Pollution Parameters, BOD, COD, Coliform bacteria, Treatment of water for potable purpose

Water Quality Parameters and Definitions

Parameters	Reason for the analysis
Chemical Parameters	
Temperature	Temperature can exert great control over aquatic communities. If the overall water body temperature of a system is altered, an aquatic community shift can be expected. In water above 30°C, a suppression of all benthic organisms can be expected. Also, different plankton groups will flourish under different temperatures. For example, diatoms dominate at 20 - 25 degrees C, green algae dominate at 30 - 35 degrees C, and cyano-bacteria dominate above 35 degrees C.
pH value	pH is an indicator of the existence of biological life as most of them thrive in a quite narrow and critical pH range.
Dissolved Oxygen (DO)	DO is essential for aquatic life. A low DO (less than 2mg/l) would indicate poor water quality and thus would have difficulty in sustaining many sensitive aquatic life.
Colour (Hazen)	Colour is vital as most water users, be it domestic or industrial, usually prefer colourless water. Determination of colour can help in estimated costs related to discolouration of the water.
Conductivity	Conductivity indicates the presence of ions within the water, usually due to in majority, saline water and in part, leaching. It can also indicate industrial discharges. The removal of vegetation and conversion into monoculture may cause run-off to flow out immediate thus decrease recharge during drier period. Hence, saline intrusion may go upstream and this can be indicated by higher conductivity.

Turbidity (NTU)	Turbidity may be due to organic and/or inorganic constituents. Organic particulates may harbour microorganisms. Thus, turbid conditions may increase the possibility for waterborne disease. Nonetheless, inorganic constituents have no notable health effects. The series of turbidity-induced changes that can occur in a water body may change the composition of an aquatic community. First, turbidity due to a large volume of suspended sediment will reduce light penetration, thereby suppressing photosynthetic activity of phytoplankton, algae, and macrophytes, especially those farther from the surface. If turbidity is largely due to algae, light will not penetrate very far into the water, and primary production will be limited to the uppermost layers of water. Cyanobacteria (blue-green algae) are favoured in this situation because they possess flotation mechanisms. Overall, excess turbidity leads to fewer photosynthetic organisms available to serve as food sources for many invertebrates. As a result, overall invertebrate numbers may also decline, which may then lead to a fish population decline. If turbidity is largely due to organic particles, dissolved oxygen depletion may occur in the water body. The excess nutrients available will encourage microbial breakdown, a process that requires dissolved oxygen. In addition, excess nutrients may result in algal growth. Although photosynthetic by day, algae respire at night, using valuable dissolved oxygen. Fish kills often result from extensive oxygen depletion.
Salinity	High salinity may interfere with the growth of aquatic vegetation. Salt may decrease the osmotic pressure, causing water to flow out of the plant to achieve equilibrium. Less water can be absorbed by the plant, causing stunted growth and reduced yields. High salt concentrations may cause leaf tip and marginal leaf burn, bleaching, or defoliation. As per Conductivity, salinity (NaCl content, g/kg) can be used to check for possible saline intrusion in future.

Parameters	Reason for the analysis
Total Suspended Solids, TSS	Total Suspended solids is an indication of the amount of erosion that took place nearby or upstream. This parameter would be the most significant measurement as it would depict the effective and compliance of control measures e.g. riparian reserve along the waterways. The series of sediment-induced changes that can occur in a water body may change the composition of an aquatic community. First, a large volume of suspended sediment will reduce light penetration, thereby suppressing photosynthetic activity of phytoplankton, algae, and macrophytes. This leads to fewer photosynthetic organisms available to serve as food sources for many invertebrates. As a result, overall invertebrate numbers may also decline, which may then lead to decreased fish populations. In addition, sediment may interfere with essential functions of organisms. The numbers of filter-feeding invertebrates will decline if their filter mechanisms are choked by suspended particles. Some zooplankton suffer decline due to clogged feeding mechanisms. Likewise, fish may suffer clogging and abrasive damage to gills and other respiratory surfaces. Abrasion of gill tissues triggers excess mucous secretion, decreased resistance to disease, and a reduction or complete cessation of feeding. Suspended sediment may also affect predator-prey relationships by inhibiting predators' visual abilities. Reproductive success may decline with an increase in fine sediment. If spawning habitats are altered by sediment deposition (e.g., filling of pools and riffles or covering of a gravel bed), fish may be unable to lay eggs. If eggs are successfully produced, the incubation period may be in jeopardy because 1) a shifting-sediment environment is unstable, and 2) burial by fine sediment prevents circulation of water around the egg, decreasing oxygenation. The egg will suffocate and may be poisoned by its own metabolic waste. If eggs do hatch into fry, the young may be less likely to survive in less-than-optimum conditions.

