Environmental Engineering
(Laboratory) Version 2023

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Abstract:
The writers of this book as a guideline to understanding of the Environmental Engineering (Laboratory) version 2023 for the course DAC 12203 offered by the Centre of Diploma Studies (CeDS), Universiti Tun Hussein Onn Malaysia (UTHM). This book is divided into six (6) experiments and one (1) analysis: -

i. Laboratory 1 Total Solid Determination (TSD) experiment to determine total solid content of water samples. In this experiment include Total Solid (TS), Total Suspended Solid (TSS), Total Dissolved Solid (TDS) and Volatile Suspended Solids (VSS)

ii. Laboratory 2 Biochemical Oxygen Demand (BOD) experiment to measures the strength of the water sample (water, wastewater, etc.) based on the amount of oxygen needed to stabilize the organic matter in the sample.

iii. Laboratory 3 Chemical Oxygen Demand (COD) experiment to determine the organic oxidizable matters content of water samples.

iv. Laboratory 4 Jar Test experiment to determine the optimal coagulant dose which will produce the highest removal of a given water turbidity.

v. Laboratory 5 Total Bacteria Count (TBC) experiment to measure the bacteriological quality of water sample using total plate count.

vi. Laboratory 6 Ammoniacal Nitrogen (AN) experiment to measure the amount of nitrogen ammonia NH3-N of water samples using Nessler Method.

vii. WQI analysis determine the water quality index for water samples.

Diploma of civil engineering students will benefit from this book.

Keywords : Ammoniacal Nitrogen, Chemical Oxygen Demand, Graduated Pipettes, Turbidity meter, Water Quality Assessment

ENVIRONMENTAL ENGINEERING

(LABORATORY) VERSION 2023

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Penerbit UTHM

FIRST EDITION

ENVIRONMENTAL ENGINEERING
(LABORATORY) VERSION 2023

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SYNOPSIS

This module is divided into 6 Laboratory:

Laboratory 1 Total Solid Determination (TSD) experiment to determine total solid content of water samples. In this experiment include Total Solid (TS), Total Suspended Solid (TSS), Total Dissolved Solid (TDS) and Volatile Suspended Solids (VSS)

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Laboratory 6 Ammoniacal Nitrogen (AN) experiment to measure the amount of nitrogen ammonia NH_3-N of water samples using Nessler Method.

WQI analysis determine the water quality index for water samples.

ASSESSMENT

To broaden the student's knowledge and understanding, this module provides discussion question for self-learning activities

UTHM Universiti Tun Hussein Onn Malaysia	Faculty: **Centre for Diploma Studies (CeDS)**
	Department: **Civil Engineering**
	Title: **ENVIRONMENTAL ENGINEERING LABORATORY SAFETY**

ENVIRONMENTAL ENGINEERING LABORATORY SAFETY

1. Three categories of safety in the laboratory as shown in Figure A.

Figure A: Categories of safety in the laboratory

2. Self-safety
   a. Make sure the clothes are always neat and appropriate while in the Laboratory
   b. Use closed shoes and rubber soles when working in the Laboratory as shown in Figure B.

Figure B: Suitable and unsuitable shoes using in Laboratory

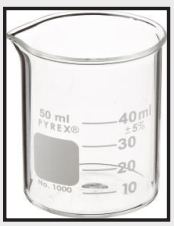
UTHM Universiti Tun Hussein Onn Malaysia	Faculty: **Centre for Diploma Studies (CeDS)**
	Department: **Civil Engineering**
	Title: **ENVIRONMENTAL ENGINEERING LABORATORY EQUIPMENT & REAGENT**

ENVIRONMENTAL ENGINEERING LABORATORY EQUIPMENT & REAGENT

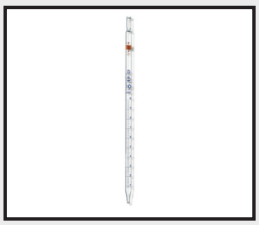
CHEMICAL OXYGEN DEMAND (COD)

Deionized water

COD Digestion Vials Low/High Range



Beaker



Graduated Pipettes

Pipette Filler, Pi-Pump

HACH DRB200 Reactor

HACH DR6000 Reactor

UTHM Universiti Tun Hussein Onn Malaysia	Faculty: **Centre for Diploma Studies (CeDS)**
	Department: **Civil Engineering**
	Title: **LABORATORY SAMPLING VOLUME & SURVIVE**

