medicine, engineering, management, economics, law, etc. Environmental engineering involves water supply, pollution control, recycling, waste (solid and liquid) disposal, radiation protection, industrial hygiene, environmental sustainability, and public health. This manual mainly deals with the determination of physio-chemical and bacteriological properties of surface water. The manual contains some fundamental chemistry and biology concepts/theories and their applications in environmental engineering. The key tests include Physical, chemical and bacteriological tests of water and wastewater. This Lab manual was prepared with the help of — Standard Methods for the Examination of Water and Waste Water, 1995, 20th Edition, American Public Health Association, APHA; some lecture notes from Bangladesh University of Engineering and Technology (BUET) and several other lecture notes.

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Experiment 1
Determination of pH
**Introduction:**
The term pH refers to the measure of hydrogen ion concentration in a solution and defined as the negative log of H⁺ ions concentration in water and wastewater

\[ \text{pH} = -\log[H^+] \]  

Where \([H^+]\) is the concentration (or activity) of hydrogen ion (or photon) in moles per liter (M)

Water dissociates to form hydrogen ion (H⁺) and hydroxyl ion (OH⁻) according to the following equation:

\[ \{\text{H}_2\text{O}\} = \{\text{H}^+\} + \{\text{OH}^-\} \]  

At equilibrium, we can write,

\[ K_w = \frac{[\text{H}^+][\text{OH}^-]}{[\text{H}_2\text{O}]} \]  

But, since concentration of water is extremely large (approximately 55.5 mol/L) and is diminished very little by the slight degree of ionization, may be considered as a constant and its activity is taken as 1.0. Thus Eq. (3) may be written as:

\[ K_w = \{\text{H}^+\} \{\text{OH}^-\} \]  

Where, \( K_w = \text{Equilibrium Constant} \)

For pure water at 25 °C, \( K_w = 10^{-7} \times 10^{-7} = 10^{-14} \). This is known as the ion product of water or ionization constant for water. In other words, water (de-ionized or distilled water) at 25°C dissociates to yield 10⁻⁷ mol/L of hydrogen ion (H⁺) and 10⁻⁷ mol/L of hydroxyl ion (OH⁻). Hence, according to Equation (1) pH of deionized water is equal to 7.

The values of pH, 0 to a little less than 7 are termed as acidic and the 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.

**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 the 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.
According to Bangladesh Environment Conservation Rules (1997), drinking water standard for pH ranges from 6.5 to 8.5.

**Principle:**
The pH electrode used in the pH measurement is a combined glass electrode. It consists of sensing half-cell and reference half-cell, together form an electrode system. The sensing half-cell is a thin pH sensitive semi permeable membrane, separating two solutions, viz., the outer solution, the sample to be analyzed and the internal solution enclosed inside the glass membrane and has a known pH value. An electrical potential is developed inside and another electrical potential is developed outside, the difference in the potential is measured and is given as the pH of the sample.

**Materials required:**

**Apparatus required**
1. pH meter
2. Standard flasks
3. Magnetic Stirrer
4. Funnel
5. Beaker
6. Wash Bottle
7. Tissue Paper
8. Forceps

**Chemicals required**
1. Buffers Solutions of known pH value
2. Distilled Water

**Sample handling and preservation**
Preservation of sample is not practical. Because biological activity will continue after a sample has been taken, changes may occur during handling and storage. The characteristics of the water sample may change. To reduce the change in samples taken for the determination of pH, keep samples at 4°C. Do not allow the samples to freeze. Analysis should begin as soon as possible.

**Precautions**
The following precautions should be observed while performing the experiment:

**i.** Temperature affects the measurement of pH at two points. The first is caused by the change in electrode output at different temperatures. This interference can be controlled by the instruments having temperature compensation or by calibrating the electrode-instrument system at the temperature of the samples. The second is the change of pH inherent in the sample at different temperatures. This type of error is sample dependent and cannot be controlled; hence both the pH and temperature at the time of analysis should be noted.

**ii.** In general, the glass electrode is not subject to solution interferences like color, high salinity, colloidal matter, oxidants, turbidity or reductants.

**iii.** Oil and grease, if present in the electrode layer, should be removed by gentle wiping or detergent washing, followed by rinsing with distilled water, because it could impair the electrode response.

**iv.** Before using, allow the electrode to stand in dilute hydrochloric acid solution for at least 2 hours.

**v.** Electrodes used in the pH meter are highly fragile, hence handle it carefully.
**Procedure:**
Three major steps are involved in the experiment. They are
1. Preparation of Reagents
2. Calibrating the Instrument
3. Testing of Sample

**Steps:**
- Perform calibration of the pH meter using standard pH solutions. The calibration procedure would depend on the 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 the water sample and check for the reading in the 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.

**Assignment**
1. pH is one of the most important controlling factors for treatment and chemical analysis of water and wastewater — explain.

2. Define pH in terms of hydrogen-ion (H\(^+\)) concentration and hydroxyl-ion (OH\(^-\)) concentration. An increase in pH of one unit represents how much decrease in hydrogen ion concentration?

3. At 25°C, pH of a solution is found 7.8. Determine the hydroxyl ion concentration of the solution.

4. Possible reasons for a relatively low pH value in a river water sample is due to
   a) Organic material decomposition to form acidic substances
   b) Running long distances
   c) Presence of fishes
   d) Presence of aquatic plants

5. Possible reasons for a relatively high pH value in a river water sample is due to
   a) Running over clay
   b) Running long distances
   c) Running of fishes
   d) Presence of aquatic plants
## DATA SHEET

Experiment Name : 
Experiment Date  : 

Student's Name : 
Student's ID : 
Year/ Semester : 
Section/ Group : 

### Table:

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Experiment 2
Determination of Color of Water
Introduction:
Pure water should not pose any color. Color in water may result from the presence of natural metallic ions (iron and manganese), humus and peat materials, plankton, weeds, and industrial wastes. Impurities in water may exist either in the colloidal form or in suspended state. Color caused by dissolved and colloidal substances is referred as "true color" and that caused by suspended matter, in addition to dissolved and colloidal matters, is called "apparent color" as it can be easily removed by filtration. Ground water may show color due to the presence of iron compounds. The color value of water is extremely pH-dependent and invariably increases as the pH of the water is raised. For this reason recording pH along with color is advised.

Environmental significance:
Though presence of color in water is not always harmful to human but in most cases it is. Even if the water is not harmful, aesthetically people do not prefer to use water with color. Moreover, disinfection by chlorination of water containing natural organics (which produces color) results in the formation of tri-halomethanes including chloroform and a range of other chlorinated organics leading to problems which is a major concern in water treatment. So it is important to limit the color of water for domestic supplies. According to Bangladesh Environment Conservation Rules (1997), drinking water guideline value for color is 15 Pt-Co Unit.

Theory on experimental method:
Available methods for determining color of water:
1. Standard Color Solutions Method
2. Dilution Multiple Method
3. Spectrophotometric method

1. Standard color solution method
Waters containing natural color are yellow-brownish in appearance.
Standard Color Solution: Solutions of potassium chloroplatinate (K₂PtCl₆) tinted with small amounts of cobalt chloride yield colors that are very much like the natural colors. In this method, the color produced by 1 mg/l of platinum (as K₂PtCl₆) and 0.5mg/l of cobalt (as CoCl₂·6H₂O) is taken as the standard one unit of color.
Usually, a stock solution stock solution of K₂PtCl₆ that contains 500mg/l of platinum is prepared, which has a color of 500 units. Then, a series of working standards may be prepared from it by dilution.
Color-comparison tubes are usually used to contain the standards. A series ranging from 0 to 70 color units is employed and samples with color less than 70 units are tested by direct comparison with the prepared standards. For samples with a color greater than 70 units, a dilution is made with distilled water distilled water to bring the resulting color within the range of the standards. In this case, the final result should be corrected using a dilution factor.

2. Dilution multiple method
Color of most domestic and industrial waste waters are not yellow-brownish hue.
Other systems of measurement have to be used to measure and describe colors that do not fall into this classification.
For dilution multiple methods, color is measured by successive dilutions of the sample with color-free water until the color is no longer detectable comparing with distilled water. The total dilution multiple is calculated and used to express the color degree.
3. Spectrophotometric method

The platinum-cobalt method is useful for measuring color of potable water and of water in which color is due to naturally occurring materials. It is not applicable to most highly colored industrial wastewaters. In the laboratory color of water is usually measured using spectrophotometer which uses light intensity of a specific wavelength (455 nm). The color test measures (inversely) an optical property of water sample which result from the absorption of light of specific wavelength by the soluble color substances present in water. Before measuring the color of water it is necessary to plot standard calibration curve for color using different standard platinum-cobalt solutions of known concentrations within the range of interest.

![Figure 2.1: Sample calculation](image)

Materials required:

Reagent:
Standard potassium chloroplatinate solution

Apparatus:
#Spectrophotometer (HACH, DR 4000U)
#Filtration system including filter paper, funnel, holder, beaker etc.

Procedure:

1. Prepare standard samples having color within a specific range by mixing different concentration of standard potassium chloroplatinate solution with distilled water. Using these samples to prepare a color calibration curve (absorbance vs. color concentration) for the spectrophotometer.
2. Take 50-mL of filtered test sample in a beaker. Take 50-mL distilled water in another beaker. Use this sample as blank.
3. Set the spectrophotometer to determine color concentration of the sample.
4. Put the blank sample inside the spectrophotometer cell and set the reading "zero".
5. Bring out the blank sample and place the test sample inside the spectrophotometer.
6. After a While the display will show the color concentration of the sample.
Figure 2.2: Optical property used in measurement of color in water using spectrophotometer

**Assignment:**
1. Define true and apparent color. Why true color is more important than apparent color?
2. Discuss the optical mechanism used in color measurement using spectrophotometer.
3. Write down the treatment methods that are commonly used for removing color from water and wastewater.
DATA SHEET

Experiment Name : 
Experiment Date : 

Student’s Name : 
Student’s ID : 
Year/ Semester : 
Section/ Group : 

Table:

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Experiment 3
Determination of Turbidity of Water
**Introduction:**
Turbidity is the technical term referring to the cloudiness of a solution and it is a qualitative characteristic which is imparted by solid particles obstructing the transmittance of light through a water sample. Turbidity often indicates the presence of dispersed and suspended solids like clay, organic matter, silt, algae and other microorganisms. So in short turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample.

**Environmental significance:**
When the turbid water in a small, transparent container such as drinking glass is held up to the light, an aesthetically displeasing opaqueness or milky coloration is apparent. The colloidal material which exerts turbidity provides adsorption sites for chemicals and for biological organism that may not be harmful. They may be harmful or cause undesirable tastes and odours. Disinfection of turbid water is difficult because of the adsorptive characteristics of some colloids and because the solids may partially shield organisms from disinfectant. In natural water bodies, turbidity may impart a brown or other color to water and may interfere with light penetration and photosynthetic reaction in streams and lakes. Turbidity increases the load on slow sand filters.

The filter may go out of operation, if excess turbidity exists. Knowledge of the turbidity variation in raw water supplies is useful to determine whether a supply requires special treatment by chemical coagulation and filtration before it may be used for a public water supply. Turbidity measurements are used to determine the effectiveness of treatment produced with different chemicals and the dosages needed. Turbidity measurements help to gauge the amount of chemicals needed from day-to-day operation of water treatment works. Measurement of turbidity in settled water prior to filtration is useful in controlling chemical dosages so as to prevent excessive loading of rapid sand filters. Turbidity measurements of the filtered water are needed to check on faulty filter operation. Turbidity measurements are useful to determine the optimum dosage of coagulants to treat domestic and industrial wastewaters. Turbidity determination is used to evaluate the performance of water treatment plants.

Turbidity in water may be caused by a wide variety of suspended matter suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and other organisms. Under flood conditions, great amounts of topsoil are washed to receiving streams. As the rivers pass through urban areas, the domestic and industrial wastewaters may be added.

