ENVIRONMENTAL MANAGEMENT BUREAU
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

WATER QUALITY MONITORING MANUAL

VOLUME I

MANUAL ON AMBIENT WATER QUALITY MONITORING

February 2008

PREFACE

This Manual on Ambient Water Quality Monitoring (WQM) constitutes Volume I of a two-volume manual on Water Quality Monitoring, Volume II being the manual on Effluent Quality Monitoring.

Volume I is a guide to monitor the country's surface waters in rivers and streams, lakes and similar water bodies, and marine waters (coastal and offshore). The objective is to standardize ambient water quality monitoring procedures to ensure that water quality monitoring programs follow certain Quality Assurance/Quality Control (QA/QC) protocols and acceptable field methods.

The primary users of the WQM manual are the technical staff of the EMB, both the Central and Regional Offices. Other users include technical staff of Laguna Lake Development Authority (LLDA), Mines and Geo-sciences Bureau (MGB) and other agencies or individuals under the DENR.

Users may also include other government regulators and implementers such as the BFAR, DPWH, NIA, PCG, LGUs, consultancy firms, industries, government-recognized NGOs, monitoring groups such as Multi-partite Monitoring Teams (MMTs), or other volunteer groups, students, and researchers.

The manual is intended to be a dynamic document that will be periodically reviewed and updated as deemed necessary.

ACKNOWLEDGMENTS

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The Technical Working Group:

- Industrial Technology Development Institute , Department of Science and Technology*, (ITDI-DOST)*
- Laguna Lake Development Authority (*LLDA*)
- League of Provinces of the Philippines (*LPP*)
- Local Water Utilities Administration (*LWUA*)
- Mines and Geo-sciences Bureau (*MGB*)
- Manila Water Company, Inc. (*MWCI*)
- Maynilad Water Services, Inc. (*MWSI*)
- Metropolitan Waterworks and Sewerage System (*MWSS*)
- Pollution Control Association of the Philippines, Inc. *(PCAPI)*
- Philippine Coast Guard (PCG)

The Environmental Management Bureau Regional Offices

The JICA Philippine Office

The JICA Project Technical Assistance Team

Woodfields Consultants, Inc.

ACRONYMS, ABBREVIATIONS, SYMBOLS AND UNITS

Agencies, Organizations, Offices

BFAR	-	Bureau of Fisheries and Aquatic Resources
CALABARZON	-	Cavite Laguna Batangas Rizal Quezon
CPDO	-	City Planning and Development Office
CENRO	-	Community Environment and Natural Resources Office
DA	-	Department of Agriculture
DA-RFU	-	DA – Regional Field Unit
DENR	-	Department of Environment and Natural Resources
DENR – FMS	-	DENR-Forest Management Service
DILG	-	Department of the Interior and Local Government
DPWH	-	Department of Public Works and Highways
DTI	-	Department of Trade and Industry
EMB	-	Environmental Management Bureau
EMB-RDD	-	EMB - Research and Development Division
EU	-	European Union
IARC	-	International Agency for Research on Cancer
IUPAC	-	International Union of Pure and Applied Chemistry
LLDA	-	Laguna Lake Development Authority
LGU	-	Local Government Unit
LWUA	-	Local Water Utilities Administration
MGB	-	Mines and Geosciences Bureau
MMT	-	Multipartite Monitoring Team
MPDO	-	Municipal Planning and Development Office
NAMRIA	-	National Mapping and Resource Information Authority
NGOs	-	Non-Government Organizations
NIA	-	National Irrigation Administration
NPC	-	National Power Corporation
NPCC	-	National Pollution Control Commission
NSO	-	National Statistics Office
NWRB	-	National Water Resources Board
PCG	-	Philippine Coast Guard
PENRO	-	Provincial Environment and Natural Resources Office
PO	-	People's Organization
PPA	-	Philippine Ports Authority
WHO	-	World Health Organization

Technical, Chemical and Scientific Terms

AAS	-	Atomic Absorption Spectrometry
AVFO	-	Animal-Vegetable Fats and Oil
AVS	-	Acid volatile substance
BS	-	Blind Sample
BTEX	-	Benzene, Toluene, Ethylene, Xylene
CAS No.	-	Chemical Abstract Service Number

