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WASTEWATER TREATMENT AND RECYCLING

Wastewater Characteristics: Quality Parameters

Week 3- Lecture 11

Dr. MANOJ KUMAR TIWARI
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Wastewater Characterization: Quality Parameters

- pH
- Temperature
- Colour
- Turbidity
- Conductivity
- Dissolved Oxygen (DO)
- BOD (Carbonaceous BOD and nitrogenous BOD)
- COD
- Acidity / Alkalinity
- Hardness
- Solids (Total, suspended, dissolved, fixed, volatile)
- Nutrients (Nitrogen, phosphorous)
- Metals (Fe, Al, As, Cr, Zn, Ni, Co etc.)
- Fecal Coliform
- … and many more

Water Quality Parameters

✓pH

- pH of fresh waters typically ranges between 6.5-8.0, however could vary from around 4.5 to over 10.0 in certain cases.
- pH of wastewater vary according to the source of its generation
- Extremes of pH may adversely affect aquatic ecology in surface water bodies. The range of pH suitable for fisheries is considered to be 5.0-9.0, though 6.5-8.5 is preferable.

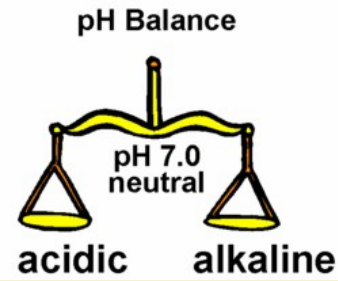

Image Source : http://tellmewhyfacts.com/science/pH+Balance+of+Your+Body

Water Quality Parameters

✓Temperature

- The effect of temperature (or change in temperature), is very critical on living organisms.
- Aquatic population can withstand only tolerable limits of temperature which varies for species to species.
- Some key constituents of a water or pollutants changes forms based on temperature.
- The rate of most of the biochemical reactions are also a factor of temperature.

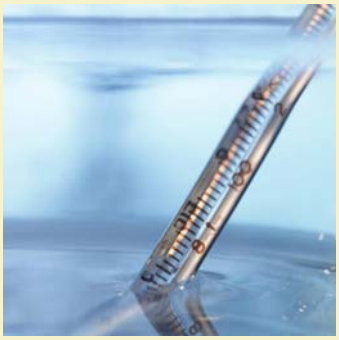

Image Source : http://www.athletesheart.org/2013/12/new-usa-triathlon-water-temperature-safety-guidelines/

Water Quality Parameters

✓Colour

- Colour is important from the standpoint of aesthetics. If water looks , people avoid using coloured waters, even though it might be safe from the public health aspect
- Often caused by organic substances such as algae or humic compounds.

Apparent colour: caused by suspended matter.

True colour: caused by dissolved or colloidal, such as vegetable or organic extracts.

Water Quality Parameters

✓Colour: Measurements

- **Standard Colour Solutions Method:** The colour produced by 1 mg/l of platinum (as K_2PtCl_6) and 0.5mg/l of cobalt (as $CoCl_2 \bullet 6H_2O$) is taken as the standard one unit of colour.
- **Dilution Multiple Method:** Measured by successive dilutions successive dilutions of the sample with colour-free water until the colour is no longer detectable comparing with distilled water. The total dilution total dilution multiple is calculated and used to express the colour degree.
- **Spectrophotometric Method:**

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Wastewater Characteristics: Quality Parameters (cont.)

Week 3- Lecture 12

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Water Quality Parameters

✓Turbidity

- An optical characteristic or property, which in general terms describes the clarity, or haziness of the water
- It is caused by the presence of very fine suspended particles (typically not filterable by routine methods).

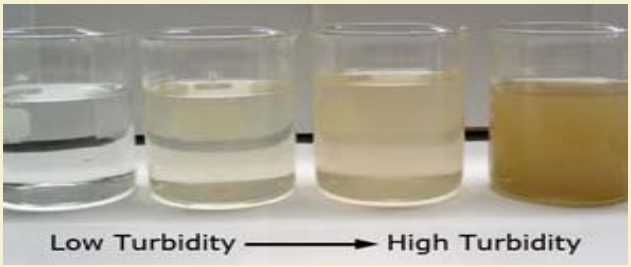


Image Source :
http://steinhardtapps.es.its.nyu.edu/nyuhudson/?page_id=168

Water Quality Parameters

✓Turbidity

- The existence of turbidity in water will affect its acceptability to consumers (in case of recycled water) and it will also affect markedly its utility in certain industries.
- The particles forming the turbidity may also interfere with the treatability of waters especially in the case of the disinfection process, as there is a risk that pathogenic organisms could be shielded by the turbidity particles and hence escape the action of the disinfectant.