**Guideline:**
According to WHO standard 5 NTU is suggested as the turbidity limit for drinking water, while 1 NTU is recommended to achieve the adequate disinfecting safety. According to Bangladesh Environment Conservation Rules (1997), drinking Water standard for Turbidity is 10 NTU (Nephelometric turbidity unit).

**Principle:**
Turbidity is based on the comparison of the intensity of light scattered by the sample under defined conditions with the intensity of the light scattered by a standard reference suspension under the same conditions. The turbidity of the sample is thus measured from the amount of light scattered by the sample taking a reference with standard turbidity suspension. The higher the intensity of scattered light the higher is the turbidity. Formazin polymer is used as the primary standard reference suspension.
Because of the wide variety of materials that cause turbidity in natural waters, it has been necessary to use an arbitrary standard. The original standard chosen was; 1 mg SiO$_2$/L = 1 unit of turbidity

The silica used had to meet certain specifications as to particle size. The Jackson candle turbidimeter has been replaced by more reliable, sensitive, and easier to use instruments that depend upon the principle of nephelometry. As a standard reference material, Silica has been replaced by formazin polymer. The formazin suspensions were first calibrated against the Jackson candle turbidimeter. The standard nephelometry procedure is now reported in nephelometric turbidity units (NTU). Because the basic principles difference for Jackson candle turbidimeter method and nephelometric method, results got from the two methods can vary widely. In order to avoid any confusion this may cause, turbidity measurements by the standard nephelometry procedure are now reported in nephelometric turbidity units (NTU), and the other one is reported in Jackson candle turbidimeter units (JTU).

40 NTU are about equivalent to 40 JTU.

The applicable range of this method is 0-40 nephelometric turbidity units (NTU). Higher values may be obtained with dilution of the sample.

**Sample handling and preservation:**
Water samples should be collected in plastic cans or glass bottles. All bottles must be cleaned thoroughly and should be rinsed with turbidity free water. Volume collected should be sufficient to insure a representative sample, allow for replicate analysis (if required), and minimize waste disposal. No chemical preservation is required. Keep the samples at 4°C. Do not allow samples to freeze. Analysis should begin as soon as possible after the collection. If storage is required, samples maintained at 4°C may be held for up to 48 hours.

**Precautions:**
The following precautions should be observed while performing the experiment:
- The presence of coloured solutes causes measured turbidity values to be low. Precipitation of dissolved constituents (for example, Fe) causes measured turbidity values to be high.
- Light absorbing materials such as activated carbon in significant concentrations can cause low readings.
- The presence of floating debris and coarse sediments which settle out rapidly will give low readings. Finely divided air bubbles can cause high readings.

**Materials required:**

**Apparatus required**
1. Turbidity Meter
2. Sample Cells
3. Standard flasks
4. Funnel
5. Wash Bottle
6. Tissue Papers

**Chemicals required**
1. Hexamethylenetetramine
2. Hydrazine sulphate
3. Distilled water
Procedure:

- For testing the given water sample first the reagents are to be prepared. Then the turbidity meter is required to be calibrated.
- To the sample cells, add sample water up to the horizontal mark, wipe gently with soft tissue and place it in the turbidity meter such that the vertical mark in the sample cell should coincide with the mark in the turbidity meter and cover the sample cell.
- Check for the reading in the turbidity meter. Wait until you get a stable reading.
- Turbidities exceeding 40 units: Dilute the sample with one or more volumes of turbidity-free water until the turbidity falls below 40 units. The turbidity of the original sample is then computed from the turbidity of the diluted sample and the dilution factor. For example, if 5 volumes of turbidity-free water were added to 1 volume of sample, and the diluted sample showed a turbidity of 30 units, then the turbidity of the original sample was 180 units.

Assignment:

- Discuss the environmental significance of "turbidity".
- Why turbidity is important in "filtration" and "disinfection" processes?
- Write down the methods that are commonly used for removing turbidity from water.
- Discuss the nature of materials causing turbidity in polluted river water.
- What limit is placed on turbidity in water supplies by the present standards and why has such a limit been set?
## DATA SHEET

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Experiment Date : 

Student’s Name : 
Student’s ID : 
Year/ Semester : 
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Experiment 4
Determination of Total Solids, Dissolved Solids and Suspended Solids in Water
**Introduction:**
Environmental engineering is concerned with the solid material in a wide range of natural waters and wastewaters. The usual definition of solids (referred to as "total solids") is the matter that remains as residue upon evaporation at 103~105°C. The various components of "total solids" can be simplified as follows

![Diagram](image)

Total Solids (TS) are the total of all solids in a water sample. They include the total suspended solids and total dissolved solids. Total Suspended Solids (TSS) are the amount of filterable solids in a water sample. Samples are filtered through a glass filter. The filters are dried and weighed to determine the amount of total suspended solids in mg/l of sample. Total Dissolved Solids (TDS) are those solids that pass through a filter with a pore size of 2.0 micron (1/1000000th of a meter, Also known as a Micrometer) or smaller. They are said to be non-filterable. After filtration the filtrate (liquid) is dried and the remaining residue is weighed and calculated as mg/l of Total Dissolved Solids.

**Environmental significance:**
Total solids measurements can be useful as an indicator of the effects of runoff from construction, agricultural practices, logging activities, sewage treatment plant discharges, and other sources. Total solids also affect water clarity. Higher solids decrease the passage of light through water, thereby slowing more rapidly and hold more heat; this, in turn, might adversely affect photosynthesis by aquatic plants. Water will heat up affect aquatic life that has adapted to a lower temperature regime. As with turbidity, concentrations often increase sharply during rainfall, especially in developed watersheds. They can also rise sharply during dry weather if earth-disturbing activities are occurring in or near the stream without erosion control practices in place. Regular monitoring of total solids can help detect trends that might indicate increasing erosion in developing watersheds. Total solids are related closely to stream flow and velocity and should be correlated with these factors. Any change in total solids over time should be measured at the same site at the same flow. Water with total solids generally is of inferior palatability and may induce an unfavorable physiological reaction. It may be esthetically unsatisfactory for purposes such as bathing. Total solids will be higher in highly mineralized waters, which result in unsuitability for many industrial applications. It indicates effectiveness of sedimentation process and it affects effectiveness of disinfection process in killing microorganisms. It is used to assess the suitability of potential supply of water for various uses. In the case of water softening, amount of total solids determine the type of softening procedure. Corrosion control is frequently accomplished by the production of stabilized waters through pH adjustment. The pH stabilization depends to some extent upon the total solids present as well as alkalinity and temperature.

Solids analyses are important in the control of biological and physical wastewater treatment processes and for assessing compliance with regulatory agency wastewater effluent limitations.

Although the waste water or sewage normally contains 99.9 percent of water and only 0.1 percent of solids, but it is the solids that have the nuisance value.
The amount of solids in wastewater is frequently used to describe the strength of the water. The more solids present in a particular wastewater, the stronger that wastewater will be. The environmental impacts of solids in all forms have detrimental effects on quality since they cause putrefaction problems. If the solids in wastewater are mostly organic, the impact on a treatment plant is greater than if the solids are mostly inorganic.

In the realm of municipal wastewater, suspended solids analysis is by far the most important gravimetric method. It is used to evaluate the strength of the raw wastewater as well as the overall efficiency of treatment. Furthermore, most waste water treatment plants (WWTP's) have effluent standards of 10 to 30 mg/L suspended solids which may be legally enforceable. As was the case with municipal wastewater, suspended solids analysis is useful as a means of assessing the strength of industrial wastewaters and the efficiency of industrial wastewater treatment.

<table>
<thead>
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<td></td>
<td></td>
<td>Low</td>
<td>Avg</td>
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<td>Storm Water</td>
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Dissolved minerals, gases and organic constituents may produce aesthetically displeasing color, taste and odor. Some dissolved organic chemicals may deplete the dissolved oxygen in the receiving waters and some may be inert to biological oxidation, yet others have been identified as carcinogens. Water with higher solids content often has a laxative and sometimes the reverse effect upon people whose bodies are not adjusted to them. Estimation of total dissolved solids is useful to determine whether the water is suitable for drinking purpose, agriculture and industrial purpose. Suspended material is aesthetically displeasing and provides adsorption sites for chemical and biological agents. Suspended organic solids which are degraded anaerobically may release obnoxious odors. Biologically active suspended solids may include disease causing organisms as well as organisms such as toxic producing strains of algae. The suspended solids parameter is used to measure the quality of wastewater influent and effluent. Suspended solids determination is extremely valuable in the analysis of polluted waters. Suspended solids exclude light, thus reducing the growth of oxygen producing plants. High concentration of dissolved solids about 3000 mg/L may also produce distress in livestock. In industries, the use of water with high amount of dissolved solids may lead to scaling in boilers, corrosion and degraded quality of the product.

**Water standards for ts, tds and tss:**
According to Bangladesh Environment Conservation Rules (1997), potable water should not contain more than 1000 mg/l of total dissolved solids (TDS)

**Principle:**
The measurement of solids is by means of the gravimetric procedure. The various forms of solids are determined by weighing after the appropriate handling procedures. The total solids concentration of a sample can be found directly by weighing the sample before and after
drying at 103°C. However, the remaining forms, TDS and TSS require filtration of the sample. For liquid samples, all these solids levels are reported in mg/L.

**Apparatus:**
1. Beaker
2. Measuring Cylinder
3. Filter paper
4. Balance

**Sample handling and preservation:**
Preservation of sample is not practical. Because biological activity will continue after a sample has been taken, changes may occur during handling and storage. Both the characteristics and the amount of solids may change. To reduce this change in samples taken for solids determinations, keep all samples at 4°C. Do not allow samples to freeze. Analysis should begin as soon as possible.

**Precautions:**
The following precautions should be observed while performing the experiment:
- Water or Wastewater samples which contain high concentrations of calcium, chloride, magnesium or sulphate can rapidly absorb moisture from the air. Such samples may need to be dried for a longer period of time, cooled under proper desiccation and weighed rapidly in order to achieve a reasonable constant weight. We should be aware prolonged drying may result in loss of constituents, particularly nitrates and chlorides.
- Non-representative particulates such as leaves, sticks, fish and lumps of fecal matter should be excluded from the sample if it is determined that their inclusion is not desired in the final result.
- Floating oil and grease, if present, should be included in the sample and dispersed by a blender device before sub-sampling.
- Volume of sample should be adjusted to have residue left after drying as 100 to 200mg. It is mainly to prevent large amount of residue in entrapping water during evaporation.
- Highly mineralized water containing significant concentration of calcium, magnesium, chloride, and/or sulphate may be hygroscopic. Hence prolonged drying, desiccation and rapid weighing.
- We should be aware prolonged drying may result in loss of constituents, particularly nitrates and chlorides.

**Procedure:**

**Total Solids**
(1) Take a clear dry glass beaker (which was kept at 103°C in an oven for 1 hour) of 150ml. capacity and put appropriate identification mark on it. Weight the beaker and note the weight.
(2) Pour 100ml of the thoroughly mixed sample, measured by the measuring cylinder, in the beaker.
(3) Place the beaker in an oven maintained at 103°C for 24 hours. After 24 hours, cool the beaker and weight. Find out the weight of solids in the beaker by subtracting the weight of the clean beaker determined in step (1)
(4) Calculator total solids (TS) as follows:

**Dissolved Solids**
(1) Same as above (step 1 of total solids).
(2) Take a 100 ml. of sample and filter it through a double layered filter paper and collect the filtrate in a beaker.
(3) The repeat the same procedure as in steps (3) and (4) of the total solids determination and determine the dissolved solids contents as follows:

**Calculation:**

**Total solids, TS (mg/l) =** mg of solids in the beaker x 1000 / (volume of sample)

**Total Dissolved Solids, TDS (mg/l) =** mg of solids in the beaker x1000 (volume of sample)

**Total Suspended Solids, TSS (mg/l) =** TS (mg/l) – TDS (mg/l)

**Assignment:**
1. Discuss possible sources of solids in ground water and surface water.
2. —Groundwater usually has higher dissolved solids and surface water usually has higher suspended solids! Explain.
3. Why water is evaporated at 103°C rather than 100 °C in assessment of solid of water?
DATA SHEET

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Experiment 5
Determination of CO2 in water
Introduction:
Carbon Dioxide is present in water in the form of a dissolved gas. Surface waters normally contain less than 10 ppm free carbon dioxide, while some ground waters may easily exceed that concentration. Carbon dioxide is readily soluble in water. Over the ordinary temperature range (0-30°C) the solubility is about 200 times that of oxygen. Calcium and magnesium combine with carbon dioxide to form carbonates and bicarbonates.