CB	-	Cartridge Blank (Filter Blank)
CDO	-	Cease and Desist Order
COC	-	Chain of Custody
CWA	-	Clean Water Act
DAO	-	Department Administrative Order
EB	-	Equipment Blank
ECC	-	Environmental Compliance Certificate
FB	-	Field Blank
FD	-	Field Duplicate
FDF	-	Field Data Form
FQC	-	Field Quality Control
GC	-	Gas Chromatography
GES	-	General Effluent Standards
GIS	-	Geographic Information System
GPS	-	Global Positioning System
HPLC	-	High Pressure Liquid Chromatography
ICP	-	Inductively Coupled Plasma
MDL	-	Method Detection Limit
MPN	-	Most Probable Number
MSDS	-	Material Safety Data Sheet
NAA	-	Non-attainment Area
NOV	-	Notice of Violation
O&M	-	Operation and Maintenance
PD	-	Presidential Decree
PNSDW	-	Philippine National Standards for Drinking Water
PPE	-	Personal Protective Equipment
QA/QC	-	Quality Assurance/Quality Control
RA	-	Republic Act
RPD	-	Relative Percent Difference
RS	-	Replicate Sample
RPSD	-	Relative Percent Standard Deviation
SI	-	System International
SS	-	Split Sample
TB	-	Trip Blank
TAL	-	Tetra Alkyl Lead
TML	-	Tetramethyl Lead
WQG	-	Water Quality Guidelines
WQM	-	Water Quality Monitoring

Symbols

As	-	Arsenic
B	-	Boron
Ba	-	Barium
BOD	-	Biochemical Oxygen Demand
P	-	Calcium
Cd	-	Cadmium

CdS	-	Cadmium sulfide
Cl	-	Chloride
CN	-	Cyanide
Cr	-	Chromium
Cr^{+6}	-	Hexavalent Chromium
Cu	-	Copper or Cuprum
$CuSO_4$	-	Copper sulfate
DDT	-	Dichloro Difluoro Trichloroethane
DO	-	Dissolved Oxygen
F	-	Fluoride
Fe	-	Ferrous or Iron
FC	-	Fecal Coliform
HCl	-	Hydrochloric Acid
Hg	-	Mercury
MBAS	-	Methylene Blue Alkyl Substances
Mn	-	Manganese
NaCl	-	Sodium Chloride (common table salt)
NH_3	-	Ammonia
NH_3-N	-	Ammonia Nitrogen
Ni	-	Nickel
N-NO_3	-	Nitrogen-Nitrate
O&G	-	Oil and Grease
PAH	-	Polyaromatic Hydrocarbon
Pb	-	Lead (Plumbum)
PCB	-	Polychlorinated Biphenyl
pH	-	Potential of Hydrogen
PO_4	-	Phosphate
SO_4	-	Sulfate
TCE	-	Trichloroethylene
TDS	-	Total Dissolved Solids
TSS	-	Total Suspended Solids
Zn	-	Zinc

Units

cm, cm^2, cm^3	-	centimeter, square centimeter, cubic centimeter
^oC	-	degree Centigrade
^oF	-	degree Fahrenheit
ft, ft^2, ft^3	-	foot, square foot, cubic foot
g	-	gram
g/L	-	gram per liter
gal	-	gallon
ha	-	hectare
hm^2	-	square hectometer
in, in^2, in^3	-	inch, square inch, cubic inch
kg	-	kilogram
km, km^2	-	kilometer, square kilometer

L	-	liter
m, m^2, m^3	-	meter, square meter, cubic meter
µg	-	microgram
µg/L	-	microgram per liter
µL	-	microliter
µm	-	micrometer
mi	-	mile
mg	-	milligram
mg/L	-	milligram per liter
mL	-	milliliter
mm	-	millimeter
n mile	-	Nautical mile
oz	-	ounce
ppb	-	parts per billion
ppm	-	parts per million
ppt, $^0/_{00}$	-	parts per thousand
qt	-	quart
t	-	ton
yd, yd^2	-	yard, square yard

CONVERSION TABLE

LENGTH		
SI/Metric	**Conversion**	**English**
1 km	1,000 m	0.62 mi 0.54 n mile
1 m	100 cm	39.4 in 3.28 ft 1.09 yd
1 cm	100 mm	0.394 in
1 mm	1000 µm	0.0394 in 39.4 mils
1 µm	0.001 mm	0.0000394 in 0.0394 mil