	The settling of suspended solids from turbid waters threatens benthic aquatic communities. Deposited particles may obscure sources of food, habitat, hiding places, and nesting sites. Most aquatic insects will simply drift with the current out of the affected area. Benthic invertebrates that prefer a low-silt substrate, such as mayflies, stoneflies, and caddis flies, may be replaced by silt-loving communities of oligochaetae, pulmonate snails, and chironomid larvae. Increased sediment may impact plant communities. Primary production will decline because of a reduction in light penetration. Sediment may damage plants by abrasion, scouring, and burial. Finally, sediment deposition may encourage species shifts because of a change of substrate. Sediment deposition may also affect the physical characteristics of the stream bed. Sediment accumulation causes stream bed elevation and a decrease in channel capacity. Flooding is more likely after sediment accumulation because the stream can not accommodate the same volume of water. Also, a substrate that is closer to the surface receives more light and supports increased numbers of photosynthetic organisms, such as rooted algae. As a result, recreational use may be threatened because moving parts of boats may become tangled in aquatic plants. Sediment, which is generally negatively charged, attracts positively charged molecules. Some of these molecules (phosphorus, heavy metals, and pesticides) are pollutants. These positively charged pollutants are in equilibrium with the water column and are often released slowly into the water resource.

Parameters	Reason for the analysis
Total Dissolved Solids, TDS	The total dissolved solids (TDS) in water consist of inorganic salts and dissolved materials. In natural waters, salts are chemical compounds comprised of anions such as carbonates, chlorides, sulphates, and nitrates (primarily in ground water), and cations such as potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na). In ambient conditions, these compounds are present in proportions that create a balanced solution. If there are additional inputs of dissolved solids to the system, the balance is altered and detrimental effects may be seen. Inputs include both natural and anthropogenic source.
Biochemical Oxygen Demand, BOD	BOD is a measure of organic pollution to both waste and surface water. High BOD is an indication of poor water quality. For this tree plantation project, any discharge of waste into the waterways would affect the water quality and thus users downstream.
Ammoniacal Nitrogen	Ammonia levels in excess of the recommended limits may harm aquatic life. Although the ammonia molecule is a nutrient required for life, excess ammonia may accumulate in the organism and cause alteration of metabolism or increases in body pH. It is an indicator of pollution from the excessive usage of ammonia rich fertilisers.
Potassium	Potassium is macro nutrient element for plant growth. It can occur naturally in minerals and from soils. High levels in surface water, especially in areas where there are agricultural activities as indicative of introduction of K due to application of fertilisers.

Chemical Oxygen Demand, COD	COD is an indicator of organics in the water, usually used in conjunction with BOD. High organic inputs trigger deoxygenation. If excess organics are introduced to the system, there is potential for complete depletion of dissolved oxygen. Without oxygen, the entire aquatic community is threatened. The only organisms present will be air- breathing insects and anaerobic bacteria. If all oxygen is depleted, aerobic decomposition ceases and further organic breakdown is accomplished anaerobically. Anaerobic microbes obtain energy from oxygen bound to other molecules such as sulphate compounds. Thus, anoxic conditions result in the mobilization of many otherwise insoluble compounds. In areas of high organics there is frequently evidence of rapid sewage fungus colonization. Sewage fungus appears as slimy or fluffy cotton wool-like growths of micro-organisms which may include filamentous bacteria, fungi, and protozoa such as *Sphaerotilus natans, Leptomitus lacteus, and Carchesium polypinuym*, respectively. The various effects of the sewage fungus masses include silt and detritus entrapment, the smothering of aquatic macrophytes, and a decrease in water flow velocities. An accumulation of sediment allows a shift in the aquatic system structure as colonization by silt-loving organisms occur. In addition, masses of sewage fungus may break off and float away, causing localized areas of dissolved oxygen demand elsewhere in the water body. Organic levels decrease with distance away from the source. In a standing water body such as a lake, currents are generally not powerful enough to transport large amounts of organics. In a moving water body, the saprotrophic organisms (organisms feeding on decaying organic matter) break down the organics during transportation away from the source. Hence, there is a decline in the oxygen demand and an increase of dissolved oxygen in the water. Community structure will gradually return to ambient with distance downstream from the source.