1.0 LABORATORY SAMPLING VOLUME

Parameters	Method	Volume (Estimate)
Total Bacteria Count	Spread Plate Pour Plate	*10mL*
BOD (mg/L)	Biochemical Oxygen Demand pH Dissolved Oxygen	*1000mL*
COD (mg/L)	Chemical Oxygen Demand (Digestion Method)	*6mL*
AN (NH_3-N mg/L)	Ammoniacal Nitrogen (Nessler Method)	*75mL*
Total Solid Determination (mg/L)	Total Solid Total Suspended Solid Total Dissolved Solid Volatile Suspended Solid	*30mL*
Jar Test	Jar Test	*6000mL*
		7121mL ≈ 7.2L

Collect more around 10 Liters for a group

2.0 HOW LONG DOES THE SAMPLE WATER SURVIVE?

Parameters	Survive Time	Reference
Total Bacteria Count	To preserve samples for later analysis, keep the samples at or below 6 °C for up to 24 hours	Guidelines For Drinking-water Quality https://www.who.int/water_sanitation_health/dwq/2edvol3d.pdf
BOD (mg/L)	To preserve samples for later analysis, keep the samples at or below 6 °C (43 °F) for up to 48 hours	Quality Assurance Manual https://www.rmbel.info/wp-content/uploads/2013/05/Sample-Collection-and-Preservation-List.pdf
pH	Analyze in 15min	
Dissolved Oxygen	Analyzed Immediately	
COD (mg/L)	Keep the preserved samples at 2–6 °C (36–43 °F) for a maximum of 28 days.	HACH
AN (NH_3-N mg/L)	Keep the preserved samples at or below 6 °C (43 °F) for a maximum of 28 days	HACH
Total Solid Determination (mg/L)	To preserve samples for later analysis, keep the samples at or below 6 °C (43 °F) for up to 7 days.	HACH
Jar Test	-	-

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CENTER FOR DIPLOMA STUDIES

DEPARTMENT OF CIVIL ENGINEERING

ENVIRONMENTAL ENGINEERING LABORATORY

LABORATORY INSTRUCTION SHEETS

COURSE CODE	DAC 12203
COURSE NAME	ENVIRONMENTAL ENGINEERING
EXPERIMENT TITLE	TOTAL SOLID DETERMINATION

UTHM Universiti Tun Hussein Onn Malaysia	Faculty: **Centre for Diploma Studies (CeDS)**
	Department: **Civil Engineering**
	Title: **TOTAL SOLID DETERMINATION**

1.0 OBJECTIVE

To determine total solid content of water samples.

2.0 LEARNING OUTCOME

At the end of this course students are able to:

a) Apply knowledge in solid determination
b) Analyse the laboratory result and differentiate between suspended solid and dissolve solid
c) Identify problems and use their generic skill to solve problems
d) Develop their ability to work in groups

3.0 THEORY

Solids refer to the matter suspended or dissolved in water or waste water that can be physically isolated either through filtration or evaporation. Solids may adversely affect water or effluent quality in a number of ways. Waters with high dissolved solids generally are of inferior palatability and may induce a favourable physiological reaction in the transient consumer. Solids analyses are important in controlling the process of biological and physical wastewater treatment and compliance with wastewater effluent limitations of the regulatory agency.

Total solids is the residue left in the dishes after sample evaporation at 103°C to 105°C. Total solids measurement is useful as the indicator for the effects of runoff from construction, agricultural practices, logging activities, sewage treatment plant discharge and other sources. Higher total solids affect the water clarity, and limiting the passing light through water; thus, slowing down the photosynthesis process. Total solids include total suspended solids and total dissolved solids.

Total suspended solids (TSS) is the portion of total solids retained after filtration, and **total dissolved solids** (TDS) is the portion of solids that passes through a filter of 2.0 µm (or smaller) pore size under specified conditions. **Fixed solids** are referred to the total, suspended, or dissolved residue of solids after heating to dryness for a specified time at a specified temperature (500°C ± 50° C for 15 minutes). The weight loss on ignition is called **volatile solids**. Determination of fixed and volatile solids does not precisely distinguish between inorganic and organic matter because it involves losses due to the decomposition or volatilization of certain mineral salts. **Settleable solids** is the material settling out of suspension within a defined period. It may include floating material, depending on the technique.