AREA		
SI	**Metric**	**English**
1 ha	10,000 m^2, 1 hm^2	2.47 acres
	1 m^2	1.196 yd^2 10.764 ft^2
	1 cm^2	0.155 in^2

VOLUME		
SI	**Metric**	**English**
1000 L	1 m^3	35.315 ft^3
1 L	0.001 m^3 1000 cm^3	0.264 gal 1.06 qt
1 mL	1 cm^3	0.06 in^3

WEIGHT			
SI/Metric	**Conversion**	**Comparable Water Volume**	**English**
1 t	1,000 kg	1 m^3	2,205 lb
1 kg	1,000 g	1 L	2.205 lb
1 g	1000 mg	1 mL or cm^3	0.035 oz
1 mg	1000 µg	1 µL	--

CONCENTRATION	
1 g/L	1 ppt , $^0/_{00}$
1 mg/L	1ppm
1 µg/L	1ppb

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ATTACHMENTS

ANNEXES

CHAPTER I
INTRODUCTION

This Manual on Ambient Water Quality Monitoring was developed to guide users in monitoring the quality of the country's rivers and streams; lakes, ponds and similar water bodies; and marine waters (coastal and offshore waters).

Water quality monitoring, as used in this manual, refers mainly to the sampling of water and subsequent measurement of the primary and secondary water quality parameters described in the ambient water quality guidelines. Sampling methods for biological and aquatic biota monitoring have been included to guide individuals or groups who may be interested in undertaking such monitoring for specific purposes.

The manual is divided into ten chapters, as follows:

CHAPTER I – INTRODUCTION

This chapter explains the purpose, coverage and limitations of the manual.

Chapter II - BASICS OF WATER QUALITY MONITORING

This chapter contains basic information about water quality monitoring. It defines water quality, explains why it is measured and briefly discusses the different purposes of water quality monitoring. The physical and chemical properties, sources, fate and transport into the environment, and impacts on health and on the environment of the significant water quality parameters are included in Annex A.

Chapter III –WATER QUALITY MONITORING PLAN

This chapter is a guide to designing a water quality monitoring plan. It explains the importance of a well-prepared monitoring plan and the components of the plan. A monitoring plan outline has been included for reference.

Chapter IV - SAMPLING AND FIELD TEST METHODS AND TOOLS

This chapter provides an overview of alternative methods and tools that may be used in water sampling, flow measurements and field analysis. It describes the suitability and limitations of each method and tool.

Chapter V – QUALITY ASSURANCE AND QUALITY CONTROL

This chapter explains the importance of quality assurance and quality control (QA/QC) in water quality monitoring and describes the various QA/QC indicators and their applicability. It also highlights the importance of qualification and training of personnel involved in water quality monitoring.

Chapter VI – AMBIENT WATER QUALITY SAMPLING

This chapter enumerates the step by step procedure in ambient water quality sampling, from the preparatory activities, establishment of monitoring stations, identification of suitable sampling points, actual sampling, in-situ measurement of selected parameters, labeling of samples for laboratory analysis, filling out of Field Data Form (FDF) and Chain of Custody (COC) form, photo documentation and sample preservation, storage and transport.

Chapter VII – SAMPLE PRESERVATION, STORAGE AND TRANSPORT

This chapter explains the procedures for proper preservation, transport and storage of water samples to be brought to the laboratory for analysis. The QA/QC protocols that must be observed during sample preservation, transport and storage were highlighted to ensure the integrity of samples brought to the laboratory.

Chapter VIII – FLOW MEASUREMENT

This chapter explains the flow measurement procedures for two common methods of measurement of river and stream flows.

CHAPTER IX – DATA STORAGE, TREATMENT AND INTERPRETATION

This chapter explains the importance of proper data management. It provides suggestions on how to present water quality data through tables and graphs. It also provides suggestions on how to interpret various water quality data.

CHAPTER X – REPORT PREPARATION

This chapter discusses the contents of a water quality monitoring report. It explains the data or information that should be included in the report and how the information should be presented for different reader groups.