Carbon dioxide does dissolve in water; however the system is somewhat complex. First the $\text{CO}_2$ dissolves according to:

$$\text{CO}_2 \text{ (g)} = \text{CO}_2 \text{ (l)}$$

At room temperature, the solubility of carbon dioxide is about 90 cm$^3$ of $\text{CO}_2$ per 100 ml water ($c_v/\text{cg} = 0.8$). Any water-soluble gas becomes more soluble as the temperature decreases, due to the thermodynamics of the reaction:

$$\text{GAS} \text{ (l)} = \text{GAS} \text{ (g)}$$

This effect is particularly large for gases like $\text{CO}_2$ that undergo specific reactions with water. Equilibrium is established between the dissolved $\text{CO}_2$ and $\text{H}_2\text{CO}_3$, carbonic acid.

$$\text{CO}_2 \text{ (l)} + \text{H}_2\text{O} \text{ (l)} = \text{H}_2\text{CO}_3 \text{ (l)}$$

Carbonic acid is a weak acid that dissociates in two steps,

$$\text{H}_2\text{CO}_3 + \text{H}_2\text{O} \Leftrightarrow \text{H}_3\text{O}^+ + \text{HCO}_3^-$$

$$\text{HCO}_3^- + \text{H}_2\text{O} \Leftrightarrow \text{H}_3\text{O}^+ + \text{CO}_3^{2-}$$

The test for determination of free carbon dioxide in water is based on the titration of water sample with standard Sodium Hydroxide solution in the presence Phenolphthalen indicator. The $\text{CO}_2$ reacts with NaOH to form Sodium Bicarbonate with a consequent increase in pH. The reaction of NaOH with free $\text{CO}_2$ reach a completion at a pH of 8.3.

Environmental significance:
Aquatic plant life depends upon carbon dioxide and bicarbonates in water for growth. Microscopic plant life suspended in the water, phytoplankton, as well as large rooted plants, utilize carbon dioxide in the photosynthesis of plant materials; starches, sugars, oils, proteins. The carbon in all these materials comes from the carbon dioxide in water.

When the oxygen concentration in waters containing organic matter is reduced, the carbon dioxide concentration rises. The rise in carbon dioxide makes it more difficult for fish to use the limited amount of oxygen present. To take on fresh oxygen, fish must first discharge the carbon dioxide in their blood streams and this is a much slower process when there are high concentrations of carbon dioxide in the water itself.

Corrosion is the principal difficulty caused by carbon dioxide. This gas on solution in water produces carbonic acid resulting in lowering of pH. With a decrease in pH corrosive characteristics is induced in water resulting severe corrosion of heat exchanger, pipes, valves
etc. Corrosion in boiler system takes place due to the presence of carbonate and bicarbonate although Carbon dioxide is not present in this case.

**Standards for CO₂:**
Bangladesh Environment Conservation Rules (1997) does not set any limits for the presence of CO₂ in water.

**Reagent:**
1. Standard N/44 Sodium Hydroxide,
2. Phenolphthalein Indicator **

** An indicator is a substance that undergoes a change in color when the end-point of a titration is reached. Acid-base indicators are used to signal the end of acid-base titrations. An acid-base indicator is itself a weak acid (or its conjugate base).

Phenolphthalein is a commonly used indicator for titrations, and is a weak acid. The weak acid is colorless and its ion is bright pink. Adding extra hydrogen ions shifts the position of equilibrium to the left, and turns the indicator colorless. Adding hydroxide ions removes the hydrogen ions from the equilibrium which tips to the right to replace them - turning the indicator pink. The half-way stage happens at pH 8.3. Since a mixture of pink and colorless is simply a paler pink, this is difficult to detect with any accuracy.

**Procedure:**
(1) Take a 100 ml of sample in a beaker and add 10 drops of Phenolphthalein indicator. If a pink color develops, no carbon dioxide is present in the water sample.

(2) Add N/44 sodium Hydroxide solution from a burette to the sample and stir gently until a slight permanent pink color appears as compared with distilled water. Record ml of sodium hydroxide used. Since excess CO₂, if present easily escapes to atmosphere, so tests should be performed immediately after collection of water sample. If this is not possible sample bottle should be completely filled and stoppered and be kept at a temperature lower than that at which it was collected.

**Calculation:**

\[
\text{Carbon dioxide (mg/L) } = \frac{\text{Normality of NaOH} \times \text{Equivalent wt of CO}_2 \times 1000 \times \text{Milliliter of N/44 NaOH added}}{\text{Milliliter of sample taken}}
\]

**Determination of CO₂ acidity:**
Phenolphthalein acidity (often called CO₂ acidity) of water is defined as the amount of standard base (usually 1/50 N NaOH) required raising the pH of a sample of water to the phenolphthalein end point of 8.3. CO₂ acidity is expressed as CaCO₃ (calcium carbonate) required to neutralize H₂CO₃

Hence, Acidity could be easily determined from the results of CO₂ determination as follows:

**Phenolphthalein Acidity as mg/L CaCO₃ = CO₂ (mg/L) × \frac{50}{44}**
Assignment:
1. Discuss changes in the form of Carbon in solution at different pH.
2. Why groundwater contains higher carbon dioxide than surface water.
3. Why test for Carbon dioxide should be performed immediately after collection of water sample.
# DATA SHEET

**Experiment Name**: 
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Experiment 6
Determination of Alkalinity of Water
**Introduction:**
Alkalinity is primarily a way of measuring the acid neutralizing capacity of water. In other words, its ability to maintain a relatively constant pH. The possibility to maintain constant pH is due to the hydroxyl, carbonate and bicarbonate ions present in water. The ability of natural water to act as a buffer is controlled in part by the amount of calcium and carbonate ions 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\(^{2+}\) and CO\(_3^{2-}\) ions and have elevated hardness and alkalinity.

**Environmental significance:**
Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Higher alkalinity levels in surface waters will buffer acid rain and other acid wastes and prevent pH changes that are harmful to aquatic life. 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 actions in waters. The resultant precipitate can corrode pipes and other accessories of water distribution systems.

Wastewaters containing excess caustic (hydroxide) alkalinity are not to be discharged into natural water bodies or sewers. Alkalinity as carbonate and bicarbonate of saline water is very important in tertiary recovery processes for recovering petroleum. Alkaline water offers better wetting to the formation rock and improve oil release. As an additional benefit, ions that provide alkalinity absorb on rock surfaces occupying adsorption sites and decrease the loss of recovery chemical by adsorption. The alkalinity value is necessary in the calculation of carbonate scaling tendencies of saline waters.

The alkalinity acts as a pH buffer in coagulation and lime-soda softening of water. In wastewater treatment, alkalinity is an important parameter in determining the amenability of wastes to the treatment process and control of processes such as anaerobic digestion, where bicarbonate alkalinity, total alkalinity, and any fraction contributed by volatile acid salts become considerations.

**Principle:**
The alkalinity of water can be determined by titrating the water sample with Sulphuric acid of known values of pH, volume and concentrations. Based on stoichiometry of the reaction and number of moles of Sulphuric acid needed to reach the end point, the concentration of alkalinity in water is calculated. 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 the pH more than 8.3, add phenolphthalein indicator, the colour changes to pink colour. This pink colour is due to presence of hydroxyl ions.

If sulphuric acid is added to it, the pink colour disappears i.e. OH\(^-\) ions are neutralized.

Then add methyl orange indicator, the presence of CO\(_3^{2-}\) and HCO\(_3^-\) ions in the solution changes the colour to yellow. While adding sulphuric acid, the color changes to slight orange ting, this color change indicates that all the CO\(_3^{2-}\) and HCO\(_3^-\) ions has been neutralized. This is the end point.

**Materials required:**

**Apparatus required:**
1. Burette with Burette stand and porcelain title
2. Pipettes with elongated tips
3. Conical flask
4. 250 mL Measuring cylinders
5. Standard flask
6. Wash Bottle  
7. Beakers  

**Chemicals required**  
1. Standard sulphuric acid  
2. Phenolphthalein  
3. Bromocresol Green  
4. Methyl orange  
5. Distilled Water  

**Sample handling and preservation:**  
Preservation of sample is not practical. Because biological activity will continue after a sample has been taken, changes may occur during handling and storage. To reduce the change in samples, keep all samples at 4°C. Do not allow samples to freeze. Analysis should begin as soon as possible. Do not open sample bottle before analysis.

**Procedure:**  
1. Measure 50 ml or 100 ml of your sample into a 250 mL beaker or erlenmeyer flask. Place your sample onto a stir plate (make sure to put a bar magnet in the flask).  
2. Measure initial pH of your sample. If the sample pH is below 8.3 (if above 8.3, do step 3 first), add several drops of methyl orange indicator. If the color of the solution turned yellow, titrate your sample with 0.02 N H₂SO₄ (you may need to dilute the acid provided in the lab) until the color changes to slightly orange ting (pH 4.5). Record the total volume of acid used for the titration.  
3. Measure initial pH of your sample. If the sample pH is above 8.3, add several drops of phenolphthalein indicator. If the color of the solution turned pink, titrate your sample with 0.02 N H₂SO₄ or HCl (you may need to dilute the acid provided in the lab) until color changes from pink to clear (pH 8.3). Record the volume of acid used for the titration. Then, proceed with step 2.  
4. Calculate both Phenolphthalein Alkalinity and Total Alkalinity using the formula provided above.

**Calculation:**  
Phenolphthalein Alkalinity (mg/L as CaCO₃)  
= Multiplying Factor (MF) x milliliter of 0.02N H₂SO₄ (added up to pH 8.3)

Total Alkalinity (mg/L as CaCO₃)  
= Multiplying Factor (MF) x milliliter of 0.02N H₂SO₄ (added up to pH approx. 4.5)

**Assignment:**  
1. Discuss the importance of alkalinity in water for different treatment processes.  
2. Define total alkalinity, phenolphthalein alkalinity, and methyl orange alkalinity. Discuss their dominant pH range.
**DATA SHEET**

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**Table -1 Phenolphthalein Alkalinity:**

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<th>Sample No</th>
<th>Volume of Sample (mL)</th>
<th>Burette Reading (mL)</th>
<th>Volume of Sulphuric acid (mL)</th>
<th>Phenolphthalein Alkalinity (mg/L as CaCO3)</th>
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**Table -2 Total Alkalinity:**

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<th>Volume of Sample (mL)</th>
<th>Burette Reading (mL)</th>
<th>Volume of Sulphuric acid (mL)</th>
<th>Total Alkalinity (mg/L as CaCO3)</th>
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Experiment 7
Determination of Chloride of water
**Introduction:**
Chlorides occur in all natural waters in widely varying concentration, the chloride content normally increases as the mineral content increases. Upland and mountain supplies usually are quite low in chlorides, whereas river and groundwater usually have a considerable amount. Sea and ocean waters represent the residues resulting from partial evaporation of natural waters that flow into them and chloride levels are very high. Chlorides gain access to natural waters in many ways. The solvent power of water dissolves chlorides from topsoil and deeper formations. Spray from the ocean is carried inland as droplets or as minute salt crystals, which result from evaporation of the water in the droplets. These sources constantly replenish the chlorides in inland areas where they fall. Ocean and seaways invade the rivers that drain into them, particularly the deeper rivers. The salt water, being denser, flows upstream under the fresh water, which is flowing downstream. There is a constant intermixing of the salt water with the fresh water above. Groundwater in areas adjacent to the ocean is in hydrostatic balance with seawater. Over-pumping of groundwater produces a difference in hydrostatic head in favor of the seawater, and it introduce into the fresh water area. Such intrusion has occurred in many areas of the coastal southern region of Bangladesh. Human excreta, particularly urine, contain chloride in an amount about equal to the chlorides consumed with flood and water. This amount average about 6 gm of chlorides per person per day and increases the amount of CC in municipal wastewater about 15 mg/l above that of the carriage water. Thus, wastewater effluents add considerable chlorides to receiving streams. Many industrial wastes (e.g., tannery waste) also contain appreciable amount of chlorides.