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ENVIRONMENTAL ENGINEERING LABORATORY

LABORATORY INSTRUCTION SHEETS

COURSE CODE	DAC 12203
COURSE NAME	ENVIRONMENTAL ENGINEERING
EXPERIMENT TITLE	BIOCHEMICAL OXYGEN DEMAND

UTHM Universiti Tun Hussein Onn Malaysia	Faculty: **Centre for Diploma Studies (CeDS)**
	Department: **Civil Engineering**
	Title: **BIOCHEMICAL OXYGEN DEMAND (BOD)**

1.0 OBJECTIVE

To measures the strength of the water sample (water, wastewater, etc) based on the amount of oxygen needed to stabilize the organic matter in the sample.

2.0 LEARNING OUTCOMES

i) the student be able to describe the importance of BOD in the environmental studies.
ii) the students be able to measure the BOD of samples with the right sample size.

3.0 THEORY

Biochemical Oxygen Demand is a common, environmental procedure for determining the extent to which oxygen within a sample can support microbial life. This method is popular in many environmental laboratories analyzing waste water, compost, sludge, and soil samples.

When a measurement is made of all oxygen consuming materials in a sample, the result is termed "Total Biochemical Oxygen demand" (TBOD) , or often just simply "Biochemical Oxygen Demand" (BOD). Because the test is performed over a five-day period, it is often referred to as a "Five Day BOD", or a BOD_5.

In addition, this procedure is only suitable for samples void of serious matrix interferences. To gain a broader appreciation of oxygen demand, additional avenues of interest may be explored including CBOD (carbonaceous oxygen demand), COD (chemical oxygen demand), and TOC (total organic carbon).

Because of complications measuring this ultimate BOD (BOD_u), BOD_u is usually extrapolated from laboratory 5-day BOD bottle tests $BODt = BOD_u (1 - e^{-kt})$

In many biological treatment plants, the facility effluent large numbers of nitrifying organisms which are developed during the treatment process. These organisms can exert an oxygen demand as they convert nitrogenous compounds (ammonia and organic nitrogen) to more stable forms (nitrites and nitrates). At least part of this oxygen demand is normally measured in a five-day BOD.

Sometimes it is advantageous to measure just the oxygen demand exerted by organic (carbonaceous) compounds, excluding the oxygen demand exerted by the nitrogenous compounds. To accomplish this, the nitrifying organisms can be inhibited from using oxygen by the addition of a nitrification inhibitor to the samples. The result is termed "Carbonaceous Biochemical Oxygen Demand "or BOD.

4.0 EQUIPMENT & REAGENTS:

1. 7 units 300 mL glass stopper BOD Bottles
2. Incubator, capable of maintaining 20 ± 1 ^{0}C
3. 100 mL beaker
4. 500 mL measuring cylinder
5. 1000 mL Volumetric flask
6. Dissolved Oxygen meter

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ENVIRONMENTAL ENGINEERING LABORATORY

LABORATORY INSTRUCTION SHEETS

COURSE CODE	DAC 12203
COURSE NAME	ENVIRONMENTAL ENGINEERING
EXPERIMENT TITLE	CHEMICAL OXYGEN DEMAND (COD)

UTHM Universiti Tun Hussein Onn Malaysia	Faculty: **Centre for Diploma Studies (CeDS)**
	Department: **Civil Engineering**
	Title: **CHEMICAL OXYGEN DEMAND (COD)**

1.0 OBJECTIVE

To determine the organic oxidizeable matters content of water samples.

2.0 LEARNING OUTCOME

At the end of this course students are able to:

a) Understand the oxidizeable matter using known amount of potassium dichromate, the titration of excess chromate, and the calculation of oxygen used.
b) Identify the organic oxidizeable matter pollutant content in water samples.
c) Evaluate the water quality status at the location of water or wastewater sampling point.
d) Practice the appropriate analytical methodology for measuring COD parameter.