CHAPTER II
BASICS OF WATER QUALITY MONITORING

2.1 Water Quality

RA 9275 or the Philippine Clean Water Act (CWA) of 2004 defines water quality as "the characteristics of water which define its use in terms of physical, chemical, biological, bacteriological or radiological characteristics by which the acceptability of water is evaluated."

This definition implies that there is no singular measure of good water quality. While it can be agreed generally that water of good quality should be clear and free from harmful substances, presence of certain concentrations of such substances is acceptable provided those are within the water quality guideline values corresponding to the beneficial uses of the water.

Clean and pure water containing almost no chemical, bacteriological and radiological constituents is desirable for water intended for drinking and food preparation but it is not really necessary or even advisable to have the same water quality for other uses.

Different uses of water require different water quality. For instance, sufficient concentration of nitrogen, phosphorous and other micronutrients is good for irrigation water but the same concentration of such chemicals is not good for drinking water. To put it simply, a water body that sustains its beneficial uses has good water quality. A water body that does not sustain its beneficial uses has poor water quality.

Measurement of water quality provides important information about the integrity of a body of water. The most widely used method is the measurement of its physical, chemical and bacteriological constituents. The quality of water is measured or monitored to determine if it is meeting the prescribed water quality for its intended uses.

Among others, water quality monitoring results are used as basis for policy or management decisions concerning a water body and its uses.

2.2 Objectives of Ambient Water Quality Monitoring

In the Philippines, most ambient water quality monitoring activities are undertaken for such purposes as:

(1) *Classification of a water body.* The water quality is monitored quarterly for a period of one year. Among other factors, e.g., existing use and social acceptability, the result of analyses are taken into account in deciding the appropriate classification of a water body or section of a water body.

(2) *Trend Monitoring to check if a water body is meeting its designated use.* The water quality is monitored at regular frequency to check if the water body is meeting the guideline values for its classification. The results are used as basis for decision-making, e.g., whether to institute management interventions to improve water quality, or to reclassify a water body, etc.

(3) *Designation of Non-Attainment Areas.* A water body or portions of a water body may be identified as NAA for parameters whose guideline values are not being met. This is based on: (a) ten monthly sampling in a period of one year within the last two years, or (b) quarterly sampling within the last two years (except for parameters requiring more frequent sampling based on the DENR water quality guidelines).

(4) *Monitoring for ECC compliance.* If required in the ECC, the quality of a water body is monitored to ensure that a project or undertaking within or near a water body is not affecting the water quality.

(5) *Monitoring to identify causes and sources of water-related problems.* In cases of occurrence of water-related problems, e.g., disease epidemic, fish kills, red tide, etc., water quality monitoring is undertaken to identify specific problem pollutants and sources, and used as basis for identification of intervention and management strategies.

(6) *Monitoring for baseline data and scientific studies.* Specific water quality parameters are analyzed for specified period of time to serve as baseline data or for certain studies.

(7) *Monitoring for Other Purposes.* Monitoring for purposes other than those mentioned above.

2.3 Water Quality for Specific Uses

The country's rivers, streams, lakes, groundwater, coastal and offshore waters are classified by the EMB according to their beneficial uses. Simply defined, beneficial uses are the ways in which water is used by humans

and other living things[1]; drinking water and habitat of aquatic organisms are two examples. The government regulates water quality by classifying water bodies according to their beneficial uses, designating the ambient water quality guideline values for each class of water body and by setting limits to the concentration of pollutants in effluent or wastewater that can be discharged into the water bodies.

The beneficial uses and guideline values for the different classes of waters in the country are specified in the Revised Water Quality Guidelines (revision of DAO 34, series of 1990).

Generally, waters in the higher classification level have more stringent water quality guideline values than waters in the lower classification level. Thus, effluent to be discharged into waters of higher classification level usually has stricter effluent standards than effluent to be discharged into waters of lower classification level.

2.4. Significance of Water Quality Parameters

Water quality parameters are the physical, chemical and biological properties of water by which its quality is measured.

Physical characteristics of water include depth, flow velocity, flow rate, temperature, color, turbidity and transparency or visibility. Measurements of these parameters are particularly useful in analyzing if the waters could support habitat requirements for fish and other aquatic wildlife.