Source : Parameters of Water Quality - Interpretation and Standards, EPA (2001)

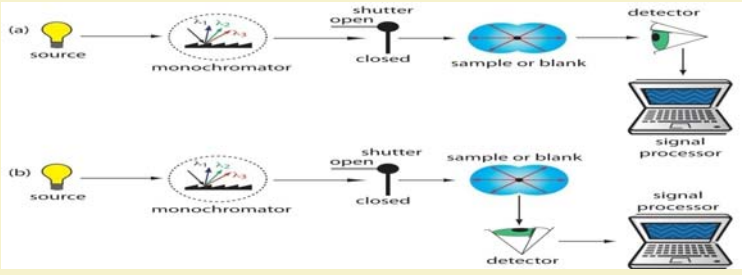
Water Quality Parameters

✓Turbidity: Measurements

- If a beam of light is passed through a turbid sample, its intensity is reduced by scattering. The quantity of light scattered is dependent upon the concentration and size distribution of the particles.

(a) In turbidimetry, the intensity of light transmitted is measured.

(b) In nephelometry the intensity of the light scattered at 90^0 is measured.



Source : http://community.asdlib.org/imageandvideoexchangeforum/2013/07/30/instrumentation-for-turbidimetry-and-nephelometry/

Water Quality Parameters

✓Conductivity

- It is the ability of water to carry an electrical current.
- Absolutely pure water is a poor conductor of electricity.
- Water shows significant conductivity when dissolved salts are present. Over most ranges, the amount of conductivity is directly proportional to the amount of salts dissolved in the water.
- A conductivity sensor measures how much electricity is being conducted through a centimeter of water. Specific conductivity is expressed as siemens per centimeter (S/cm).

Water Quality Parameters

✓Acidity and Alkalinity

- The acidity and alkalinity of water is an indicator of its capacity to react with a acids or base. The concept of acidity is opposite that of alkalinity and is also based on the carbonate system.
- The acidity of a water source is generally attributable to the carbonate molecules H_2CO_3 and HCO_3^- and sometimes to strong acids releasing H^+.

$H^+ + OH^- \rightarrow H_2O$

$H_2CO_3 + OH^- \rightarrow HCO_3^-$

$HCO_3^- + OH^- \rightarrow CO_3^{2-}$

Water Quality Parameters

✓Acidity and Alkalinity

- Alkalinity is a function of the carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and hydroxide (OH^-) content of water.
- When there are mostly acidic carbonate molecules in solution (H_2CO_3, HCO_3^-, and H^+), the pH is correspondingly acidic (< 7)
- If the carbonate molecules in solution are mostly HCO_3^-, CO_3^{2-}, and OH^-, the pH is correspondingly basic (> 7).
- Alkalinity can exist down to pH 4.5 because of the fact that HCO_3^- is not completely neutralized until this pH is reached.
- The amount of acidity or alkalinity present is expressed in terms of $CaCO_3$.
- Total Alk = $[HCO_3^-] + 2[CO_3^{2-}] + [OH^-] - [H^+]$

Water Quality Parameters

✓Acidity and Alkalinity: Measurements

- ❖ Acidity of water can be determined by titration with sodium hydroxide solution. The amount of sodium hydroxide required for the sample (pH below 4.5) to reach pH 4.5 (methyl orange end point) is a measure of mineral acidity while the amount of sodium hydroxide to reach pH 8.3 (phenolphthalein end point) is a measure of total acidity.
- ❖ Titration with a standard acid to an end point of 8.3 pH is reported as phenolphthaline alkalinity (or caustic alkalinity) and titration to an end point of approximately 4.5 is reported as total alkalinity.

Water Quality Parameters

✓Hardness

- Caused by the presence of Ca^{2+} and Mg^{2+} ions as Hydrogencarbonate - $Ca(HCO_3)_2$, $Mg(HCO_3)_2$; Sulphates- $CaSO_4$, $MgSO_4$; Chloride - $CaCl_2$, $MgCl_2$ etc.

✓ Temporary hardness – Bicarbonates of Ca & Mg

✓ Permanent hardness – Sulphates/chlorides/nitrates of Ca & Mg

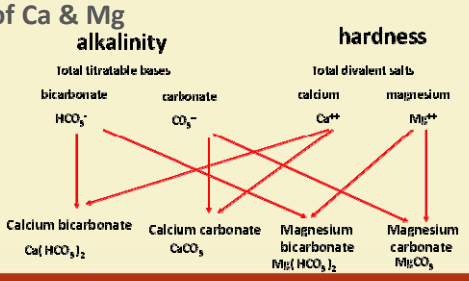


Image Source : https://www.tankonyvtar.hu/hu/tartalom/tamop412A/2011_0009_Stundl_Laszlo-Fisheries_and_Aquaculture/ch07s02.html