Parameters	Reason for the analysis
Nitrate Nitrogen	The growth of macrophytes and phytoplankton is stimulated principally by nutrients such as nitrates. Many bodies of freshwater are currently experiencing influxes of nitrogen and phosphorus from outside sources. The increasing concentration of available phosphorus allows plants to assimilate more nitrogen before the phosphorus is depleted. Thus, if sufficient phosphorus is available, high concentrations of nitrates will lead to phytoplankton (algae) and macrophyte (aquatic plant) production. This is mostly due to the usage of fertilisers.
Oil & Grease	To check if there is any indiscriminate dumping of waste oil or poor management of oily waste within the site.
Microbiological	
Total Coliform Count Faecal Coliform Count	Microbiological test is to detect the Level of pollutions caused by living thing especially human who live or work in the area especially upstream of the site. These tests are based on coliform bacteria as the indicator organism. The presence of these indicative organisms is evidence that the water has been polluted with faeces of humans or other warm-blooded animals.
Pesticides	
Chlorinated Glyphosphate Paraquat Methamidaphos	These parameters are common tests for the level of agrochemical pollution. Since a specific type of agrochemical to use is unknown at this stage, it is unknown at this stage the type of agrochemical that would be used in the proposed development, a range of test is recommended for analysing to gauge the existing condition that could be used as baseline information or reference.

Biological Oxygen Demand (BOD)

- Biochemical oxygen demand (BOD), is the amount of dissolved oxygen needed (i.e., demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period.

- Biological oxygen demand (BOD) is the most commonly used parameter to define the strength of a municipal or organic industrial waste water.

- Widest application is in measuring waste loading to treatment plants and in evaluating the efficiency of such treatment systems.

- In addition, the BOD test is used to determine the relative oxygen requirements of treated effluents and polluted waters.
- BOD can be used as a gauge of the effectiveness of wastewater treatment plants. It is listed as a conventional pollutant in the U.S. Clean Water Act.

- The BOD value is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 °C and is often used as a surrogate of the degree of organic pollution of water.

- BOD is similar in function to chemical oxygen demand (COD), in that both measure the amount of organic compounds in water. However, COD is less specific, since it measures everything that can be chemically oxidized, rather than just levels of biodegradable organic matter.

Chemical Oxygen Demand, COD	COD is an indicator of organics in the water, usually used in conjunction with BOD. High organic inputs trigger deoxygenation. If excess organics are introduced to the system, there is potential for complete depletion of dissolved oxygen. Without oxygen, the entire aquatic community is threatened. The only organisms present will be air- breathing insects and anaerobic bacteria. If all oxygen is depleted, aerobic decomposition ceases and further organic breakdown is accomplished anaerobically. Anaerobic microbes obtain energy from oxygen bound to other molecules such as sulphate compounds. Thus, anoxic conditions result in the mobilization of many otherwise insoluble compounds. In areas of high organics there is frequently evidence of rapid sewage fungus colonization. Sewage fungus appears as slimy or fluffy cotton wool-like growths of micro-organisms which may include filamentous bacteria, fungi, and protozoa such as *Sphaerotilus natans, Leptomitus lacteus, and Carchesium polypinuym*, respectively. The various effects of the sewage fungus masses include silt and detritus entrapment, the smothering of aquatic macrophytes, and a decrease in water flow velocities. An accumulation of sediment allows a shift in the aquatic system structure as colonization by silt-loving organisms occur. In addition, masses of sewage fungus may break off and float away, causing localized areas of dissolved oxygen demand elsewhere in the water body. Organic levels decrease with distance away from the source. In a standing water body such as a lake, currents are generally not powerful enough to transport large amounts of organics. In a moving water body, the saprotrophic organisms (organisms feeding on decaying organic matter) break down the organics during transportation away from the source. Hence, there is a decline in the oxygen demand and an increase of dissolved oxygen in the water. Community structure will gradually return to ambient with distance downstream from the source.

Coliform Bacteria

- Coliforms are bacteria that are always present in the digestive tracts of animals, including humans, and are found in their wastes. They are also found in plant and soil material.
- "Indicator" Organisms" of water pollution

What are coliform bacteria?

Coliform bacteria are present in the environment and feces of all warm-blooded animals and humans. Coliform bacteria are unlikely to cause illness. However, their presence in drinking water indicates that disease-causing organisms (pathogens) could be in the water system. Most pathogens that can contaminate water supplies come from the feces of humans or animals. Testing drinking water for all possible pathogens is complex, time-consuming, and expensive. It is easy and inexpensive to test for coliform bacteria. If testing detects coliform bacteria in a water sample, water systems search for the source of contamination and restore safe drinking water.