**Environmental significance:**
Chlorides in reasonable concentrations are not harmful to human. At concentrations above 250 mg/L they give a salty taste to water, which is objectionable to many people. For this reason, chlorides are generally limited to 250 mg/L in supplies intended for public use. In many areas of the world where water supplies are scarce, source be containing as much as 2,000 mg/L are used for domestic purposes without the development of adverse effects, once the human system becomes adapted to the water. According to Bangladesh Environment Conservation Rules (1997), drinking water standard for chloride is 150 - 600 mg/L; but for coastal regions of Bangladesh, the limit - has been relaxed to 1000 mg/L.

**Principle:**
This method determines the chloride ion concentration of a solution by titration with silver nitrate. As the silver nitrate solution is slowly added, a precipitate of silver chloride forms.

\[ \text{Ag}^+_{(aq)} + \text{Cl}^-_{(aq)} \rightarrow \text{AgCl}_{(s)} \]  

**7.1**

The end point of the titration occurs when all the chloride ions are precipitated. Then additional silver ions react with the chromate ions of the indicator, potassium chromate, to form a red-brown precipitate of silver chromate.

\[ 2\text{Ag}^+_{(aq)} + \text{CrO}_4^{2-}_{(aq)} \rightarrow \text{Ag}_2\text{CrO}_4^{4-}_{(aq)} \]  

**7.2**

This method can be used to determine the chloride ion concentration of water samples from many sources such as seawater, stream water, river water and estuary water. The pH of the sample solutions should be between 6.5 and 10. If the solutions are acidic, the gravimetric method or Volhard’s method should be used.

***The end point of titration cannot be detected visually unless an indicator capable of demonstrating the presence of excess Ag⁺ is present. The indicator normally used is potassium chromate, which supplies chromate ions. As the concentration of CI⁻ ions becomes...***
exhausted, the silver ion concentration increases and a reddish brown precipitate of silver chromate is formed.

\[2\text{Ag}^+ + \text{CrO}_4^{2-} = \text{Ag}_2\text{CrO}_4 \text{ (reddish brown precipitate)}\]

This is taken as evidence that all chloride has been precipitated. Since an excess Ag\(^+\) is needed to produce a visible amount of Ag\(_2\)CrO\(_4\), the indicator error is subtracted from all titrations. The indicator error or blank varies somewhat with the ability of individuals to detect a noticeable color change. The usual range is 0.2 to 0.4 mL of titrant. An error of 0.2 mL will be used in the class.

**Precautions:**

- A uniform sample size must be used, preferably 100 mL (or 50 mL), so that ionic concentrations needed to indicate the end point will be constant.
- The pH must be in the range of 7 to 8 because Ag\(^+\) precipitates at high pH levels and the CrO\(_4^{2-}\) is converted to Cr\(_2\)O\(_7^{2-}\) at low pH levels.
- A definite amount of indicator must be used to provide a certain concentration of CrO\(_4^{2-}\); otherwise Ag\(_2\)CrO\(_4\) may form too soon or not soon enough.
- The chromate solution needs to be prepared and used with care as chromate is a known carcinogen.
- Silver nitrate solution causes staining of skin and fabric (chemical burns). Any spills should be rinsed with water immediately.

**Materials required:**

**Reagents**
- Potassium chromate indicator
- Silver nitrate solution (0.0141 N)

**Apparatus**
- Burette and stand
- 10 and 20 mL pipettes
- 100 mL volumetric flask
- 250 mL conical flasks
- 10 mL and 100 mL measuring cylinders

**Procedure:**

1. Take 50 mL of the sample in a beaker and add 5 drops (about 1 mL) of potassium chromate indicator to it.
2. Add standard (0.0141 N) silver nitrate solution to the sample from a burette, a few drops at a time, with constant stirring until the first permanent reddish color appears. This can be determined by comparison with distilled water blank. Record the mL of silver nitrate used.
3. If more than 7 or 8 mL of silver nitrate solution are required, the entire procedure should be repeated using a smaller sample diluted to 50 mL with distilled water.

**Calculation:**

Chloride, Cl\(^-\) (mg/L) = (mL of AgNO\(_3\) used - "error" or "blank") x Multiplying Factor (M.F.)
Normality of $\text{AgNO}_3$ equivalent wt. of $\text{Cl}^-$ x 1000
\[
\text{Where, M.F.} = \frac{\text{Normality of } \text{AgNO}_3 \times \text{equivalent wt. of } \text{Cl}^- \times 1000}{\text{mL of sample taken}}
\]

**Assignment**

1. "Chlorides can introduce into natural waters in many ways" --explain.
2. Why it is necessary to dilute sample if end point does not obtained even after adding more than 7 or 8 mL silver nitrate to the original sample?
3. In determination of chloride, why an indicator "blank" or "error" is subtracted from the amount of silver nitrate used in titration? Explain.
## DATA SHEET

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Experiment 8
Determination of Biochemical oxygen demand
**Introduction:**
The biochemical oxygen demand determination is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic organisms in a water body to break the organic materials present in the given water sample at certain temperature over a specific period of time.

BOD of water or polluted water is the amount of oxygen required for the biological decomposition of dissolved organic matter to occur under standard condition at a standardized time and temperature. Usually, the time is taken as 5 days and the temperature is 20°C.

The test measures the molecular oxygen utilized during a specified incubation period for the biochemical degradation of organic material (carbonaceous demand) and the oxygen used to oxidize inorganic material such as sulfides and ferrous ion. It also may measure the amount of oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand).

**Environmental significance:**
BOD is the principle test to give an idea of the biodegradability of any sample and strength of the waste. Hence the amount of pollution can be easily measured by it. Efficiency of any treatment plant can be judged by considering influent BOD and the effluent BOD and so also the organic loading on the unit.

Application of the test to organic waste discharges allows calculation of the effect of the discharges on the oxygen resources of the receiving water. Data from BOD tests are used for the development of engineering criteria for the design of wastewater treatment plants. Ordinary domestic sewage may have a BOD of 200 mg/L. Any effluent to be discharged into natural bodies of water should have BOD less than 30 mg/L. This is important parameter to assess the pollution of surface waters and ground waters where contamination occurred due to disposal of domestic and industrial effluents. Drinking water usually has a BOD of less than 1 mg/L. But, when BOD value reaches 5 mg/L, the water is doubtful in purity. The determination of BOD is used in studies to measure the self-purification capacity of streams and serves regulatory authorities as a means of checking on the quality of effluents discharged to stream waters.

The determination of the BOD of wastes is useful in the design of treatment facilities. It is the only parameter, to give an idea of the biodegradability of any sample and self purification capacity of rivers and streams. The BOD test is among the most important method in sanitary analysis to determine the polluting power, or strength of sewage, industrial wastes or polluted water. It serves as a measure of the amount of clean diluting water required for the successful disposal of sewage by dilution.

According to Bangladesh Environment Conservation Rules (1997), drinking water standard for biochemical oxygen demand (BOD) is 0.2 mg/L (at 20°C). For wastewater effluent allowable concentration of BOD varies from 50-250 mg/L depending on discharge point of the effluent (e.g., inland water, irrigation land, public sewer etc.)

**Principle:**
The sample is filled in an airtight bottle and incubated at specific temperature for 5 days. The dissolved oxygen (DO) content of the sample is determined before and after five days of incubation at 20°C and the BOD is calculated from the difference between initial and final DO.

The initial DO is determined shortly after the dilution is made; all oxygen uptake occurring after this measurement is included in the BOD measurement.
Since the oxygen demand of typical waste is sever hundred milligrams per liter, and since the saturated value of DO for water at 20°C is only 9.1 mg/L, it is usually necessary to dilute the sample to keep final DO above zero. If during the five days of experiment, the DO drops to zero, then the test is invalid since more oxygen would have been removed had more been available.

The five-day BOD of a diluted sample is given by,

$$\text{BOD}_5 = [\text{DO}_1 - \text{DO}_0] \times \text{D.F.}$$  \hspace{1cm} 8.1

Here,

$$\text{Dilution factor (D.F.)} = \frac{(\text{Volume of waste water + Volume of dilution water})}{\text{Volume of waste water}}$$

In some cases, it becomes necessary to seed the dilution water with microorganisms to ensure that there is an adequate bacterial population to carry out the biodegradation. In such cases, two sets of BOD bottles must be prepared, one for just the seeded dilution water (called the "blank") and the other for the mixture of wastewater and dilution water. The changes in DO in both are measured. The oxygen demand of waste water (BOD$_w$) is then determined from the following relationship:

$$\text{BOD}_m \times V_m = \text{BOD}_w \times V_w + \text{BOD}_d \times V_d$$  \hspace{1cm} 8.2

Where, BOD$_m$ is the BOD of the mixture of wastewater and dilution water and BOD$_d$ is the BOD of the dilution water alone; $V_w$ and $V_d$ are the volumes of wastewater and dilution water respectively in the mixture and $V_m = V_w + V_d$

**Sample handling and preservation:**

Preservation of sample is not practical. Because biological activity will continue after a sample has been taken, changes may occur during handling and storage.

If analysis is to be carried out within two hours of collection, cool storage is not necessary. If analysis can not be started with in the two hours of sample collection to reduce the change in sample, keep all samples at 4°C.

Do not allow samples to freeze. Do not open sample bottle before analysis. Begin analysis within six hours of sample collection.

**Materials required:**

**Reagents:**
- Manganese sulfate solution
- Alkaline potassium iodide solution
- 0.025N sodium thiosulfate
- Starch solution (indicator)
- Concentrated sulfuric acid.

**Apparatus:**
- BOD bottle
- Beaker (250 ml)
- Measuring cylinder
- Dropper
- Stirrer

**Procedure:**

Fill two BOD bottles with sample (or diluted sample); the bottles should be completely filled. Determine initial DO (DO$_0$) in one bottle immediately after filling with sample (or diluted
sample). Keep the other bottle in dark at 20°C and after particular days (usually 5-days) determine DO (DOₜ) in the sample (or diluted sample). Dissolved oxygen (DO) is determined according to the following procedure:

1. Add 1 mL of manganous sulfate solution to the BOD bottle by means of pipette, dipping in end of the pipette just below the surface of the water.
2. Add 1 mL of alkaline potassium iodide solution to the BOD bottle in a similar manner.
3. Insert the stopper and mix by inverting the bottle several times.
4. Allow the "precipitates" to settle halfway and mix again.
5. Again allow the "precipitates" to settle halfway.
6. Add 1 mL of concentrated sulfuric acid. Immediately insert the stopper and mix as before.
7. Allow the solution to stand at least 5 minutes.
8. Withdraw 100 mL of solution into an Erlenmeyer flask and immediately add 0.025N sodium thiosulfate drop by drop from a burette until the yellow color almost disappears.
9. Add about 1 mL of starch solution and continue the addition of the thiosulfate solution until the blue color just disappears. Record the ml. of thiosulfate solution used (disregard any return of the blue color).

**Calculation:**

Dissolved oxygen, DO (mg/L) = mL of 0.025N sodium thiosulfate added x 2

Calculate BOD of the sample according to Eq. – 8.1 or Eq. – 8.2.