Water Quality Parameters

✓Hardness: Calculations

- Convert each ions as mg/L of $CaCO_3$
- Do an ion balance
- Estimate equivalence of Ca^{2+} and Mg^{2+}
- Express in mg/L as $CaCO_3$

Ca^{2+}	Mg^{2+}	Na^+
HCO_3^-	SO_4^{2-}	Cl^-

	mg/L as $CaCO_3$	
Hardness classification	U.S.	International
Soft	0–60	0–50
Moderate soft		51–100
Slightly hard		101–150
Moderate hard	61–120	151–200
Hard	121–180	201–300
Very hard	> 180	> 300

Source : Handbook of Environmental Engineering Calculations by Li and Lin

Water Quality Parameters

✓Dissolved Oxygen (DO)

- The water/wastewater stream system both produces and consumes oxygen. It gains oxygen from the atmosphere (phase transfer) and from plants as a result of photosynthesis, while respiration by aquatic animals, decomposition, and various chemical reactions consume dissolved oxygen in water.
- Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 4.0 mg/l, aquatic life is put under stress.
- DO levels that remain below 1-2 mg/l for a few hours can result in large fish kills.

Water Quality Parameters

✓Dissolved Oxygen (DO): Measurements

- **Winkler Method:**

The Winkler method involves filling a sample bottle (**BOD Bottle**) completely with water (no air is left to bias the test). The dissolved oxygen is then "fixed" using a series of reagents that form an acid compound that is titrated. Titration involves the drop-by-drop addition of a reagent that neutralizes the acid compound and causes a change in the colour of the solution. The point at which the colour changes is the "endpoint" and is equivalent to the amount of oxygen dissolved in the sample. The sample is usually fixed and titrated in the field at the sample site. It is possible, however, to prepare the sample in the field and deliver it to a lab for titration.

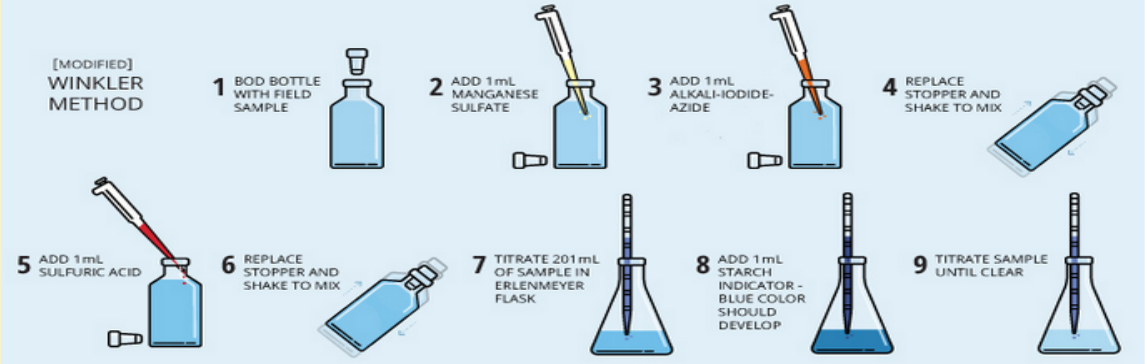
Several modified Winkler methods were also created to respond to interfering contaminant. The ***Azide-Winkler method***, which addresses the issues with iodine present, is the most popular of these.

Source : https://archive.epa.gov/water/archive/web/html/vms52.html

Water Quality Parameters

✓Dissolved Oxygen (DO): Measurements

❖ **Azide-Winkler Method:**



Source : https://www.fondriest.com/environmental-measurements/equipment/measuring-water-quality/dissolved-oxygen-sensors-and-methods/

Water Quality Parameters

✓Dissolved Oxygen (DO): Measurements

❖ **Meters and Probes:**

Currently, the most popular method for DO measurements is with a DO meter and sensor.

Optical as well as ***Electrochemical*** DO sensors are available in the market.

Most meters and probes also measure temperature, and give standard analog output as well as digital outputs in the smart sensor platforms.

The meter/probe must be calibrated from time to time to ensure the accuracy of the measurements.

Source : https://www.fondriest.com/environmental-measurements/equipment/measuring-water-quality/dissolved-oxygen-sensors-and-methods/

Water Quality Parameters

✓Dissolved Oxygen (DO): Fluctuations

- DO levels fluctuate seasonally and over a 24-hour period.
- DO vary with water temperature and altitude. Cold water holds more oxygen than warm water and water holds less oxygen at higher altitudes.
- Aquatic animals are most vulnerable to lowered DO levels in the early morning on hot summer days when stream flows are low, water temperatures are high, and aquatic plants have not been producing oxygen since sunset.
- In smaller, shallower streams, DO changes more horizontally along the course of the waterway. However, in larger, deeper rivers, some vertical stratification of DO might also occur.