Chemical properties include nutrient composition, pH, and chemicals that affect the chemistry of water. Water contains countless chemicals, thus water quality studies focus only on the chemicals that are most important considering the objectives of the study.

Changes in water's chemical properties can be caused both by land and water activities, either natural or man-made. In waters affected by agricultural runoff, chemicals of concern could include those found in manure, fertilizers, and pesticides. In waters affected by industrial discharges, measurements may be limited to the chemicals used or by-products of the nearby industries.

[1] The CWA defines "beneficial use" as the use of the environment or any element or segment thereof conducive to public or private welfare, safety and health; and shall include, but not be limited to the use of water for domestic, municipal, irrigation, power generation, fisheries, livestock raising, industrial, recreational and other purposes.

The biological properties of an aquatic system consist of organisms and their life functions. Organisms found in aquatic environments include microscopic organisms like bacteria, viruses and protozoa; or creatures such as algae, vertebrates and invertebrates. Photosynthesis, decomposition, respiration and metabolism of organisms in water affect BOD, DO and nutrient levels.

More detailed discussions on the primary and secondary water quality parameters specified in the water quality guidelines can be found in Annex A of this manual.

2.5 Water Quality Monitoring Activities

Careful planning and coordination is critical to a successful sampling program. Activities are planned depending on the type of assessment required. Some activities may be extensive and involve multimedia parameters and indicators, while others may involve only a few parameters. Whatever the objective and methodology, ambient water quality monitoring would always proceed according to the steps shown in Figure 2.1.

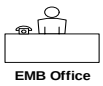
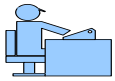
Step	Activity		Responsibility
1	Preparation of a monitoring plan to ensure that all the requirements for monitoring are met.	 EMB Office	Head of monitoring team
2	Collection of water samples from rivers or streams; lakes, ponds or similar water bodies; or marine waters (coastal and offshore)	 Sampling	Field personnel/ sampling team
3	Field tests and measurements; e.g., pH, temperature, dissolved oxygen, flow measurements; sample preservation	 Field testing	Field personnel/ sampling team
4	Record field observations, on-site test results and field activities on the field book, field data form and COC form	 Recording Field Observations	Field personnel/ sampling team
5	Pre-treatment, preservation, storage and transport of samples to the laboratory	 Packing and Transport	Field personnel/ sampling team
6	Analysis of samples in the laboratory	 Laboratory Testing	Laboratory personnel
7	Data processing, interpretation, analysis and storage	 Documentation	Encoder/head of monitoring team
8	Preparation of report	 Reporting	Head of monitoring team

Figure 2.1 Steps in Water Quality Monitoring

CHAPTER III
WATER QUALITY MONITORING PLAN

3.1 Introduction

A monitoring plan is a report that describes how the water body will be monitored and how the water quality will be measured. A well-designed monitoring plan will help ensure that the procedures for water sampling and other activities will conform to the objectives of monitoring.

Plans are designed according to the objectives of monitoring and take into account such factors as time, budget, equipment, manpower, and implementation constraints. As water quality monitoring entails time and resources, the activities should be properly planned to optimize the use of resources.

This chapter guides through the preparation of a monitoring plan. A sample is provided in **Attachment 3.1** for reference.

3.2 Components of a Monitoring Plan

A monitoring plan typically includes the following components:

- Background Information
- Objectives of Monitoring
- Monitoring Stations
- Water Quality Parameters for Measurement
- Timing and Frequency of Monitoring
- Water Quality Sampling and Test Methods
- Quality Assurance and Quality Control Procedures
- Budget for the Monitoring Activity

3.3 Background Information

The monitoring plan should contain background information on the water body to be monitored, a brief account of past monitoring programs, if any, or the rationale behind the monitoring activities.

The following steps may be used as guide in obtaining background information on the water body to be monitored.

3.3.1 Preliminary Surveys

If the water body will be monitored for the first time, it is advisable to conduct preliminary survey of the watershed area to get the latest picture of the existing conditions. If monitoring stations have been established in earlier surveys, it is not necessary to include preliminary survey in the monitoring plan unless there is intention to establish a different monitoring station.

Preliminary survey will facilitate identification of appropriate sampling sites and sampling methods. It will help the monitoring team gain an understanding of the type and nature of the water body, the spatial and temporal variability within the water body, its existing beneficial uses and factors that can possibly affect water quality.

