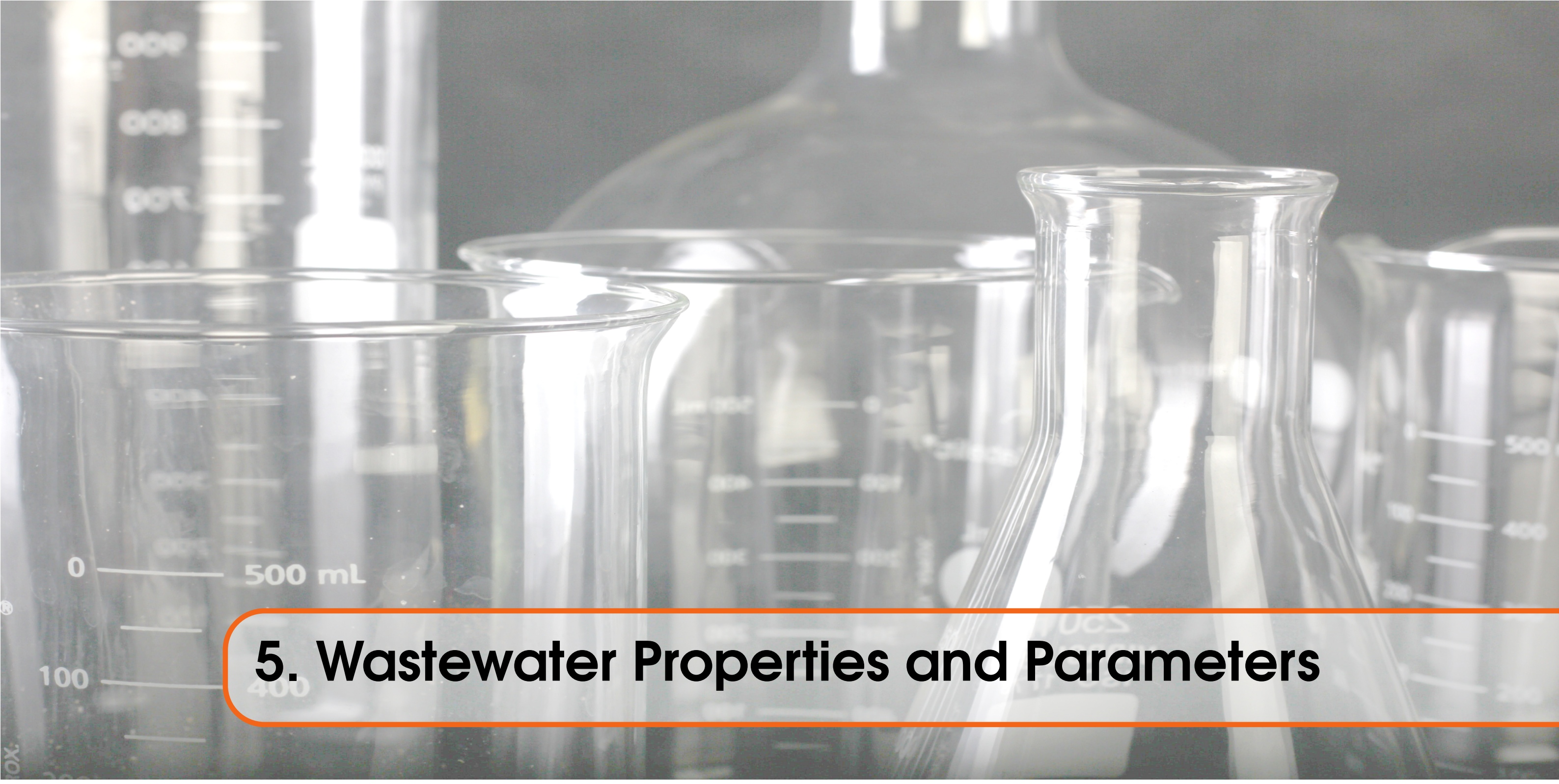


# 5. Wastewater Properties and Parameters

Laboratory and field tests are conducted to measure parameters which are critical for monitoring and controlling treatment. The following are the key parameters that are measured.

### 5.0.1 pH

pH is a measure of the hydrogen ion ($H^+$) content or the acidity or basicity of a solution. pH impacts the chemical and micribiological elements of wastewater treatment processes and thus pH measurement and control is critical.

- Pure water dissociates into equal concentration of hydrogen ions and hydroxide ions: $H_2O \rightarrow H^+ + OH^-$.
- The $H^+$ are responsible for acidic properties and the $OH^-$ ions for the basic properties.
- pH is the inverse of $H^+$ concentration; pH increases when the concentration of $H^+$ decreases relative to the concentration of OH-.
- pH scale ranges from 0 – 14. When the concentration of both $H^+$ and $OH^-$ are equal, as in pure water, it is considered neutral and its pH is 7.0.
- If the pH of a sample solution is below 7.0, the sample is termed acidic and is alkaline or basic if its pH is above 7.0.
- Each change of 1 pH unit represents a 10 fold change in concentration. For example, a sample with a pH of 2.0 is 1000 times more acidic than a sample with a pH of 5.0.
- pH is measured by an electrode that is sensitive only to $H^+$ or using a pH strip which is essentially an adsorbent paper which is pre-impregnated with chemicals which change color under different $H^+$ concentrations.
- Most organisms involved in biological wastewater treatment processes do well within a a narrow range of pH near neutral (pH of 7).