**Assignment:**

- In a BOD test on a diluted wastewater sample (1:20 dilution, but not seeded), the initial DO is 8.2 mg/L and final DO after 5 days is 3.2 mg/L. If the reaction rate constant is 0.2/day, calculate: (a) 5-day BOD of the wastewater, (b) Ultimate carbonaceous BOD of the wastewater, (c) Remaining Oxygen demand after 5-days.
- A test bottle containing just seeded dilution water has its DO level drop by 0.6 mg/L in a 5-day test. A 300 mL BOD bottle filled with 40 mL of wastewater and the rest with seeded dilution water experiences a drop of 7.1 mg/L in the same period (5-day), Calculate the BOD₅ of the wastewater.
- A sample of sewage is mixed with water (no seeding done) in the ratio of 1:30 (i.e., 1 mL of sewage diluted to 30 mL by adding water) for BOD test. The initial DO is 8 mg/L and final DO, after 5 days, is 2.1 mg/L. Calculate BOD₅ of the sewage.
DATA SHEET

Experiment Name : 
Experiment Date : 

Student’s Name : 
Student’s ID : 
Year/ Semester : 
Section/ Group : 

Table:

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Temperature of Sample (°C)</th>
<th>BOD (mg/L)</th>
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<tbody>
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Course Teacher : 
Designation : 
Signature :
Experiment 9
Determination of Chemical oxygen demand
**Introduction:**
The chemical oxygen demand (COD) test allows measurement of oxygen demand of the waste in terms of the total quantity of oxygen required for oxidation of the waste to carbon dioxide and water. The test is based on the fact that all organic compounds, with a few exceptions, can be oxidized by the action of strong oxidizing agents under acid conditions.

\[
\text{Organic matter + Oxidizing agent} = \text{CO}_2 + \text{H}_2\text{O}
\]

The reaction in Eq.-1 involves conversion of organic matter to carbon dioxide and water regardless of the biological assimilability of the substance. For example, glucose and lignin (biologically inert substance) are both oxidized completely by the chemical oxidant. As a result, COD values are greater than BOD values, especially when biologically resistant organic matter is present.

Thus one of the chief limitations of COD test is its inability to differentiate between biodegradable and non-biodegradable organic matter. In addition, it does not provide any evidence of the rate at which the biologically active material would be stabilized under conditions that exist in nature.

The major advantage of COD test is the short time required for evaluation. The determination can be made in about 3 hours rather than the 5-days required for the measurement of BOO. For this reason, it is used as a substitute for the BOD test in many instances.

**Environmental Significance:**
"COD is often measured as a rapid indicator of organic pollutant in water; it is normally measured in both municipal and industrial wastewater treatment plants and gives an indication of the efficiency of the treatment process. COD has further applications in power plant operations, chemical manufacturing, commercial laundries, pulp & paper mills, environmental studies and general education. According to Bangladesh Environment Conservation Rules (1997), drinking water standard for chemical oxygen demand (COD) is 40 mg/L. For wastewater effluent allowable concentration of CBOD varies from 200- 400 mg/L depending on discharge point of the effluent (e.g., inland water, irrigation land, public sewer etc.)

**Principle:**
Potassium dichromate or potassium permanganate is usually used as the oxidizing agent in the determination of COD. In this class potassium permanganate would be used in the determination of COD. Potassium permanganate is selective in the reaction and attacks the carbonaceous and not the nitrogenous matter.

In any method of measuring COD, an excess of oxidizing agent must be present to ensure that all organic matter is oxidized as completely as possible within the power of the reagent. This requires that a reasonable excess be present in all samples. It is necessary, therefore, to measure the excess in some manner so that the actual amount can be determined. For this purpose, a solution of a reducing agent (e.g., ammonium oxalate) is usually used.

**Materials required:**
- Diluted sulfuric acid solution
- Standard potassium permanganate solution
- Standard Ammonium Oxalate solution
**Apparatus:**
- Beaker (250 mL)
- Dropper
- Stirrer

**Procedure:**
1. Pipette 100 mL of the sample into a 250 mL Erlenmeyer flask.
2. Add 10 mL of diluted sulfuric acid and 10 mL of standard KMnO₄ solution.
3. Heat the flask in a boiling water bath for exactly 30 minutes, keeping the water in the bath above the level of the solution in the flask. The heating enhances the rate of oxidation reaction in the flask.
4. If the solution becomes faintly colored, it means that most of the potassium permanganate has been utilized in the oxidation of organic matter. In such a case, repeat the above using a smaller sample diluted to 100 mL with distilled water.
5. After 30 minutes in the water bath, add 10 mL of standard ammonium oxalate [(NH₄)₂C₂O₄] solution into the flask. This 10 mL ammonium oxalate, which is a reducing agent, is just equivalent to the 10 mL potassium permanganate (oxidizing agent) added earlier. The excess of reducing agent [(NH₄)₂C₂O₄] now remaining in the flask is just equivalent to the amount of the oxidizing agent (KMnO₄) used in the oxidation of organic matter.
6. The quantity of ammonium oxalate remaining in the flask is now determined by titration with standard potassium permanganate. Titrate the content of the flask while hot with standard potassium permanganate to the first pink coloration. Record the mL of potassium permanganate used.

**Calculation:**

\[
\text{COD (mg/L)} = \frac{\text{mL of KMnO}_4 \text{ used in step 6} \times 100}{\text{mL of sample used}}
\]

**Assignment:**
1. What are the principal advantages and disadvantages of the COD test over the BOD test?
2. Explain why COD values are greater than BOD values.
3. What could be inferred from the following analytical results regarding the relative ease of—biodegradability of each waste?

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<th>Type of Waste</th>
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<th>COD (mg/L)</th>
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### DATA SHEET

**Experiment Name** :

**Experiment Date** :

**Student’s Name** :

**Student’s ID** :

**Year/ Semester** :

**Section/ Group** :

#### Table:

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**Course Teacher** :

**Designation** :

**Signature** :
Experiment 10
Chemical Coagulation of water: Alum Coagulation
**Introduction:**
Chemical coagulation is a treatment method widely used for removal of small sized and colloidal impurities from water. Surface water generally contains a wide variety of colloidal impurities that may cause the water to appear turbid and may impart color to the water. Colloidal particles that cause color and turbidity are difficult to separate from water because the particles will not settle by gravity and are so small that they pass through the pores of most common filtration media. In order to be removed, the individual colloids must aggregate and grow in size so that they can settle by gravity. Chemical agents are used to promote colloid aggregation by destroying the forces that stabilize colloidal particles.

The process of destroying the stabilizing forces and causing aggregation of colloids is referred to as chemical coagulation. Coagulation involves reduction of electrical forces of repulsion and promotion of "chemical type" interaction between colloids, which eventually results in settling of the colloids and accomplishes removal of turbidity and color. At higher coagulant doses, "charge reversal" is possible which may result in re-suspension of the colloids. Hence optimum coagulant doses are determined through laboratory model tests where the water to be treated are subjected to a range of doses of a coagulant and the removal efficiencies are observed.

Many authors use the term "coagulation" to describe the process by which the charge on particles is destroyed, and the term "flocculation" to describe the aggregation of particles into larger units. The chemical used for this purpose is called are called coagulants. The most common coagulants used in water and wastewater treatment are aluminum and ferric salts such as alum, ferric chloride and ferric sulfate.

The common metal salt alum (aluminum sulfate) is a good coagulant for water containing appreciable organic matter. The chemical formula used for commercial alum is Al₂(SO₄)₃·14H₂O. Once dissolved in water, aluminum forms hydroxo-complexes and solids [e.g., Al(OH)₃(s), Al(OH)₃⁺, Al(OH)₄⁺, Al(OH)₅⁺; [Eqs. 1-5] and as a result pH of water is lowered, especially if alkalinity of water is low. Theoretically, each mg/L of alum consume approximately 0.50 mg/L (as CaCO₃) of alkalinity. For water with low alkalinity, this may result in significant reduction in pH that may interfere with formation of aluminum hydroxide flocs. If the alkalinity is insufficient, coagulant aids such as lime [Ca(OH)₂], soda ash (Na₂CO₃), activated silica and polyelectrolytes are used to provide the necessary alkalinity. Iron coagulants can be operated over a wider pH range and are generally effective in removing turbidity and color from water. However, they are usually more costly.

\[
\begin{align*}
\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O} \text{ (alum)} & = 2\text{Al}^{3+} + 3\text{SO}_4^{2-} \\
\text{Al}^{3+} + 3\text{H}_2\text{O} & = \text{Al(OH)}_3(s) + 3\text{H}^+ \\
\text{Al}^{3+} + \text{H}_2\text{O} & = \text{Al(OH)}_2^+ + \text{H}^+ \\
\text{Al}^{3+} + \text{H}_2\text{O} & = \text{Al(OH)}_3^+ + \text{H}^+ \\
\end{align*}
\]

**Environmental Significance:**
Besides efficient removal of turbidity and color, coagulation with alum and ferric chloride or ferric sulfate is also widely used for removal of heavy metal ions (e.g., lead, arsenic) from water. In this process heavy metal ions are primarily removed by adsorption (and subsequent precipitation) onto coagulated flocs of metal (either aluminum or iron) hydroxides. Coagulation with alum and ferric chloride / sulfate are being successfully used for removal of arsenic from water.
Theory on the Experiment:
Treatment of water by coagulation involves -
(1) Determination of optimum dose of coagulant by jar test.
(2) Determination of power input for the flocculator.

In the class jar test to determine optimum coagulant dose will be carried out, it is important to determine the optimum dose to avoid charge reversal and resuspension colloids. Optimum coagulant dose is considered as the amount of coagulant which produces water with lowest turbidity.

Materials required:
Reagent:
- Standard Alum solution.

Apparatus:
- Coagulation (stirring) device
- pH meter
- Turbidity meter
- Glass beakers (1000 mL)

Procedure:
1. Determine pH and turbidity of the water to be treated. You may be instructed to determine color and arsenic concentration of the water to be treated (if removal efficiencies of these parameters are to be determined).
2. Fill six 1000 mL beakers each with 500 mL water to be treated.
3. Add required (as instructed by teacher) coagulant (standard alum solution) to each beaker.
4. Mix the samples in the beaker with the help of the stirring device. Subject the samples to one minute of rapid mixing followed by 15 minutes of slow mixing (about 40 rpm).
5. Allow the flocs to settle down for about 15 minutes. Observe the characteristics of the flocs and the settling rates.
6. Collect the supernatant from each beaker and measure pH and turbidity of each. You may be instructed to measure color and arsenic concentration of the supernatant samples (if removal efficiencies of these parameters are to be determined).
7. Plot pH versus alum dose in a graph paper and observe effect of alum dose on pH.
8. Plot turbidity (NTU) versus the coagulant (alum) dose (mg/L) in a graph paper. Determine optimum dose of alum from this plot.

Assignment:
1. What is charge reversal? When and why it happens?
2. Why addition of alum may result in a drop in pH value. Discuss the effect of alum dose on pH from your experimental results.
3. What is the primary mechanism by which heavy metal ions are removed during coagulation?
## DATA SHEET

Experiment Name : 
Experiment Date : 

Student’s Name : 
Student’s ID : 
Year/ Semester : 
Section/ Group : 

### Table:

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Course Teacher : 
Designation : 
Signature :
Experiment 11
Break Point Chlorination
**Introduction:**
Chlorination of public water supplies and polluted waters serves primarily to destroy or deactivate disease-producing microorganisms. Disinfection with chlorine is widely practiced. Chlorination may produce some adverse effects including taste and odor problem. In recent years, chlorination has been found to produce trihalomethanes (THMs) and other organics of health concern (THMs are suspected human carcinogens). Thus, use of alternative disinfectants, such as chlorine dioxide and ozone that do not cause this particular problem, is increasing.

**Theory:**
Disinfectant capabilities of chlorine depend on its chemical form in water, which in turn is dependent on pH, temperature, organic content of water, and other water quality factors. Chlorine is used in the form of free chlorine [e.g., chlorine gas] or as hypochlorites [e.g., NaOCl and Ca(OCl)₂]. Chlorine applied to water either as free chlorine or hypochlorite initially undergoes hydrolysis to form free chlorine consisting of aqueous molecular chlorine, hypochlorous acid and hypochlorite ion.