A preliminary assessment form for assessment of a site's suitability for monitoring is shown in **Attachment 3.2**. All preliminary assessment forms and recommendations should be kept on file.

3.3.1.1 Secondary Data Collection and Analysis

(1) Look for possible sources of useful information about the water body to be monitored. Try to find at least one detailed map or an aerial photograph of the area where the water body is located. Copy it or make a simplified outline that can be filled with other information during the field survey.

The following references are particularly useful:

- Topographic maps with municipal boundaries, provincial maps, land use maps, aerial photos, vegetation cover maps, water resources maps and soil maps.

  Topographic maps can be obtained from NAMRIA. Other maps may be available in the local CPDO or MPDO.

  Topographic maps with scale of 1:25,000 are preferable but if not available, 1:50,000 scale maps may be used. (In case the latter is used, it is advisable to use a GPS to confirm boundaries on site).

  [Note: Some websites such as Google Earth, Google Map allow free access to satellite images of a place and can be very useful in assessing the general ecological conditions, in determining land uses, in delineating the boundaries of water bodies and even in identifying benchmarks.]

- Bathymetric map of lakes and marine areas

- Reports or studies containing description of the water body
- Land use plans and zoning plans of the LGUs where the water body is located
- Reports containing water quality information, if available

(2) Review the existing information. Collect data that are deemed relevant, including:

- For rivers: The river system (name of main stream and tributary streams) boundaries, drainage area and river length. Check the topography, land use, vegetation cover, location of major pollution sources, point of discharge or the receiving bay or coast. If available, other information such as occurrence of deltas, sand bars, general nature of the stretch, slope, width, depth, discharge, water quality and other relevant information like important flora and fauna would be useful.

- For lakes and similar water bodies: Identify the location, type of lake or water body, surface area, depth and existing uses. Check the topography, land use, vegetation cover, important fauna and location of major pollution sources within the basin.

- For bays and coastal areas: Identify the administrative boundaries of coastal areas, existing uses and conditions.

(3) Initial analysis and familiarization

The team who will undertake monitoring must familiarize themselves with the water body to be monitored. Familiarization with the physical conditions of the monitoring site will make planning and execution of surveys easier. Initial analysis and familiarization with the secondary data available will enable identification of information gaps that may later be filled in during the primary data collection.

(4) Mapping

Plot or indicate key information on a topographic map or prepare a thematic map indicating the following:

- The river system consisting of the main river and the tributaries, or the lake basin or the bay area
- Administrative boundary of the river system or water body

- Major point sources of pollution, e.g., factories, solid waste dumpsites or landfill sites, drain pipes, poultry, piggery, cattle farms.
- Non-point sources of pollution, e.g., residential clusters, farm lands, grazing areas, barren land, erosion area
- Intake point of drinking water supply or irrigation water supply
- Diversion dams, floodways or man-made channels

3.3.1.2 Coordination with LGUs and Concerned Agencies

Coordinate with the LGUs and other concerned agencies before the conduct of field surveys.

- LGUs could provide valuable information on the water body to be monitored.
- Alternatively, the PENROs and/or CENROs of the DENR could be tapped for assistance in the field surveys

3.3.1.3 Field Survey

Field surveys should be planned in advance to give time for necessary arrangements.

- Establish local contact. If not one member of the team is familiar with the survey area it is necessary to establish local contact or point person in advance. The best contact person may be a local or a tribal leader, NGO or PO volunteer, PENRO/CENRO or any person respected or recognized by the local communities in the survey area.

- Verify weather forecast. For safety reasons, fieldwork during rainy periods should be avoided.

- Prepare the timetable. Make a realistic estimate of the days needed to complete the fieldwork, providing reasonable allowance for possible delays. If it is impossible to completely cover the entire area at one time, the activity may be phased as necessary.

- Ensure provisions for logistics.

- Prepare materials and equipment. Before going on fieldwork, be sure that the necessary materials and equipment have been prepared. These include: maps of the project area, tracing paper or transparencies (acetate or plastic paper used for book cover

can be used for overlays), Manila paper, marking pen, pen, compass, time piece, GPS and altimeter, record book, safety aid kits, etc. Table 6.2 in Chapter 6 is a checklist that may be used to verify if all the necessary preparatory activities, materials, equipment and supplies for the field work are available.