- Water pollution caused by fecal contamination is a serious problem due to the potential for contracting diseases from pathogens (disease causing organisms).

- Frequently, concentrations of pathogens from fecal contamination are small, and the number of different possible pathogens is large.

- As a result, it is not practical to test for pathogens in every water sample collected.
- Instead, the presence of pathogens is determined with indirect evidence by testing for an "indicator" organism such as coliform bacteria.
- Coliforms come from the same sources as pathogenic organisms.

- Coliforms are relatively easy to identify, are usually present in larger numbers than more dangerous pathogens, and respond to the environment, wastewater treatment, and water treatment similarly to many pathogens.

- As a result, testing for coliform bacteria can be a reasonable indication of whether other pathogenic bacteria are present.

- There are three groups of coliform bacteria.

- Each is an indicator of drinking water quality and each has a different level of risk.

- **Total coliform** is a large collection of different kinds of bacteria. **Fecal coliform** are types of total coliform that exist in feces. ***E. coli*** is a subgroup of fecal coliform. Labs test drinking water samples for total coliform. If total coliform is present, the lab also tests the sample for *E. coli*.

Total Coliforms, Fecal Coliforms, and E. *Coli*

- The most basic test for bacterial contamination of a water supply is the test for **total coliform bacteria**. Total coliform counts give a general indication of the sanitary condition of a water supply.

1. **Total coliforms** include bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste.

- Total coliform bacteria are common in the environment (soil or vegetation) and are generally harmless.
- If a lab detects only total coliform bacteria in drinking water, the source is probably environmental and fecal contamination is unlikely.

- However, if environmental contamination can enter the system, pathogens could get in too. It is important to find and resolve the source of the contamination.

2. Faecal coliforms are the group of the total coliforms that are considered to be present specifically in the gut and feces of warm-blooded animals.

- Because the origins of fecal coliforms are more specific than the origins of the more general total coliform group of bacteria, fecal coliforms are considered a more accurate indication of animal or human waste than the total coliforms.

3. *Escherichia coli (E. coli)* is the major species in the fecal coliform group. Of the five general groups of bacteria that comprise the total coliforms, only E. coli is generally not found growing and reproducing in the environment. Consequently, E. coli is considered to be the species of coliform bacteria that is the best indicator of fecal pollution and the possible presence of pathogens

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Treatment of Water for Potable Purpose

- The most common water treatment processes used for treatment of raw water from a surface source are:
- Coagulation
- Rapid mixing
- Flocculation
- Sedimentation
- Filtration
- Disinfection

1. Coagulation

- **Chemical coagulation (in a mixing tank):**

Addition of chemicals (coagulant) in a mixing tank to encourage the small and non-settleable solids (suspended solids) to coagulate into large particles (chemical flocs) that will more easily settle.

- The coagulant chemical neutralizes the electrical charge on the surface of the small particles, resulting in destabilization of the colloidal suspension.

- Coagulation and flocculation occur in successive steps intended to overcome the forces stabilizing the suspended particles, allowing particle collision and growth of floc

- Coagulation neutralizes the forces; once the repulsive forces have been neutralized these particles can stick together (agglomerate) when they collide.

- The force which holds the floc together is called the Van der Waals force.

Primary Coagulants:

- Purpose is to aid in the removal of nonsettleable solids from water.
- Used to cause particles to become destabilized and begin to clump together.
- Suspended particles in water normally have a negative (-) charge. Since these particles all have the same charge, they repel each other, keeping each other from settling.

Types of Primary Coagulants

- Metallic salts

o Aluminum Sulfate (Alum) – $Al_2(SO_4)_3 \cdot 14\ H_2O$
o Ferric Sulfate - $Fe_2(SO_4)_3 \cdot 9\ H_2O$
o Ferric Chloride - $FeCl_3 \cdot 6\ H_2O$

- Synthetic inorganic polymers

o Polyaluminum Chloride - $Al_n(OH)_mCl_{(3n-m)} \cdot H_2O$

Coagulant Aids - Chemicals used to add density to slow-settling floc and to strengthen floc formation.