3.0 THEORY

The chemical oxygen demand (COD) is the amount of oxygen consumed to completely chemically oxidized the organic water constituents to inorganic end products. COD is an important, rapidly measured variable for determination of the organic matter content of water samples. However, there are substances are hard to be oxidized in water samples resulting in incomplete oxidation under given test methods. Due these circumstances, COD values may be a poor measure of the theoretical oxygen demand. It should also be noted that the value significantly depends on the composition of the studied water.

COD is used to measure the pollutants in natural and wastewater in assessing the strength of discharged waste such as sewage and industrial effluent waters. It is normally used for indicating the efficiency of water treatment plants process for municipal and industrial wastewater treatment. Most applications of COD determine the quantity of organic pollutants found in surface water (e.g. lakes and rivers), making COD a useful measure for water quality. It is expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution. It also expressed in parts per million (ppm).

The basis for the COD test is that assuming nearly all organic compounds fully oxidized to carbon dioxide using a strong oxidizing agent under acidic conditions. The amount of oxygen required to oxidize an organic compound to carbon dioxide, ammonia and water is given by:

$$C_nH_aO_bN_c + (n + a/4 - b/2 - 3c/4)\ O_2 \rightarrow nCO_2 + (a/2 - 3c/2)\ H_2O + cNH_3$$

This expression excluding the oxygen demand caused by the oxidation of ammonia into nitrate. The process of ammonia being converted into nitrate is referred to as nitrification. The following is the correct equation for the oxidation of ammonia into nitrate.

$$NH_3 + 2O_2 \rightarrow NO_3^- + H_3O^+$$

The second equation should be applied after the first one to include oxidation due to nitrification if the oxygen demand from nitrification must be known. Dichromate does not oxidize ammonia into nitrate, so this nitrification can be safely ignored in the standard COD test. The International Organization for Standardization describes a standard method for measuring COD in ISO 6060.

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COURSE CODE	DAC 12203
COURSE NAME	ENVIRONMENTAL ENGINEERING
EXPERIMENT TITLE	JAR TEST

UTHM Universiti Tun Hussein Onn Malaysia	Faculty: **Centre for Diploma Studies (CeDS)**
	Department: **Civil Engineering**
	Title: **JAR TEST**

1.0 OBJECTIVE

- To determine the optimal coagulant dose which will produce the highest removal of a given water turbidity.

2.0 LEARNING OUTCOME

1. To identify the most common coagulant used in the coagulant process.
2. To determine the most effective and optimum dosage of coagulant for a particular mixing intensity and duration.
3. To understand the complex interrelationships that exists between the chemicals and the constituents of the water being treated, as well as other factors such as pH, temperature, the intensity and duration of mixing.

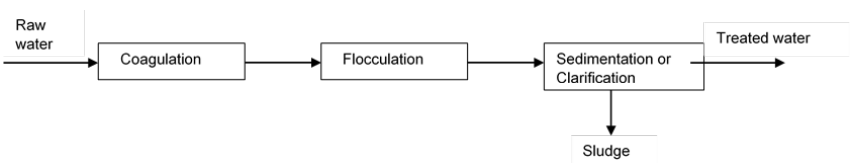
3.0 THEORY

Raw water and wastewater is normally turbid containing solid particles of varying sizes. Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microspic organisms. Particles with sizes greater than 50 µm settle fairly rapidly. The settling velocities of colloidal particles of sizes less than 50 µm are very slow. Thus, these particles are encouraged to collide leading to coalescence of particle to form flocs particles, which are bigger and heavier. These particles will have higher settling velocities and easily settle out.

A very important step in water and wastewater treatment is the coagulation-flocculation process which is widely used, due to its simplicity and cost-effectiveness. Coagulation and flocculation consist of adding a floc-forming chemical reagent into water or wastewater to encourage the non-settleable colloidal solids (or particles) to collide, leading to coalescence of particle to form flocs particles (which are bigger and heavier).