Temp. vs Saturation DO

Temperature (°C)	DO (mg/l)	Temperature (°C)	DO (mg/l)
0	14.60	23	8.56
1	14.19	24	8.40
2	13.81	25	8.24
3	13.44	26	8.09
4	13.09	27	7.95
5	12.75	28	7.81
6	12.43	29	7.67
7	12.12	30	7.54
8	11.83	31	7.41
9	11.55	32	7.28
10	11.27	33	7.16
11	11.01	34	7.16
12	10.76	35	6.93
13	10.52	36	6.82
14	10.29	37	6.71
15	10.07	38	6.61
16	9.85	39	6.51
17	9.65	40	6.41
18	9.45	41	6.41
19	9.26	42	6.22
20	9.07	43	6.13
21	8.90	44	6.04
22	8.72	45	5.95

Source : https://archive.epa.gov/water/archive/web/html/vms52.html

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WASTEWATER TREATMENT AND RECYCLING

Wastewater Characteristics: Quality Parameters (cont.)

Week 3- Lecture 13

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Water Quality Parameters

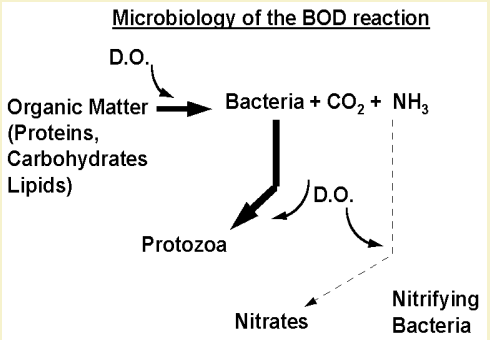
✓Biochemical (or Biological) Oxygen Demand (BOD):

- Organic matter (pollutants) present in water serves as substrate (food source) for the microorganisms present there. Often many of such compounds are broken to less complex organic substances and ultimately to simple compounds such as carbon dioxide and water.
- The wastewater receiving rivers and streams have some background DO, and aerobic microorganism present, consume the DO for decomposing the organic matter into simpler compounds. However DO keeps on getting replenished by natural atmospheric transfer and from photosynthesis.
- The amount of oxygen required by aerobic microorganisms to decompose the organic matter in a water sample (generally polluted) is typically referred as ***Biochemical Oxygen Demand*** or ***Biological Oxygen Demand (BOD).***

Water Quality Parameters

✓BOD:

- BOD is a time dependent parameter, as oxygen consumed by bacteria would increase with the progress of time.
- When BOD levels are high, dissolved oxygen (DO) levels decrease because the oxygen that is available in the water is being consumed by the bacteria.
- If the quantity of organic waste present is sufficiently large, the rate of bacterial uptake of oxygen will outstrip that at which the DO is replenished, and ultimately the receiving water will become anoxic / anaerobic.

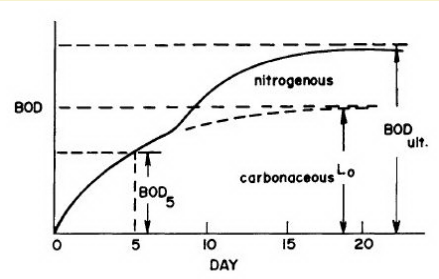


Source: http://web.deu.edu.tr/atiksu/toprak/ani4024.html

Water Quality Parameters

✓BOD: Carbonaceous and Nitrogenous BOD

- The oxygen demand could also arise from nitrification requirements where the nitrogenous waste such as ammonia is converted to nitrates by autotrophic bacteria using oxygen as an energy source.
- The requirement of DO for the process is called Nitrogenous Biochemical Oxygen Demand (NBOD) while requirement of oxygen for degrading carbonaceous organic matter is referred as Carbonaceous Biochemical Oxygen Demand (CBOD).
- Generally, the nitrifiers have slower growth rates and do not flourish until the food supply for the heterotrophic (CBOD consuming) microbes has diminished, therefore NBOD does not become discernable until approximately 7 days of incubation have occurred.



Source: https://www.tankonyvtar.hu/en/tartalom/tamop412A/2011_0009_Juhasz_Csaba-Environment_and_Land_Use/ch11s04.html

Water Quality Parameters

✓BOD:

- BOD is a time dependent parameter, as oxygen consumed by bacteria would increase with the progress of time.
  - ***BOD_5:*** **Quantifies the oxygen consumed in a sample within a five-day period**
  - ***Ultimate BOD (UBOD or BOD_u):*** **Quantifies the oxygen required for the total biochemical degradation of organic matter.**
- Generally the five-day period is not long enough for complete oxidation, but it provides sufficient time for microbial acclimatization and for substantial oxidation.
- The BOD test is a standardized test where final DO (say after 5 days) is subtracted from the initial DO to know the oxygen consumed during the period of incubation.