### 5.0.2 Oxidation Reduction Potential (ORP)

- ORP measurements are common in wastewater process control for monitoring conditions and process efficiency
- ORP is measured in milivolts (mV) using a probe

- ORP is a measure of the potential of oxidation/reduction – electron transfer, based chemical reactions to occur
- If the measured ORP value (in mV), is positive it indicates an environment where oxidation will occur and if negative, an environment where reduction reactions will occur
- Higher positive value indicates a stronger oxidative environment and likewise, a lower (more negative) ORP value indicates a stronger reductive environment
- For example, during chlorine disinfection, which is an oxidation process, the wastewater will exhibit a positive ORP. Stronger the oxidative power of chlorine, higher will be the wastewater ORP value
- All living matter, including microbes depend upon respiration to generate energy and respiration involves series of chemical oxidation-reduction reactions
- Bacteria grow and thrive only in specific chemical - oxidative-reductive environments which support its inbuilt metabolic pathways
- Aerobic bacteria need molecular oxygen as the terminal electron acceptor as part of its cellular respiration proces. Bacteria adapted to exist in an environment where molecular oxygen is not present (anoxic and anaerobic), rely on electron acceptors such as $NO_3^-$ (denitrification), $SO_4^-$ (sulfide formation) and carbon (methane formers in anaerobic digestion)
- Aerobic bacteria responsible for cBOD removal in the secondary treatment process would be inhibited or wiped-out if the wastewater oxidation potential dropped and become reductive. Likewise, if the wastewater in the sewer pipes which is normally of reductive (negative ORP) was to become oxidative because of aeration (dissolving oxygen) it would cease the hydrogen slufide activity of the anaerobic bacteria

| Typical Wastewater Process ORPs | |
|---|---|
| Clorine disinfection | +650 to +700 mV |
| Nitrification | +100 to +350 mV |
| Biological phosphorous removal | +20 to +250mV |
| Activated sludge cBOD degradation with free molecular oxygen | +50 to +250 mV |
| Denitrification | +50 to -50 mV |
| Influent wastewater | - 200 mV |
| Sulfide formation | -50 to -250 mV |
| Anaerobic Digestion: Acid formation (Acidogenesis) | -100 to -225 mV |
| Biological phosphorous removal | -100 to -250 mV |
| Anaerobic Digestion: Methane production (Methanogenesis) | -75 to -400 mV |

### 5.0.3 Alkalinity

- Alkalinity is the ability of a water to neutralize acids.
- During certain wastewater treatment processes including anaerobic digestion, acids are generated as a result of microbiological activity. The bacteria and other biological entities which play an active role in wastewater treatment are most effective at a neutral to slightly alkaline pH of 7 to 8. In order to maintain these optimal pH conditions for biological activity there must be sufficient alkalinity present in the wastewater to neutralize acids generated by the active biomass.
- This ability to maintain the proper pH in the wastewater as it undergoes treatment is the reason why alkalinity is so important to the wastewater industry.

- The alkalinity is due to the presence of acid neutralizing bases in the water including the hydroxyl ($OH^-$), carbonate ($CO_3^-$) and bicarbonate ($HCO_3^-$) ions. These ions are of mineral origin and are also formed from carbon dioxide which comes from the atmosphere and from the microbial decomposition of organic material. The resistance to pH change of the water will continue until all the alkalinity contributing ions are neutralized.
- The pH of a water serves as a guide to the types of alkalinity present in the water but is unrelated to the alkalinity content of a water. Important Note: Alkalinity is a measure of the ability to neutralize acids whereas a solution is termed alkaline (or basic) if its pH greater than 7.
- Alkalinity is expressed as milligrams per liter of $CaCO_3$

### 5.0.4 Dissolved Oxygen

- Dissolved oxygen (DO) is the concentration of oxygen dissolved in the wastewater sample and is typically measured in the field using a DO probe. A titration based Winkler Test is used in the laboratory
- The presence of oxygen indicates an aerobic environment where dissolved, free oxygen is available for aerobic microorganisms to live, BOD removal in the activated sludge process occurs as a result of the activity of aerobic bacteria. The absence of DO indicates that the environment or condition is either anoxic or anaerobic.
- In an anoxic environment, free oxygen is not present, but oxygen is available from its combined forms - nitrate ($NO_3^-$) and sulfate ($SO_4^-$) for the the consumption of microorganisms. Example of an anoxic process is denitrification. In denitrification, the anoxic bacteria in the presence of food (cBOD) consume the combined oxygen in nitrates ($NO_3^-$) and convert it to nitrogen gas.
- The complete absence of oxygen including free and combined oxygen is an anaerobic environment.
- Microorganisms are termed as obligate aerobes if they cannot survive without free oxygen. Facultative aerobes are microorganisms which can survive in both aerobic and anaerobic environments.