Colloidal particles which are not agglomerate by itself due to the presence of repulsive forces need a process to suppress these forces so as to allow flocs formation. This process is called **coagulation** process. Coagulant that are normally used are salts of aluminium namely **aluminium sulphate, $Al_2(SO_4)_3$** and ferric salts namely **ferric sulphate, $Fe_2(SO_4)_3$** and **ferric chloride, $FeCl_3$**. The non-settleable particles have a negative (-ve) charge, so the positively charged (+ve) coagulant chemicals neutralized the particles during coagulation. The next process is **flocculation** process. It is the gentle agitation process to agglomerate the smaller non-settleable particles (the neutralized particles). During this process, the neutralized particles (which are not repelling each other) are drawn together by van der Waal's forces, hence, forming flocs. The flocs will then settle out in the sedimentation basin, with remaining floc being removed in the filter.

Concept structure:



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COURSE CODE	DAC 12203
COURSE NAME	ENVIRONMENTAL ENGINEERING
EXPERIMENT TITLE	TOTAL BACTERIA COUNT

UTHM Universiti Tun Hussein Onn Malaysia	Faculty: **Centre for Diploma Studies (CeDS)**
	Department: **Civil Engineering**
	Title: **TOTAL BACTERIA COUNT**

1.0 OBJECTIVE

To measure the bacteriological quality of water sample using total plate count.

2.0 LEARNING OUTCOMES

At the end of this course students are able to:

a) Be more proficient at dilutions
b) Be more proficient at performing a standard plate count and determining bacterial counts in a sample

3.0 THEORY

The standard plate count method involving a dilution of the sample with phosphate buffer diluent until the diluted bacteria counted accurately. Hence, the final plates in the series should contain within 30 and 300 colonies. The colonies below 30 count considered not acceptable for statistical reasons due to too few to be representative of the whole sample, and more than 300 colonies on a plate are likely to produce colonies too close to each other resulting in difficulty to be distinguished as distinct colony-forming units (CFUs).

The assumption is that each viable bacterial cell is separate from all others and develop into a single discrete colony (CFU). Thus, the number of colonies should give the number of bacteria that can grow under the employed incubation conditions. A series of dilutions (e.g., 10-4 to 10-10) is normally plated because the exact number of bacteria is usually unknown.

Greater accuracy can be achieved by plating duplicates or triplicates of each dilution. Increased turbidity in a culture is another index of bacterial growth and cell numbers (biomass). By using a spectrophotometer, the amount of transmitted light decreases as the cell population increases. The transmitted light is converted to electrical energy, and this can be indicated on a galvanometer. The reading, called absorbance or optical density, indirectly reflects the number of bacteria. This method is faster than the standard plate count, but there is a limitation where sensitivity is restricted to bacterial suspensions of 107 cells or greater.

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ENVIRONMENTAL ENGINEERING LABORATORY

LABORATORY INSTRUCTION SHEETS

COURSE CODE	**DAC 12203**
COURSE NAME	**ENVIRONMENTAL ENGINEERING**
EXPERIMENT TITLE	**AMMONIACAL NITROGEN**

UTHM Universiti Tun Hussein Onn Malaysia	Faculty: **Centre for Diploma Studies (CeDS)**
	Department: **Civil Engineering**
	Title: **AMMONIACAL NITROGEN**

1.0 OBJECTIVE

To determine the amount of ammoniacal nitrogen (NH_3-N) of water samples.

2.0 LEARNING OUTCOME

At the end of this course students are able to:

a) Apply knowledge in ammoniacal nitrogen
b) Analyse the laboratory result from the data obtained
c) Develop their ability to work in groups

3.0 THEORY

Ammoniacal nitrogen (NH_3-N) is a measure for the amount of ammonia, a toxic pollutant often found in landfill leachate and in waste products, such as sewage, liquid manure and other liquid organic waste products. It can also be used as a measure of the health of water in natural bodies such as rivers or lakes, or in manmade water reservoirs. The term is used widely in waste treatment and water purification systems. Ammonia can directly poison humans and upset the equilibrium of water systems.

The values of ammoniacal nitrogen in water or waste liquids are measured in milligram per liter and are used for specifying water treatment systems and facilities. The typical output of liquid manure from a dairy farm, after separation from the solids is 1600 mg NH_3-N /L. Sewage treatment plants, receiving lower values, typically remove 80% and more of input ammonia and reach NH_3-N values of 250 mg/L or less.

The ammonium nitrogen value is also used in the context of properly designed landfill systems, where the leachate is being pumped to the surface and treated before it enters the ground water, testing the quality of the water exiting the treatment system. The term NH_3-N removal is also commonly used in scientific publications as a short way to depict Ammonia in water, and not the measure of its quantity.