Source: http://web.deu.edu.tr/atiksu/toprak/ani4024.html

Water Quality Parameters

✓Chemical Oxygen Demand (COD):

- COD is measure of organic materials in a wastewater in terms of the oxygen required to oxidize the organic materials chemically.
- Chemical oxygen demand is measured as a standardized laboratory assay in which a closed water sample is incubated with a strong chemical oxidant, potassium dichromate ($K_2Cr_2O_7$), which is used in combination with boiling sulfuric acid (H_2SO_4).
- COD along with BOD are two different ways to measure how much oxygen the water will consume when it enters the recipient. In both the COD and BOD tests, the organic material concentration is calculated from the oxidant consumption necessary for the oxidation of the organic material.
- Since biologically on biodegradable organic matter can be oxidize while chemically almost all oxidizable matters could be oxidized, COD values are always higher than BOD.

Water Quality Parameters

✓Chemical Oxygen Demand (COD):

Dichromate COD Chemistry:

- When organic matter is oxidized by dichromate in sulfuric acid, most of the carbon is converted to CO_2. Hydrogen present is converted to H_2O. The reaction is illustrated using the primary standard, potassium acid phthalate (KHP):

$$2\,KC_8H_5O_4 + 10\,K_2Cr_2O_7 + 41\,H_2SO_4 \longrightarrow 16\,CO_2 + 46\,H_2O + 10\,Cr_2(SO_4)_3 + 11\,K_2SO_4$$

- Dichromate ions ($Cr_2O_7^{-2}$) form orange-coloured solutions.
- Chromic ion (Cr^{+3}) turns the solution becomes green.

Water Quality Parameters

✓**Chemical Oxygen Demand (COD):**

Theoretical COD:

$KC_8H_5O_4 + 7.5\ O_2 \rightarrow 8\ CO_2 + 2\ H_2O + KOH$

$C_xH_yO_z + ¼\cdot(4x+y-2z)\cdot O_2 \rightarrow x\cdot CO_2 + y/2\cdot H_2O$

So, ***COD = 8(4x+y-2z)/(12x+y+16z) g COD/g***

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Wastewater Characteristics: Quality Parameters (cont.)

Week 3- Lecture 14

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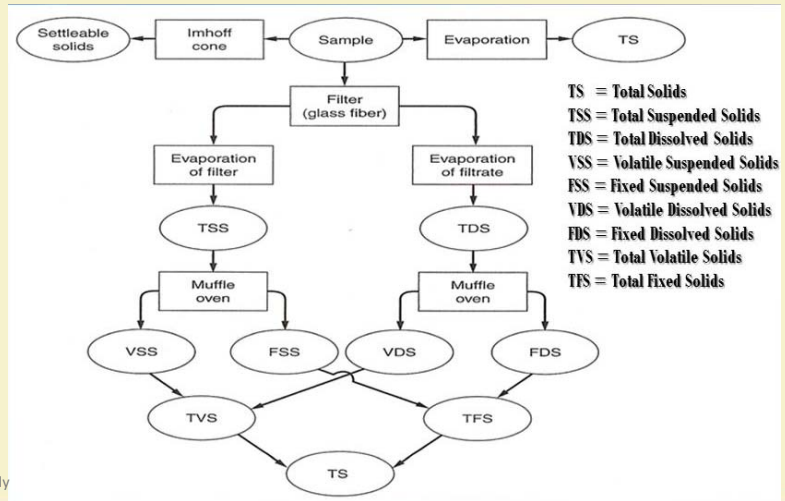
Water Quality Parameters

✓Solids:

- It refers to the mass of solids present in the water. The Total Solids (TS) mass present in the water could be in suspended (TSS) or dissolved (TDS) state, and could be volatile (TVS) or fixed (TFS) by nature. Based on these different measures of solids are estimated.
- Inorganic salts in water often remains in dissolved stats and are non-volatile even at high temperatures, therefore contributes to Fixed Dissolved Solids (FDS). While, Fixed Suspended Solids (FSS) are inorganic particles suspended in the liquid; such as undissolved salt crystals and silt particles.
- Organic compounds are often volatile when gets burn at high temperature. The dissolved organics in the liquid, e.g. sugars, fatty acids etc. constitutes Volatile Dissolved Solids (VDS), while suspended organic matters, and especially microorganisms constitute Volatile Suspended Solids (VSS).
- The sum of FDS and VDS is referred to as Total Dissolved Solids (TDS), and similarly sum of VSS and FSS is called Total Suspended Solids (TSS).