Chlorine gas rapidly hydrolyzes to hypochlorous acid according to:
\[ \text{Cl}_2 + \text{H}_2\text{O} = \text{HOCl} + \text{H}^+ + \text{Cl}^- \quad \text{11.1} \]

Aqueous solutions of sodium or calcium hypochlorite hydrolyze too:
\[ \text{Ca(OCl)}_2 + 2\text{H}_2\text{O} = \text{Ca}^{2+} + 2\text{HOCl} + 2\text{OH}^- \quad \text{11.2} \]
\[ \text{NaOCl} + \text{H}_2\text{O} = \text{Na}^+ + \text{HOCl} + \text{OH}^- \quad \text{11.3} \]

Hypochlorous acid is a weak acid and will disassociate according to:
\[ \text{HOCl} \Leftrightarrow \text{H}^+ + \text{OCl}^- \quad \text{11.4} \]

The two chemical species formed by chlorine in water, hypochlorous acid (HOCl) and hypochlorite ion (OCl⁻), are commonly referred to as — free or — available chlorine.

In waters with pH between 6.5-8.5, the reaction is incomplete and both species (HOCl and OCl) will be present. Hypochlorous acid is the more germicidal of the two.

![Figure 11.1: Free Chlorine Distribution with pH](image)

The graph illustrates the percentage of free chlorine species at different pH levels. At pH 7.5, there is a 50:50 equilibrium. Below pH 7.5, the availability of hypochlorite (OCl⁻) increases, which could lead to corrosivity concerns.
Reactions of Chlorine with Impurities in Water:

Reactions with Ammonia:
Free chlorine reacts readily with ammonia and certain nitrogenous compounds to form what are collectively known as "combined chlorine". The inorganic chloramines consist of three species: monochloramine (NH₂Cl), dichloramine (NHCl₂) and trichloramine or nitrogen trichloride (NCl₃). The presence and concentrations of these combined forms depend on a number of factors including the ratio of chlorine to ammonia-nitrogen, chlorine dose, temperature, pH and alkalinity.

$$\text{NH}_3 + \text{HOCl} = \text{NH}_2\text{Cl} + \text{H}_2\text{O}; \text{pH} 4.5 \text{ to } 8$$  
$$\text{NH}_2\text{Cl} + \text{HOCl} = \text{NHCl}_2 + \text{H}_2\text{O}; \text{pH} 4.5 \text{ to } 8$$  
$$\text{NHCl}_2 + \text{HOCl} = \text{NCl}_3 + \text{H}_2\text{O}; \text{pH} < 4.5$$  

In addition to chlorinating ammonia, chlorine also reacts to oxidize ammonia to chlorine-free products (e.g., nitrogen gas and nitrate) as shown below.

$$3 \text{ Cl}_2 + 2 \text{ NH}_3 = \text{N}_2 (g) + 6\text{H}^+ + 6 \text{Cl}^-$$  
$$4\text{Cl}_2 + \text{NH}_3 + 3\text{H}_2\text{O} = 8\text{Cl}^- + \text{NO}_3^- + 9\text{H}^+$$  

The mono- and dichloramines have significant disinfecting power and are therefore of interest in the measurement of chlorine residuals. Combined chlorine in water supplies may be formed in the treatment of raw waters containing ammonia; chlorinated wastewater effluents, as well as certain chlorinated industrial effluents normally contain only combined chlorine.

Reactions with Other Impurities:
Chlorine combines with various reducing agents and organic compounds thus increasing the chlorine demand which must be satisfied before chlorine is available to accomplish disinfection. Fe²⁺, Mn²⁺, NO₃⁻, and H₂S are examples of inorganic reducing agents present in water supplies that will react with chlorine. Chlorine can react with phenols to produce mono-, di-, or trichlorophenols, which can impart tastes and odors to waters. Chlorine also reacts with humic substances present in water to form trihalomethanes (THMs, e.g., chloroform, bromoform, etc.) which are suspected human carcinogens (Note: According to USEPA, maximum allowable level of THMs in drinking water is 100 µg/L).

Break Point Chlorination
If chlorine is added to water containing reducing agents and ammonia (either naturally present or added to water to produce combined chlorine), a hump-shaped breakpoint curve is produced as shown in Fig. The different segment of the curve is described below:

a. If the water is free of ammonia and other compounds that may react with chlorine, the application of chlorine will yield free available chlorine residual of same concentration. This is denoted by the "no demand line" or the "zero demand line" (see Fig.).

b. Chlorine first reacts with reducing agents such as H₂S, Fe²⁺, Mn²⁺ and develops no measurable residual as shown by the portion of the curve from Origin up to point A.
Figure 11.2: Generalized curve obtained during breakpoint chlorination of a water sample containing ammonia (Source: Peavy et al., 1985).

c. Addition of chlorine beyond point A results in forming mainly mono- and di-chloramines. With mole ratios of chlorine to ammonia up to 1:1 [i.e., \(\text{Cl}_2:\text{NH}_3\text{-N} = 1:1\)], both mono and di-chloramines are formed. Chloramines thus formed are effective disinfectants and are shown as combined available chlorine residual in Fig. (From A to B).

d. Further increase in the mole ratio of chlorine to ammonia result in formation of some trichloramine and oxidation of part of ammonia to \(\text{N}_2\) and \(\text{NO}_3^-\). These reactions are essentially complete when 1.5 mole of chlorine has been added for each mole of ammonia nitrogen originally present in water [i.e., \(\text{Cl}_2:\text{NH}_3\text{-N} = 1.5:1\)]. This is represented by the portion of the curve from B to C.

e. Addition of chlorine beyond point C would produce free chlorine residuals and is referred to as "breakpoint chlorination". In other words, chlorination of water to the extent that all ammonia is converted to \(\text{N}_2\) or higher oxidation state is referred to as "breakpoint chlorination".

f. Addition of chlorine beyond point C would produce free chlorine residuals and is referred to as "breakpoint chlorination". In other words, chlorination of water to the extent that all ammonia is converted to \(\text{N}_2\) or higher oxidation state is referred to as "breakpoint chlorination".

**Environmental Significance:**
Breakpoint chlorination is required to obtain a free chlorine residual for better disinfection if ammonia is present in a water supply. While free chlorine residuals have good disinfecting powers, they are usually dissipated quickly in the distribution system. For this reason, final treatment with ammonia if often practiced to convert free chlorine residuals to longer-lasting combined chlorine residuals. The difference between the amount of chlorine added to the water and the amount of residual chlorine (i.e., free and combined available chlorine remaining) at the end of a specified contact period is termed as "chlorine demand".
**Materials required:**

**Reagents:**
- Starch Indicator
- Standard 0.025 N Sodium thiosulfate
- Potassium Iodine crystal
- Concentrated Acetic Acid
- Chlorine water

**Apparatus:**
- Erlemeyer flask (250 mL)
- Bottle
- Beaker (250 mL)
- Measuring cylinder
- Dropper
- Stirrer

**Procedure:**
1. Place 200-mL portion of the water to be chlorinated in each of six 250-mL flasks.
2. Add required quantity (as instructed by your teacher) of "chlorine water" (stock solution of bleaching powder in water) in each of the flasks. The chlorine content of the "chlorine water" (determined earlier in the laboratory) would be provided to you by your teacher. Calculate the chlorine dose for each of the six flasks.
3. Shake each flask gently and allow to stand for 30 minutes.
4. Determine residual chlorine of water from each flask by the starch-iodine method as described below:

**Starch-Iodine Method:**
The starch-iodine method is based on the oxidizing power of free and combined chlorine residuals to convert iodide ion into free iodine at pH 8 or less, as shown below.

\[ Cl_2 + 2I^- = I_2 + 2Cl^- \]

In the starch-iodine method, the quantity of chlorine residuals is determined by measuring the quantity of iodine by titration with a reducing agent sodium thiosulfate (Na$_2$S$_2$O$_3$). The end point of titration is indicated by the disappearance of blue color, produced by the reaction between iodine and starch (which is added as indicator during the titration),

\[ I_2 + 2Na_2S_2O_3 = Na_2S_3O_6 + 2NaI \]
\[ or, I_2 + 2S_2O_3^{2-} = S_4O_6^{2-} + 2I^- \]
\[ I_2 + \text{starch} = \text{blue color} \]

(Quantitative test for the presence of iodine/chlorine)

The titration is carried out at pH 3 to 4, because the reaction with thiosulfate is not stoichiometric at neutral pH due to partial oxidation of the thiosulfate to sulphate.

**Procedure for determination of Chlorine concentration in water:**

a. Place 200 mL of the sample in an Erlenmeyer flask.
b. Add 'about 1g of potassium iodide (estimated on a spatula) and 2 mL of concentrated Acetic acid to the water.
c. Add 0.025 N sodium thiosulfate drop by drop from a burette until the yellow color almost disappears.
d. Add 1 mL of starch solution to the water.
e. Continue addition of standard sodium thiosulfate (Na$_2$S$_2$O$_3$) solution until the blue color just disappears.
f. Record the quantity (in mL) of sodium thiosulfate (Na$_2$S$_2$O$_3$) solution used.

**Calculation:**

**Residual chlorine (mg/L) =** mL of 0.025N sodium thiosulfate used x M.F.

**M.F. =** $\frac{\text{Normality of } N_2S_2O_3 \times \text{Equivalent wt. of Cl}_2 \times 1000}{\text{mL of sample taken}}$

**Assignment:**

1. What are the major disadvantages of chlorination? Name some of the alternate disinfectants.

2. You would like to perform chlorination to a water sample with pH 7.5. At this pH, what would be the relative proportions of HOCl and OCI (see Fig. 1)? What kind of change in pH would you propose in order to increase the relative proportion of HOCl, which is a better disinfectant?

3. Schematically draw a —chlorine residual” versus "chlorine dose” curve for a water sample with no ammonia or organic matter.
DATA SHEET

Experiment Name : 
Experiment Date : 

Student’s Name : 
Student’s ID : 
Year/ Semester : 
Section/ Group : 

Table:

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<th>Observation No.</th>
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<th>Chlorine Dose (mg/L)</th>
<th>Residual Chlorine (mg/L)</th>
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Course Teacher : 
Designation : 
Signature :
Experiment 12
Determination of Total and Fecal Coliform in water
**Introduction:**
A variety of different microorganisms are found in untreated water. Most of these organisms do not pose a health hazard to humans. Certain organisms, referred to as pathogens, cause disease to humans which include species of bacteria, viruses and protozoa. These organisms are not native to aquatic systems and usually require an animal host for growth and reproduction. Pathogens are likely to gain entrance sporadically, and they do not survive for very long period of time; consequently they could be missed in a sample submitted to the laboratory. Although it is possible to detect the presence of various pathogens in water, the isolation and identification of many of these is often extremely complicated, time-consuming and expensive proposition. Hence in most cases (except when presence of any particular microorganism is suspected) the microbiological quality of water is checked using some indicator organisms.

An **indicator organism** is one whose presence presumes that contamination has occurred and suggests the nature and extent of the contaminants. An indicator organism should be a microorganism whose presence is evidence of fecal contamination of warm-blooded animals. Indicators may be accompanied by pathogens, but typically do not cause disease themselves. The ideal indicator organism should have the following characteristics:

- Always be present when pathogens are present
- Always be absent where pathogens are absent
- Numbers should correlate the degree of pollution
- Be present in greater number than pathogens
- There should be no after-growth or re-growth in water
- There should be greater or equal survival time than pathogens
- Be easily and quickly detected by simple laboratory tests
- Should have constant biochemical and identifying characteristics
- Harmless to humans

No organisms or group of organisms meet all of these criteria; but the **coliform** bacteria fulfill most of them, and this group is most common indicator used in microbial examination of water. Total coliforms are grouped into two categories (1) **Fecal coliform** (thermo-tolerant coliform) and (2) **Non-Fecal coliform**

**Total coliforms** are defined as gram negative bacteria which ferment lactose at 35° or 37° C with the production of acid, gas and aldehyde within 24 or 48 hours. **Fecal coliform** are a subgroup of total coliforms, which live in the warm blooded animals and have the same properties as the **total coliform** but tolerate and grow at higher selective temperature range of 44° to 44.5°C. In addition, they form indole from tryptophan. And these combined properties, when positive, are regarded as presumptive *Escherichia coli* (presumptive E. coli). Some coliform species are frequently associated with plant debris or may be common inhabitants in soil or surface waters which are called non-fecal coliforms.