Malaysian standard A prescribed that the effluent discharge limit of phosphorus into any inland water within the catchment is 5 mg/L (standard A) and standard B to any other inland water or Malaysian waters is 10 mg/L.

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LABORATORY INSTRUCTION

COURSE CODE	DAC 12203
COURSE NAME	ENVIRONMENTAL ENGINEERING
EXPERIMENT TITLE	WATER QUALITY ASSESSMENT

UTHM Universiti Tun Hussein Onn Malaysia	Faculty: **Centre for Diploma Studies (CeDS)**
	Department: **Civil Engineering**
	Title: **WATER QUALITY ASSESSMENT**

1.0 OBJECTIVE

To determine the water quality index for water samples.

2.0 LEARNING OUTCOME

At the end of this course students are able to:

a) Evaluate the water quality status at the location of water sampling point.
b) Classify the DOE Water Quality Classification Based On Water Quality Index.

3.0 WQI FORMULA

WQI=(0.22*SIDO) +(0.19*SIBOD) +(0.16*SICOD) +(0.15*SIAN) +(0.16*SISS) + (0.12*SipH)

where;
SIDO = SubIndex DO (% saturation)
SIBOD = SubIndex BOD
SICOD = SubIndex COD
SIAN = SubIndex NH_3–N
SISS = SubIndex SS
SipH = SubIndex pH

$0 \leq WQI \leq 100$

BEST FIT EQUATIONS FOR THE ESTIMATION OF VARIOUS SUBINDEX VALUES

SubIndex for DO (In % saturation)	
$SIDO = 0$	for $x \leq 8$
$SIDO = 100$	for $x \geq 92$
$SIDO = -0.395 + 0.030x^2 - 0.00020x^3$	for $8 < x < 92$
SubIndex for BOD	
$SIBOD = 100.4 - 4.23x$	for $x \leq 5$
$SIBOD = 108^* \exp(-0.055x) - 0.1x$	for $x > 5$
SubIndex for COD	
$SICOD = -1.33x + 99.1$	for $x \leq 20$
$SICOD = 103^* \exp(-0.0157x) - 0.04x$	for $x > 20$
SubIndex for NH_3–N	
$SIAN = 100.5 - 105x$	for $x \leq 0.3$
$SIAN = 94^* \exp(-0.573x) - 5^* \lvert x - 2 \rvert$	for $0.3 < x < 4$
$SIAN = 0$	for $x \geq 4$
SubIndex for SS	
$SISS = 97.5^* \exp(-0.00676x) + 0.05x$	for $x \leq 100$
$SISS = 71^* \exp(-0.0061x) + 0.015x$	for $100 < x < 1000$
$SISS = 0$	for $x \geq 1000$
SubIndex for pH	
$SIpH = 17.02 - 17.2x + 5.02x^2$	for $x < 5.5$
$SIpH = -242 + 95.5x - 6.67x^2$	for $5.5 \leq x < 7$
$SIpH = -181 + 82.4x - 6.05x^2$	for $7 \leq x < 8.75$
$SIpH = 536 - 77.0x + 2.76x^2$	for $x \geq 8.75$
Note: *means multiply	

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Author's Biography

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(LABORATORY) VERSION 2023

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ii. **Laboratory 2 Biochemical Oxygen Demand (BOD)** experiment to measures the strength of the water sample (water, wastewater, etc.) based on the amount of oxygen needed to stabilize the organic matter in the sample.

iii. **Laboratory 3 Chemical Oxygen Demand (COD)** experiment to determine the organic oxidizable matters content of water samples.

iv. **Laboratory 4** Jar Test experiment to determine the optimal coagulant dose which will produce the highest removal of a given water turbidity.

v. **Laboratory 5 Total Bacteria Count (TBC)** experiment to measure the bacteriological quality of water sample using total plate count.

vi. **Laboratory 6 Ammoniacal Nitrogen (AN)** experiment to measure the amount of nitrogen ammonia NH3-N of water samples using Nessler Method.

vii. **WQI analysis** determine the water quality index for water samples.

Diploma of civil engineering students will benefit from this book.

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