Water Quality Parameters

✓Solids: Measurements



Source:
Wastewater Engineering: Treatment and Reuse by Metcalf & Eddy

Water Quality Parameters

✓Fecal Coliform: Most Probable Number (MPN):

- MPN is most commonly applied parameter for microbiol quality testing of water. Fecal coliforms act as an indicator for fecal contamination of water. Very few fecal coliform bacteria would indicate that a water probably contains no disease-causing organisms, while microbiolly contaminated water will exhibit the presence of large numbers of fecal coliform bacteria and high MPN values.
- Fecal coliform are indicator organisms and are usually not pathogenic by themselves. Pathogens are typically present in such small amounts it is impractical monitor them directly.
- The separate estimates could be obtained for total and fecal coliform bacteria, if needed

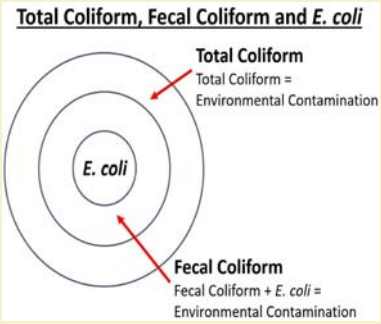
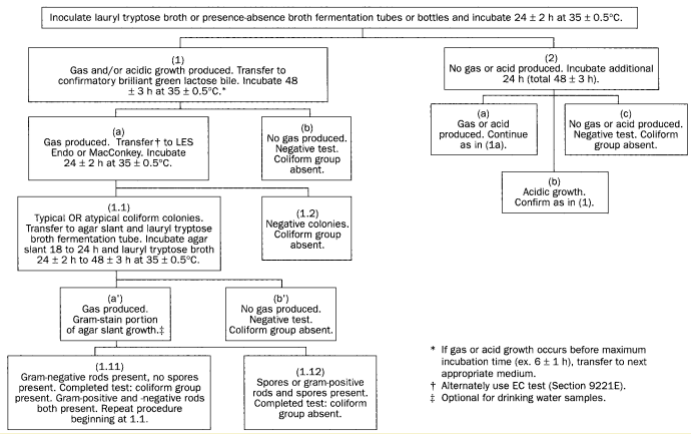


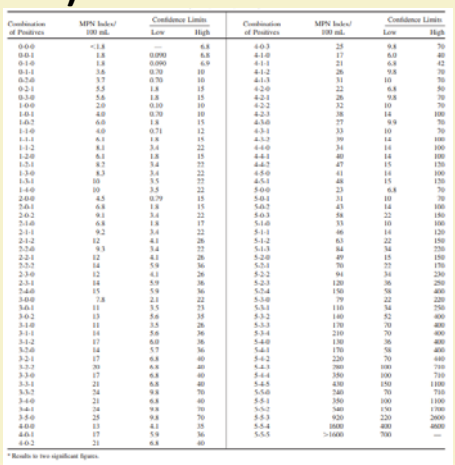
Image Source: https://ietbuildinghealth.com/blog/sewage-testing-methods/total-and-fecal-coliform/

Water Quality Parameters

✓Fecal Coliform: Most Probable Number (MPN): Test Procedure



Source: : AWWA, WEF, APHA, 1998, Standard Methods for the Examination of Water and Wastewater



Water Quality Parameters

✓Metals:

- Metals, in small/trace quantities in water are useful for sustainability of biological life, while, when present in excess, they become toxic and imposes human health as well as environmental risk .
- Both municipal and industrial wastewater usually contains various metals, however industrial discharges, at time, may have excessively high metal concentrations depending on industrial processes.
- Metals are determined using flame atomic absorption, electrothermal atomic absorption, inductively coupled plasma, or IPC/mass spectrometry.
- Some of the metals are also classified as priority pollutants.

Water Quality Parameters

✓Metals *(Classified as priority pollutants):*

Name	Formula	Use	Concern
Arsenic	As	Alloying additive for metals, especially lead and copper as shot, battery grids, cable sheaths, boiler tubes. High-purity (semiconductor) grade	Carcinogen and mutagen. *Long-term*—sometimes can cause fatigue and loss of energy; dermatitis
Barium	Ba	Getter alloys in vacuum tubes, deoxidizer for copper, Frary' s metal, lubricant for anode rotors in x-ray tubes, spark-plug alloys	Flammable at room temperature in powder form. *Long-term*—Increased blood pressure and nerve block
Cadmium	Cd	Electrodeposited and dipped coatings on metals, bearing and low-melting alloys, brazing alloys, fire protection system, nickel-cadmium storage batteries power transmission wire, TV phosphors, basis of pigments used in ceramic glazes, machinery enamels, fungicide, photography and lithography, selenium rectifiers, electrodes for cadmium-vapor lamps and photoelectric cells	Flammable in powder form. Toxic by inhalation of dust or fume. A carcinogen. Soluble compounds of cadmium are highly toxic. *Long-term*—concentrates in the liver, kidneys, pancreas, and thyroid; hypertension suspected effect