**Total coliform (TC) = Fecal coliform (FC) + Non-fecal coliform.**
Thus, the total coliform group should not be regarded as an indicator of organisms exclusively of fecal origin. The use of total coliforms as an indicator may therefore be of little value in assessing the fecal contamination of surface water, unprotected shallow wells etc. where contamination by coliforms of non fecal origin can occur. The measurement of total coliforms is of particular relevance for treated and / or chlorinated water supplies; in this case the absence of total coliforms would normally indicate that the water has been sufficiently treated / disinfected to destroy various pathogens. Measurement of focal coliforms is a better
indicator of general contamination by material of fecal origin. The predominant species of fecal coliform group is *Escherichia coil* (E. coil), which is exclusively of fecal origin, but strains of *Klebsella pneumonia* and *Enterobacter* species may also be present in contaminated water.

Using coliform as indicators of the presence and absence of pathogens sometimes may cause the following drawbacks:

- False positive result can be obtained from the bacterial genus aeromonas, which can biochemically mimic the coliform group
- False negative result can be obtained when conforms are present along with high population of other bacteria. The latter bacteria can act to suppress coliform activity.
- A number of pathogens have been shown to survive longer in natural waters and/or through various treatment processes than coliform.

But the use of coliforms was established first and there does not appear to be any distinct advantages to warrant shifting to other indicator organisms. Since bacteria are used as indicator organisms, the microbiological examination of water is commonly called bacteriological examination.

**Methods of Bacteriological Examination of Water:**

Basically there two methods of bacteriological analysis of water: (a) Multiple Tube or Most Probable Number (MPN) method, and (b) Membrane Filter (MF) method.

(a) **Multiple Tube/ Most Probable Number (MPN) method**

MPN is a procedure to estimate the population density of viable microorganisms in a test sample. It’s based upon the application of the theory of probability to the numbers of observed positive growth responses to a standard dilution series of sample inoculums placed into a set number of culture media tubes. Positive growth response after incubation may be indicated by such observations as gas production in fermentation tubes or visible turbidity in broth tubes, depending upon the type of media employed.

(b) **Membrane Filter Method**

In contrast to the multiple-tube (MT) method, the membrane filter (IVIF) method gives a direct count of total coliforms and fecal coliforms present in a given sample of water. The method is based on the filtration of a known volume of water through a membrane filter consisting of a cellulose compound with a uniform pore diameter of 0.45 μm; the bacteria are retained on the surface of the membrane filter. When the membrane containing the bacteria is incubated in a sterile container at an appropriate temperature with a selective differential culture medium, characteristic colonies of coliforms and fecal coliforms develop, which can be counted directly. This technique is popular with environmental engineers. This method is not suitable for turbid waters, but otherwise it has several advantages. Its particular advantages and limitations are as follows:

**Advantages:**

- Results are obtained more quickly as the number of coliforms can be assessed in less than 24 hours, whereas the multiple tube technique requires 48 hours both for a negative or a presumptive positive test;
- Saving in work, certain supplies and glassware;
- Method gives direct results;
- Easy to use in laboratories, or even in the field if portable equipment is used.
Disadvantages:
- High turbidity caused by clay, algae, etc. prevents the filtration of a sufficient volume of water for analysis and it may also produce a deposit on the membrane which could interfere with bacterial growth;
- Presence of a relatively high non-coliform count may interfere with the determination of coliforms;
- Waters containing particular toxic substances which may be absorbed by the membranes, can affect the growth of the coliforms.

Test Procedure (For MF method):
This section describes the general procedures, It should be noted that different types of filtration units and equipment are available in the market for performing the tests.

Determination of Total Coliforms (TC):
1. Connect the Erlenmeyer (side-arm) flask to the vacuum source (turned off) and place the porous support in position. If an electric pump is used, it is advisable to put a second flask between the Erlenmeyer and the vacuum source; this second flask acts as a water trap and thus protects the electric pump.
2. Open a Petri-dish and place a pad in it.
3. With a sterile pipette add 2 mL of selective broth (culture) medium to saturate the pad.
4. Assemble the filtration unit by placing sterile membrane filter on the porous support, using forceps, or sterilized earlier by flaming.
5. Place the upper container in position and secure it with the special clamps. The type of clamping to be used will depend on the type of equipment.
6. Pour tide volume of sample chosen as optimal, in accordance with the type of water, into the upper container. If the test sample is less than 10 mL, at least 20 mL. of sterile dilution water should be added to the top container before filtration applying the vacuum.
7. After the sample has passed through the filter, disconnect the vacuum and rinse the container with 20-30 mL of sterile dilution water. Repeat the rinsing after all the water from the first rinse has passed through the filter.
8. Take the filtration unit apart and using the forceps, place the membrane filter in the Petri-dish on the pad with the grid side up. Make sure that no air bubbles are trapped between the pad and the filter.
9. Invert the Petri-dish for incubation.
10. Incubate at 35°C or 37°C for 18-24 hours with 100% humidity (to ensure this, place a piece of wet cotton wool in the incubator). If ointment containers or plastic dishes with tight-fitting lids are used, humidification is not necessary.

Bacterial Colony observation:
Colonies of coliform bacteria are a medium red or dark red color, with a greenish gold or metallic surface sheen. This sheen may cover the entire colony or appear only in the centre of the colony. Colonies of other types should not be counted. The colonies can be counted with the aid of a lens. The number of total coliforms per 100 mL is then given by:

Determination of Fecal Coliforms (FC):
The procedure for fecal coliforms is similar to that used for determining total coliforms. Filter the sample as described, and place the membrane filter on the pad saturated with appropriate culture medium.
1. Place the dishes in an incubator at 44±0.5 °C for 24 hours at 100% humidity.
   Alternatively, tight-fitting or sealed Petri-dishes may be placed in water-proof plastic bags for incubation.
2. Submerge the bags in a water-bath maintained at 44±0.5°C for 24 hours. The plastic bags must be below the surface of the water throughout the incubation period. They can be held down by means of a suitable weight, e.g., a metal rack.

**Bacterial Colony observation:**
Colonies of fecal coliform bacteria are blue in color. This color may cover the entire colony, or appear only in the center of the colony. Colonies of other types should not be counted. The colonies can be counted with the aid of a lens. The number of fecal coliforms per 100 ml is then given by:

**Calculation:**

Total coliform (Nos. / 100 mL) = \[ \frac{\text{No.of coliform colonies counted}}{\text{mL of sample filtered}} \] x 100

Fecal coliform (Nos. / 100 mL) = \[ \frac{\text{No.of coliform colonies counted}}{\text{mL of sample filtered}} \] x 100

**Assignment:**

1. What do you understand by "indicator organisms"? Why water samples are usually tested for indicator organisms instead of specific pathogenic organisms?
2. Define and differentiate between total coliform (TC) and fecal coliform (FC)?
3. What are the major advantages of "membrane filtration method" over "multiple tube method"?
# DATA SHEET

Experiment Name : 
Experiment Date : 

Student’s Name : 
Student’s ID : 
Year/ Semester : 
Section/ Group : 

Table:

<table>
<thead>
<tr>
<th>Observation No.</th>
<th>Total Coliform per 100 ml</th>
<th>Fecal Coliform per 100 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Course Teacher : 
Designation : 
Signature :
Appendix 1
The Environment Conservation Rules, 1997

(A) Standards for inland surface water

<table>
<thead>
<tr>
<th>Best Practice based classification</th>
<th>pH</th>
<th>BOD mg/l</th>
<th>DO mg/l</th>
<th>Total Coliform number/100</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Source of drinking water for supply only after disinfecting:</td>
<td>6.5-8.5</td>
<td>2 or less</td>
<td>6 or above</td>
<td>50 or less</td>
</tr>
<tr>
<td>b. Water usable for recreational activity:</td>
<td>6.5 – 8.5</td>
<td>3 or less</td>
<td>5 of more</td>
<td>200 or less</td>
</tr>
<tr>
<td>c. Source of drinking water for supply after conventional treatment:</td>
<td>6.5 – 8.5</td>
<td>6 of less</td>
<td>6 or more</td>
<td>5000 or less</td>
</tr>
<tr>
<td>d. Water usable by fisheries:</td>
<td>6.5 – 8.5</td>
<td>6 of less</td>
<td>5 or more</td>
<td>---</td>
</tr>
<tr>
<td>e. Water usable by various process and cooling industries:</td>
<td>6.5 – 8.5</td>
<td>10 or less</td>
<td>5 or more</td>
<td>5000 or less</td>
</tr>
<tr>
<td>f. Water usable for irrigation:</td>
<td>6.5 – 8.5</td>
<td>10 or less</td>
<td>5 or more</td>
<td>1000 or less</td>
</tr>
</tbody>
</table>

Notes:
1. In water used for pisiculture, maximum limit of presence of ammonia as Nitrogen is 1.2 mg/l.
2. Electrical conductivity for irrigation water – 2250 µhmoms/cm (at a temperature of 25°C); Sodium less than 26%; boron less than 0.2%.