- Coagulant aids are added to the water during the coagulation process to:

1. Improve coagulation
2. Build a stronger, more settleable floc
3. Overcome slow floc formation in cold water
4. Reduce the amount of coagulant required

Types of Coagulant Aids

- Activated Silica
  - Better settling, decrease sludge
  - Strengthen floc at low temperatures
  - Color removal
- Weighting Agents – Bentonite Clay
  - Used to treat water with high color
  - Used to treat water with low turbidity issues
  - Used to treat water with low mineral content
- Synthetic organic polymers
  - Commonly referred to as polyelectrolytes
  - Cationic – positively charged
  - Adsorb on negatively charged particles (turbidity) to neutralize the charge. Forming an interparticle bridge trapping particles which helps increase floc strength in the coagulation basin.

2. Rapid Mixing

- The purpose of rapid mixing is to disperse coagulant chemicals uniformly throughout the raw water as rapidly as possible in order to destabilize the colloidal particles (i.e. neutralize the negative charges around the colloid surface) present in water.
- Theoretical and experimental studies have shown that the contact between coagulant and colloidal

particles should occur before the hydrolysis reaction with alkalinity-causing components of water is completed.

- This requires very rapid dispersion of coagulant in the mass of water within a few seconds.

- To facilitate the rapid dispersion, the water is agitated vigorously with the aid of mixing devices and the coagulant is added at the most turbulent zone. Effective rapid mixing can basically be accomplished either hydraulically or mechanically.

3. Flocculation

- Following rapid mixing/coagulation the flocculation process occurs; this is done through a continuous agitation of the coagulated water with less intensity but a longer duration.

- This gentle mixing stage is where the microflocs formed during coagulation are brought into contact with each other.

- Collisions of the microfloc particles cause them to bond and produce larger, visible flocs called pinflocs.

- The floc size continues to build through additional collisions and interaction with inorganic polymers formed by the coagulant or with the addition of coagulant aids.

- Macroflocs are then formed and once the floc has reached its optimum size and strength, the water is ready for the sedimentation process.
- The goal of flocculation is to promote growth of flocs to a size that can be removed by sedimentation and filtration

Floc Formation

Figure 2.9 Flocculation

Floc formation is controlled by three factors:

- The effectiveness of coagulation,
- The effectiveness of collisions in promoting attachment between particles. Stable colloidal suspensions will not floc well, and
- The rate at which collisions occur.

- To increase the size of floc particles, collision of floc particles is necessary. This is achieved through:

 Proper stirring time (detention time).

 Proper stirring intensity.

 Properly shaped basin for uniform mixing.

 Having a means of creating the stirring action.

4. Sedementation

- After flocculation, the water and floc moves slowly through large basins known as sedimentation or settling basins.

- The water moves very slowly through these basins due to their large size.

- This allows the floc to settle to the bottom of the basin.

- The floc that falls to the bottom of the basins is collected into a hopper by large rotating scrapers where it is removed several times daily by the plant operators.
- Clear water above the floc layer (referred to as treatment residuals) flows out of the sedimentation basin and to the filters.

- Removal of particles in the sedimentation basin improves the operation of the filters that comprises the next treatment process after sedimentation.

- The sedimentation process removes many particles including clay and silt based turbidity, natural organic matter, and other associated impurities.

- These impurities include microbial contaminants, toxic metals, synthetic organic chemicals, iron, manganese and humic substances.

- Humic substances come from soil are produced within natural water and sediments by chemical and biological processes such as the decay of vegetation.

- Removal of humic substances from drinking water is desirable since they form disinfection byproducts when chlorine is added to the water.

- At high concentrations, disinfection by-products such as trihalomethanes are a public health concern.

5. Filtration

- The last step in purifying the water is accomplished by passing water through a bed of sand and gravel.

- As water filters through the sand, the remaining particles of suspended matter are trapped in the sand bed.

- In the filtration process, water flows on top of the sand bed and travels through the bed until it is collected at the bottom in underdrains.

- Filtered water flows from the underdrains into clearwells or filtered water reservoirs. The rate of filtration is regulated using controllers.

- The filters must be cleaned periodically as material becomes trapped in the filter and reduces the rate of filtration.

6. Disinfection or chlorination:

- To disinfect the filtered water so that all pathogenic bacteria will become killed. Chlorination using chlorine gas (Cl_2), sodium hypochlorite ($NaOCl$) or calcium hypochlorite [$Ca(OCl)_2$] is the most commonly used method of disinfection.

- **Prechlorination:** to add a relatively large dose of chlorine (3 to 5 ppm) to water to oxide the taste- and odor-causing chemicals which are produced by the presence of algae, and to kill algae cells.

- **Fluoridation:** Normally groundwater (or well water) is particle free, thus not requiring for coagulation & flocculation process.