Source: Wastewater Engineering Treatment and Reuse, Metcalf and Eddy, Indian Edition, 2003

Water Quality Parameters

✓**Metals** *(Classified as priority pollutants):*

Name	Formula	Use	Concern
Chromium	Cr	Alloying and plating element on metal and plastic substrates for corrosion resistance, chromium-containing and stainless steels, protective coating for automotive and equipment accessories, nuclear and high-temperature research, constituent of inorganic pigments	Hexavalent chromium compounds are carcinogenic and corrosive on tissue. *Long-term*—skin sensitization and kidney damage
Lead	Pb	Storage batteries, gasoline additive, cable covering, ammunition, piping, tank linings, solder and fusible alloys, vibration damping in heavy construction, foil, babbitt and other bearing alloys	Toxic by ingestion or inhalation of dust or fumes. *Long-term*—brain and kidney damage; birth defects
Mercury	Hg	Amalgams, catalyst electrical apparatus, cathodes for production of chlorine and caustic soda, instruments, mercury vapor lamps, mirror coating, arc lamps, boilers	Highly toxic by skin absorption and inhalation of fume or vapor. *Long-term*—toxic to central nervous system, may cause birth defects
Selenium	Se	Electronics, xerographic plates, TV cameras, photocells, magnetic computer cores, solar batteries (rectifiers, relays), ceramics (colorant for glass), steel and copper, rubber accelerator, catalyst, trace element in animal feeds	*Long-term*—red staining of fingers, teeth, and hair; general weakness; depression; irritation of nose and mouth

Source: Wastewater Engineering Treatment and Reuse, Metcalf and Eddy, Indian Edition, 2003

Water Quality Parameters

✓**Metals** *(Classified as priority pollutants):*

Name	Formula	Use	Concern
Silver	Ag	Manufacture of silver nitrate, silver bromide, photochemicals; lining vats and other equipment for chemical reaction vessels, water distillation, etc.; mirrors, electric conductors, silver plating electronic equipment; sterilant, water purification, surgical cements, hydration and oxidation catalyst, special batteries, solar cells, reflectors for solar towers, low-temperature brazing alloys, table cutlery, jewelry, dental, medical, and scientific equipment, electrical contacts, bearing metal, magnet windings, dental amalgams, colloidal silver used as a nucleating agent in photography and medicine, often combined with protein	Toxic metal. *Long-term*—permanent gray discoloration of skin, eyes, and mucous membranes

Source: Wastewater Engineering Treatment and Reuse, Metcalf and Eddy, Indian Edition, 2003

Water Quality Parameters

✓Nutrients:

- Nutrient pollution in water refers to excess nitrogen and phosphorus in the water and is one of world's most widespread, and challenging environmental problems.
- Nutrient pollution has impacted many streams, rivers, lakes, bays and coastal waters for the past several decades, resulting in serious environmental and human health issues, and impacting the economy.
- Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle resulting in large growths of algae (algal blooms). This harm water quality, food resources and habitats, and decrease or eliminate the oxygen that fish and other aquatic life need to survive. Some algal blooms are harmful to humans because they produce elevated toxins and bacterial growth that can make people sick if they come into contact with polluted water, consume tainted fish or shellfish, or drink contaminated water.

Source: https://www.epa.gov/nutrientpollution/problem

Water Quality Parameters

✓Nutrients: Measurements

- Nitrogen and phosphorous are found in organic forms (not immediately available for plant use) and inorganic forms (immediately available for plant use). Organic forms of nutrients are eventually converted to inorganic forms. Typically, all forms of nutrients are measured in surface water even if they are unavailable for plant use in the short term.
- The forms of phosphorus that are usually measured include Total Phosphorus (TP), Total Dissolved Phosphorus (TDP) and the inorganic component, Orthophosphate (PO_4).
- The forms of nitrogen that are usually measured include Total Nitrogen (TN) or Total Kjeldahl Nitrogen (TKN), and the inorganic forms of Nitrate (NO_3), Nitrite (NO_2) and Ammonium (NH_4).
- Standard chemical procedure or field chemistry kits are typically used for the measurement of nutrients.

Source: http://www.pfra.ca/doc/Water%20Quality/Water%20Quality%20Protection/using_field_chem_kits_final.pdf

Water Quality Parameters

✓Emerging Pollutants

- These include various compounds such as, pesticides, pharmaceuticals and personal care products, antimicrobials and antibiotics, hormones, phthalate plasticizers, surfactants etc..
- These are generally unregulated group of chemicals which are, persistent, anthropogenic and toxic in nature, and have become identifiable with the new techniques for identification and separation, in the field of chemical analysis.