(B) Standards for drinking water

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameter</th>
<th>Unit</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aluminum</td>
<td>mg/l</td>
<td>0.2</td>
</tr>
<tr>
<td>2</td>
<td>Ammonia (NH₃)</td>
<td>,</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>Arsenic</td>
<td>,</td>
<td>0.05</td>
</tr>
<tr>
<td>4</td>
<td>Barium</td>
<td>,</td>
<td>0.01</td>
</tr>
<tr>
<td>5</td>
<td>Benzene</td>
<td>,</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>------------</td>
<td>---</td>
</tr>
<tr>
<td>6</td>
<td>BOD$_5$ 20°C</td>
<td>&quot; &quot;</td>
<td>0.2</td>
</tr>
<tr>
<td>7</td>
<td>Boron</td>
<td>&quot; &quot;</td>
<td>1.0</td>
</tr>
<tr>
<td>8</td>
<td>Cadmium</td>
<td>&quot; &quot;</td>
<td>0.005</td>
</tr>
<tr>
<td>9</td>
<td>Calcium</td>
<td>&quot; &quot;</td>
<td>75</td>
</tr>
<tr>
<td>10</td>
<td>Chloride</td>
<td>&quot; &quot;</td>
<td>150 – 600*</td>
</tr>
<tr>
<td>11</td>
<td>Chlorinated alkanes carbontetrachloride</td>
<td>&quot; &quot;</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>1,1 dichloroethylene</td>
<td>&quot; &quot;</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>1,2 dichloroethylene</td>
<td>&quot; &quot;</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>tetrachloroethylene</td>
<td>&quot; &quot;</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>trichloroethylene</td>
<td>&quot; &quot;</td>
<td>0.09</td>
</tr>
<tr>
<td>12</td>
<td>Chlorinated phenols</td>
<td>mg/l</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>- pentachlorophenol</td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>- 2,4,6 trichlorophenol</td>
<td>&quot; &quot;</td>
<td>0.03</td>
</tr>
<tr>
<td>13</td>
<td>Chlorine (residual)</td>
<td>&quot; &quot;</td>
<td>0.2</td>
</tr>
<tr>
<td>14</td>
<td>Chloroform</td>
<td>&quot; &quot;</td>
<td>0.09</td>
</tr>
<tr>
<td>15</td>
<td>Chromium (hexavalent)</td>
<td>&quot; &quot;</td>
<td>0.05</td>
</tr>
<tr>
<td>16</td>
<td>Chromium (total)</td>
<td>&quot; &quot;</td>
<td>0.05</td>
</tr>
<tr>
<td>17</td>
<td>COD</td>
<td>&quot; &quot;</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>Coliform (fecal)</td>
<td>n/100 ml</td>
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</tr>
<tr>
<td>19</td>
<td>Coliform (total)</td>
<td>n/100 ml</td>
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</tr>
<tr>
<td>20</td>
<td>Color</td>
<td>Hazen unit</td>
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</tr>
<tr>
<td>21</td>
<td>Copper</td>
<td>mg/l</td>
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</tr>
<tr>
<td>22</td>
<td>Cyanide</td>
<td>&quot; &quot;</td>
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</tr>
<tr>
<td>23</td>
<td>Detergents</td>
<td>&quot; &quot;</td>
<td>0.2</td>
</tr>
<tr>
<td>24</td>
<td>DO</td>
<td>&quot; &quot;</td>
<td>6</td>
</tr>
<tr>
<td>25</td>
<td>Fluoride</td>
<td>&quot; &quot;</td>
<td>1</td>
</tr>
<tr>
<td>26</td>
<td>Hardness (as CaCO$_3$)</td>
<td>&quot; &quot;</td>
<td>200 – 500</td>
</tr>
<tr>
<td>27</td>
<td>Iron</td>
<td>&quot; &quot;</td>
<td>0.3 – 1.0</td>
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<tr>
<td>28</td>
<td>Kjeldahl Nitrogen (total)</td>
<td>&quot; &quot;</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>Lead</td>
<td>&quot; &quot;</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
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</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>30.</td>
<td>Magnesium</td>
<td>„„</td>
<td>30 – 35</td>
</tr>
<tr>
<td>31.</td>
<td>Manganese</td>
<td>„„</td>
<td>0.1</td>
</tr>
<tr>
<td>32.</td>
<td>Mercury</td>
<td>„„</td>
<td>0.001</td>
</tr>
<tr>
<td>33.</td>
<td>Nickel</td>
<td>„„</td>
<td>0.1</td>
</tr>
<tr>
<td>34.</td>
<td>Nitrate</td>
<td>„„</td>
<td>10</td>
</tr>
<tr>
<td>35.</td>
<td>Nitrite</td>
<td>„„</td>
<td>&lt;1</td>
</tr>
<tr>
<td>36.</td>
<td>Odor</td>
<td>„„</td>
<td>Odorless</td>
</tr>
<tr>
<td>37.</td>
<td>Oil and grease</td>
<td>„„</td>
<td>0.01</td>
</tr>
<tr>
<td>38.</td>
<td>pH</td>
<td>„„</td>
<td>6.5 – 8.5</td>
</tr>
<tr>
<td>39.</td>
<td>Phenolic compounds</td>
<td>„„</td>
<td>0.002</td>
</tr>
<tr>
<td>40.</td>
<td>Phosphate</td>
<td>„„</td>
<td>6</td>
</tr>
<tr>
<td>41.</td>
<td>Phosphorus</td>
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<td>0</td>
</tr>
<tr>
<td>42.</td>
<td>Potassium</td>
<td>„„</td>
<td>12</td>
</tr>
<tr>
<td>43.</td>
<td>Radioactive materials (gross alpha activity)</td>
<td>Bq/l</td>
<td>0.01</td>
</tr>
<tr>
<td>44.</td>
<td>Radioactive materials (gross beta activity)</td>
<td>Bq/l</td>
<td>0.1</td>
</tr>
<tr>
<td>45.</td>
<td>Selenium</td>
<td>mg/l</td>
<td>0.01</td>
</tr>
<tr>
<td>46.</td>
<td>Silver</td>
<td>„„</td>
<td>0.02</td>
</tr>
<tr>
<td>47.</td>
<td>Sodium</td>
<td>„„</td>
<td>200</td>
</tr>
<tr>
<td>48.</td>
<td>Suspended particulate matters</td>
<td>„„</td>
<td>10</td>
</tr>
<tr>
<td>49.</td>
<td>Sulfide</td>
<td>„„</td>
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</tr>
<tr>
<td>50.</td>
<td>Sulfate</td>
<td>„„</td>
<td>400</td>
</tr>
<tr>
<td>51.</td>
<td>Total dissolved solids</td>
<td>„„</td>
<td>1000</td>
</tr>
<tr>
<td>52.</td>
<td>Temperature</td>
<td>°C</td>
<td>20-30</td>
</tr>
<tr>
<td>53.</td>
<td>Tin</td>
<td>mg/l</td>
<td>2</td>
</tr>
<tr>
<td>54.</td>
<td>Turbidity</td>
<td>JTU</td>
<td>10</td>
</tr>
<tr>
<td>55.</td>
<td>Zinc</td>
<td>mg/l</td>
<td>5</td>
</tr>
</tbody>
</table>
### SCHEDULE – 9

**Standards for Sewage Discharge**  
[See Rule 12]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Standard Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>miligram/l</td>
<td>40</td>
</tr>
<tr>
<td>Nitrate</td>
<td>''</td>
<td>250</td>
</tr>
<tr>
<td>Phosphate</td>
<td>''</td>
<td>35</td>
</tr>
<tr>
<td>Suspended Solids (SS)</td>
<td>''</td>
<td>100</td>
</tr>
<tr>
<td>Temperature</td>
<td>Degree Centigrade</td>
<td>30</td>
</tr>
<tr>
<td>Coliform</td>
<td>number per 100 ml</td>
<td>1000</td>
</tr>
</tbody>
</table>

**Notes:**

1. This limit shall be applicable to discharges into surface and inland waters bodies.
2. Sewage shall be chlorinated before final discharge.

### SCHEDULE – 10

**Standards for Waste From Industrial Units or Projects Waste**  
[See Rule 13]

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameter</th>
<th>Unit</th>
<th>Inland Surface Water</th>
<th>Public Sewerage system connected to treatment at second stage</th>
<th>Irrigated Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ammonical Nitrogen (as elementary N)</td>
<td>mg/l</td>
<td>50</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>2</td>
<td>Ammonia (as free ammonia)</td>
<td>''</td>
<td>5</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Arsenic (as)</td>
<td>''</td>
<td>0.2</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td>4</td>
<td>BOD$_{2}$ at 20°C</td>
<td>''</td>
<td>50</td>
<td>250</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>Boron</td>
<td>''</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>---</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>6</td>
<td>Cadmium (as Cd)</td>
<td>„ „</td>
<td>0.50</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>7</td>
<td>Chloride</td>
<td>„ „</td>
<td>600</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>8</td>
<td>Chromium (as total Cr)</td>
<td>„ „</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>9</td>
<td>COD</td>
<td>„ „</td>
<td>200</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>10</td>
<td>Chromium (as hexavalent Cr)</td>
<td>„ „</td>
<td>0.1</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>11</td>
<td>Copper (as Cu)</td>
<td>„ „</td>
<td>0.5</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>12</td>
<td>Dissolved Oxygen (DO)</td>
<td>„ „</td>
<td>4.5 – 8</td>
<td>4.5 – 8</td>
<td>4.5 – 8</td>
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<tr>
<td>13</td>
<td>Electro-conductivity (EC)</td>
<td>microhm/cm</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
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<tr>
<td>14</td>
<td>Total Dissolved Solids</td>
<td>„ „</td>
<td>2,100</td>
<td>2,100</td>
<td>2,100</td>
</tr>
<tr>
<td>15</td>
<td>Fluoride (as F)</td>
<td>„ „</td>
<td>2</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>16</td>
<td>Sulfide (as S)</td>
<td>„ „</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>Iron (as Fe)</td>
<td>„ „</td>
<td>2</td>
<td>2</td>
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<tr>
<td>18</td>
<td>Total Kjeldahl Nitrogen (as N)</td>
<td>„ „</td>
<td>100</td>
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<td>19</td>
<td>Lead (as Pb)</td>
<td>„ „</td>
<td>0.1</td>
<td>1.0</td>
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<tr>
<td>20</td>
<td>Manganese (as Mn)</td>
<td>„ „</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>21</td>
<td>Mercury (as Hg)</td>
<td>„ „</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>22</td>
<td>Nickel (as Ni)</td>
<td>„ „</td>
<td>1.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>23</td>
<td>Nitrate (as elementary N)</td>
<td>mg/l</td>
<td>10.0</td>
<td>Not yet Fixed</td>
<td>10</td>
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<tr>
<td>24</td>
<td>Oil and Grease</td>
<td>„ „</td>
<td>10</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>25</td>
<td>Phenolic Compounds (as C₆H₅OH)</td>
<td>„ „</td>
<td>1.0</td>
<td>5</td>
<td>1</td>
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<tr>
<td>26</td>
<td>Dissolved Phosphorus (as P)</td>
<td>„ „</td>
<td>8</td>
<td>8</td>
<td>15</td>
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<td>27</td>
<td>Radioactive substance</td>
<td>To be specified by Bangladesh Atomic Energy Commission</td>
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<tr>
<td>28</td>
<td>pH</td>
<td>6 – 9</td>
<td>6 – 9</td>
<td>6 – 9</td>
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<tr>
<td>29</td>
<td>Selenium (as Se)</td>
<td>mg/l</td>
<td>0.05</td>
<td>0.05</td>
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<tr>
<td>30</td>
<td>Zinc (as Zn)</td>
<td>Degree</td>
<td>5</td>
<td>10</td>
<td>10</td>
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<td>4</td>
<td>5</td>
<td>6</td>
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</tr>
<tr>
<td>31</td>
<td>Total Dissolved Solids</td>
<td>‚‘</td>
<td>2,100</td>
<td>2,100</td>
<td>2,100</td>
</tr>
<tr>
<td>32</td>
<td>Temperature</td>
<td>Centigrade</td>
<td>40</td>
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<td>40-Summer</td>
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<td></td>
<td>45</td>
<td>45</td>
<td>45-Winter</td>
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<tr>
<td>33</td>
<td>Suspended Solids (SS)</td>
<td>mg/l</td>
<td>150</td>
<td>500</td>
<td>200</td>
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<tr>
<td>34</td>
<td>Cyanide (as Cn)</td>
<td>‚‘</td>
<td>0.1</td>
<td>2.0</td>
<td>0.2</td>
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Notes:
1. These standards shall be applicable to all industries or projects other than those specified under the heading — Standards for sector wise industrial effluent or emission.
2. Compliance with these standards shall be ensured from the moment an industrial unit starts trial production, and in other cases, from the a project starts operation.
3. These standards shall be inviolable even in case of any sample collected instantly at any point of time. These standards may be enforced in a more stringent manner if considered necessary in view of the environmental conditions of a particular situation.
4. Inland Surface Water means drains/ponds/tanks/water bodies/ditches, canals, rivers, springs and estuaries.
5. Public sewerage system means treatment facilities of the first and second stage and also the combined and complete treatment facilities.
6. Irrigable land means such land area which is sufficiently irrigated by waste water taking into consideration the quantity and quality of such water for cultivation of selected crops on that land.
7. Inland Surface Water Standards shall apply to any discharge to a public sewerage system or to land if the discharge does not meet the requirements of the definitions in notes 5 and 6 above.
Appendix 2
Lab Report Format

1. All students must have a same colored printed cover page. The design of cover page is provided with the lab manual. Students have to compose only the course teacher’s name and designation and their information.

2. An index is provided. It should be printed and set after the cover page. Table may be fill up by pen during each submission after test.

3. Each report must have a common printed top page. Only the experiment name and no. and the date may be filled up by pen. A top page design is provided.

4. A4 papers have to be used for preparing the lab report. Writing should be done with pen. Pencil may be used for any kind of sketch.

5. In each experiment of the lab report the following points must have to be present: Objective, Equipment, Procedure, Data Table (signed), Sample Calculation, Result and Discussion.
CE 332
Environmental Engineering- Lab I
(Lab Manual)
<table>
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<th>Date of Performance</th>
<th>Date of Submission</th>
<th>Signature</th>
<th>Comments</th>
<th>Page no.</th>
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</tbody>
</table>
Experiment No. :
Experiment Name:

Date of Performance:
Date of Submission:

Prepared For
Name of Course Teacher
Designation of Course Teacher

Prepared By
Prof. Nagesh Kumar
Appendix 3
Lab Instructions

1. All students must have to be present at laboratory just in time.
2. All students must have to submit the lab report just after the entrance and before the class start.
3. Lab reports have to be submitted serially according to Student’s ID.
4. Students have to complete the data sheet in class and complete sample calculations and graphs in class and take sign from the course teacher. (In some experiment which require more times, data sheet should be completed as possible in class time.)
5. Students should be very careful about any test. They should conduct the tests by taking maximum care of the equipment during test.

Thank You