### 5.0.5 Microbiological testing and monitoring

Microbes play a critical role in wastewater treatment.

- Heterotrohic (organisms that consume organic material) microbes are responsible for the biological wastewater treatment processes - secondary treatment process, digestion and nutrient removal; and
- Pathogens - agents that cause disease are present in wastewater effluent.

Microbiological testing and monitoring is conducted as part of the wastewater treatment typically for the following:

1. Microbiological testing related to monitoring and troubleshooting biological wastewater treatment

   Microbes involved in biological wastewater treatment processes include:

   - Fungi - Filamentous fungi occasionally bloom in activated sludge processes due to low pH or nutrient deficiency and cause problems with the settleability.
   - Protozoa - Protozoas play a important role in the secondary treatment process. Common protozoas in the activated sludge process include:
     - Amoeba
     - Flagellate
     - Cilliate
   - Rotifers

- Nematodes
- Bacteria - Bacteria is the predominant microorganism responsible for the biological wastewater water treatment.
- The effectiveness of the biological wastewater treatment processes is primarily due to the presence of a microbial ecosystem with a right balance of populations of different microbial species.
- Methods used for monitoring the microbial composition include direct monitoring using a light microscope to see which and how many of the different microbial species are present - typically used for activated sludge process.
- Indirect method includes monitoring other parameters such as pH and alkalinity which are influenced by microbiological activity.
- The microbial monitoring ensures process stability and helps identify potential process upset conditions caused by changes to the microbial population due to other external factors - toxicty, organic loading, temperature etc.

2. Microbiological testing related to monitoring and controlling pathogens in treated wastewater effluent

   Pathogens in wastewater belong to the following groups:

   - Bacteria: Although, bacteria is present in large numbers in feces, pathogenic or bacteria are present only because of an infection and this pathogenic bacteria can potentially spread the infection to other healthy individuals. Disease spread by pathogenic bacteria include diarrhea, cholera and typhoid among many others.
   - Viruses: A large number of viruses may infect humans and are present in feces. These include enteroviruses (including polioviruses), hepatitis A virus, reoviruses and diarrhea-causing viruses (especially rotavirus).
   - Protozoa: Many species of protozoa can infect humans and cause diarrhoea and dysentery. Girardia which casues diarrheal illness is an example of a protozoan pathogen
   - Helminths: These are parasitic worms that can infect humans and are transmitted to others through its eggs or larval forms
   - As one of the main reasons for treating wastewater is to protect public health, microbiological/pathogen testing of the wastewater effluent and the surface water impacted by the wastewater discharge is conducted to meet the requirements of a wastewater discharge permit, to monitor the pathogen impact of treated wastewater discharge and assess the level of contamination of a public body of water.
   - The bacteriological tests involves detection and quantification of one or more of the following bacteria: total coliforms, fecal coliforms, E. Coli, and Enterococcus.
     - The main reason why these bacteria such as coliforms and enterococcus are used as it is not practical to detect and quantify all pathogens associated with wastewater.
     - These selected bacteria originate from feces and indicate fecal contamination and thus serve as an indicator organisms for pathogens of wastewater origin.
     - Also, they are abundant, potentially less harmful, and easy to detect. E. coli has been shown to be a better predictor of the potential for impacts to human health and therefore many newer wastewater discharge permits require E. Coli testing in lieu of fecal coliform testing requirements.
   - The microbiological test sample is always collected as a grab in a clean, sterile borosilicate glass or plastic bottle containing sodium thiosulfate.
     - Sodium thiosulfate is added to remove residual chlorine which will kill coliforms during transit.
     - If the sample is not preserved or maintained under proper conditions until the

test is conducted in the laboratory, the test would provide erroneous results.
  - Samples must be refrigerated if they cannot be analyzed within 1 hour of collection and must be handled with care to prevent contamination and adverse conditions such as prolonged exposure to direct sunlight.
  - The maximum holding time for state or federal permit reporting purposes is 6 hours.
- As it is not possible to exactly quantify the number of bacteria present, a statistical based - Most Probable Number (MPN) approach is utilized. The methods for wastewater bacteriological tests include: multiple-tube fermentation technique, membrane filtration and quanti-tray testing.

### 5.0.6 Specific Gravity

- Specific gravity is a term to express the weight of a solution with respect to that of water
- Water weighs 1 kg/L or 8.34 lbs/gallon or 62.4 lbs/$ft^3$
- A solution with a specific gravity of 1.2 will weigh 1.2 times the same volume of water. 1 L of that solution will weigh ( 1.2 kg )/L or ( 1.2*8.34=10lbs )/gallon.
- Typically wastewater and the associated unthickened sludge, for all practical purposes is assumed to have a specific gravity of 1 - implying 8.34 lbs/gallon.
- Specific gravity is typically used for calculations related to chemicals used in wastewater treatment.