Sex and Steroidal Hormones

Biogenics	*Pharmaceuticals*	*Sterols*
17β-estradiol (E2)	17α-ethynylestradiol	cholesterol
17α-estradiol (E1)	mestranol	3β-coprostanol
estrone	19-norethisterone	stigmastanol
estriol	equilenin	
testosterone	equilin	
progesterone		
cis-androsterone		

Household and Industrial Chemicals

Insecticides	*PAHs*	*Plasticizers*	*Surfactant Derivatives*
carbaryl	anthracene	bis(2-ethylhexyl)adipate	nonylphenol-monoethoxylate
chlorpyrifos	benzo(*a*)pyrene	ethanol-2-butoxyphosphate	nonylphenol diethoxylate
cis-chlordane	fluoranthene	bis(2-ethylhexyl)phthalate	octylphenol-monoethoxylate
diazinon	naphathalene	diethylphthalate	octylphenol-diethoxylate
dieldrin	phenanthrene	triphenyl phosphate	*p*-nonylphenol
lindane	pyrene		
methyl parathion			
N,N-diethyltoluamide			

Antioxidants	*Fire Retardants*	*Others*
butylatedhydroxyanisole	tri(2-chloroethyl)-phosphate	Acetophenone
butylatedhydroxytoluene	tri(dichlorisopropyl)-phosphate	bisphenol-A
2,6-di-tert-butylphenol		1,2-dichlorbenzene
2,6-di-tert-butyl-p-benzoquinote		*p*-cresol
5-methyl-1H-benzotriazole		phenol
		phthalic anhydride
		tetrachloroethylene
		triclosan

Source: Contaminants of Emerging Concern, Bhandari et.al., 2009, ASCE Publications

Water Quality Parameters

✓Emerging Pollutants

Antibiotics (Human and Veterinary)		Other Human Pharmaceuticals	
Tetracyclines	*Sulfonamides*	*Prescription*	*Non-Prescription*
chlortetracycline	sulfachlorpyridazine	cimetidine	acetaminophen
doxycycline	sulfadimethoxine	dehydronifedipine	ibuprofen
oxytetracycline	sulfamerazine	digoxygenin	codeine
tetracycline	sulfamethazine	digoxin	caffeine
	sulfamethiazole	diltiazem	1,7-dimethylxanthine
Fluoroquinolones	sulfamethoxazole	fluoxetine	cotinine
ciprofloxacin	sulfathiazole	gemfibrozil	
enrofloxacin		metformin	
norfloxacin		paroxetine	
sarafloxacin	*Other Antibiotics*	ranitidine	
	carbadox	salbutamol	
Macrolides	lincomycin	warfarin	
erythromycin-H_2O	trimethoprim		
roxithromycin	virginiamycin		
tylosin			

Source: Contaminants of Emerging Concern, Bhandari et.al., 2009, ASCE Publications

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

WASTEWATER TREATMENT AND RECYCLING

Wastewater Characteristics: Practice Problems

Week 3- Lecture 15

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Practice Problem: COD Calculation

- Glycine ($CH_3.NH_2.CH.COOH$) undergoes following reaction in the presence of oxygen.

  $CH_3.NH_2.CH.COOH + 3O2 = 3CO_2 + NH_3 + 2H_2O$

  Calculate theoretical COD of 890 mg/L glycine solution.

Practice Problem: Solids Estimation

- Solid analyses performed using an influent water sample volume of 50 ml resulted in following observation. Determine the concentration (in mg/L) of: a) total solids b) total volatile solids c) total suspended solids d) volatile suspended solids e) total dissolved solids.

Weight of evaporating dish = 54.6423 g;

Weight of evaporating dish plus residue after evaporation at 105°C = 54.7184 g;

Weight of evaporating dish plus residue after ignition at 550°C = 54.6818 g;

Weight of Whatman glass fiber filter = 1.5434 g;

Weight of Whatman glass fiber filter and residue after drying at 105°C = 1.5625 g;

Weight of Whatman glass fiber filter and residue after ignition at 550°C = 1.5531 g;

Assume no loss in weight of dish and filter after drying or ignition.

Practice Problem: BOD Estimation

- A series of dilutions were prepared in 300 mL BOD bottles using settled raw sewage and unseeded dilution water. The dilution range, initial DO, and final DO were recorded as under.

Bottle #	mL Seed	Initial DO	Final DO	Depletion
1	3	7.95	5.20	2.75
2	6	7.95	3.85	4.10
3	9	7.90	2.40	5.50
4	12	7.85	1.35	6.50

Determine the BOD of each test sample and the average BOD.

Thank You!!