The field survey aims to confirm the initial findings of the secondary data review through any combination of the following methods: (1) visual survey (observation), (2) participatory mapping, and (3) interview survey. The choice of method is discretionary and can be decided upon during the planning stage.

(1) Visual Survey

Visual survey may be done by transect walk. The transect walk will:

- Confirm the information initially plotted on the topographic map or thematic map produced in 3.3.1.1.
- Confirm the different actual uses and conditions of the water body and basin area
- Enable designation of monitoring stations.

The use of survey checklist can facilitate the visual survey. A sample visual stream survey checklist is shown in **Attachment 3.3**. This survey checklist may be revised as deemed necessary.

(2) Participatory mapping

Participatory mapping may be undertaken in place of transect walk or to substantiate transect walk for purposes of confirming the actual uses and conditions of the water body and surrounding areas. It makes use of indigenous knowledge of local communities.

Using the thematic map produced in Sec. 3.3.1.1, a group of local residents or indigenous cultural communities may be asked to help confirm and identify the boundaries of different uses of water bodies, and the biophysical conditions in the designated areas.

(3) Interview survey

Group interview is recommended because it is expected to yield reasonably dependable results, is easier and faster to conduct, and the data are easier to manage and analyze.

Key informants should be chosen carefully. Key informants are persons with special or ample knowledge of the area and local situations that

influence the water uses, and the biophysical conditions in the study area. Usually, key informants are: local community officials, tribal leaders, leaders of community organizations, elders, model citizens, teachers or community achievers. A good mix of key informants is expected to yield reasonably accurate results.

Guide questions for purposes of confirming water usage, corresponding boundaries of water body for different uses, and issues related to water quality can be found in **Attachment 3.4**. The guide questions may be modified, as the survey team may deem necessary for better results.

> The monitoring program must be adapted to its objectives and not the other way around.

3.4 Objectives of Monitoring

A water quality monitoring program should have clear objectives. The objectives would be the basis for deciding the parameters to measure, the number of samples, the frequency of sampling, the type of container, preservation method, sampling techniques and analytical methods to be used. Some of the more common objectives of monitoring in the Philippines are described in Section 2.2.

3.5 Monitoring Stations

3.5.1 Monitoring Stations in Rivers and Streams

In rivers, sampling stations are often identified in terms of distance or number of kilometers the station is upstream from the river mouth. Stationing should start from the mouth going upstream.

Listed below are some suggestions in selecting monitoring stations. It is not imperative to consider all these suggestions for all rivers. Selection of the monitoring station should be based on the objective of monitoring, availability of resources, site accessibility and educated judgment as to whether a site can represent the water quality and biological diversity of the river or stream or segment thereof.

Refer to the illustration in **Figure 3.1** (p. 3-8). The numbers in the illustration correspond to the numbers in the suggestions below.

(1) Points immediately before the inflow of river or stream into a marine water body

(2) Points along the main river; (a) downstream of confluence and (b) upstream of the confluence with tributaries or drainage channels that may greatly affect the water quality.

Select areas with the greatest degree of cross-sectional homogeneity. Sites immediately upstream or downstream from the confluence of two streams or rivers should generally be avoided because the flow from two tributaries may not immediately mix and can produce backflow that can upset the depositional flow patterns.

(3) Points in the tributaries or drainage channel immediately before the confluence with the main or a major river

(4) At areas of public use for water contact recreation (e.g. swimming areas)

(5) Points along the river where there is a marked transition in topography such as where a waterfall occurs; (a) upstream of the waterfall, and (b) downstream at a point where mixing has already occurred

(6) Points immediately before the inflow of the river or stream into a lake, marsh or reservoir

(7) At habitat areas of sensitive species (e.g. spawning areas important to fresh water fishes)

(8) Variability of flow patterns caused by artificial physical structures such as dams, weirs, and wing walls must be considered in sampling site selection. These structures may influence the representative quality of the water. Samples should be taken (a) upstream of the structure and (b) downstream of the structure.

(9) Tributaries should be sampled as near the mouth of the tributary as possible. Care should be exercised to avoid collecting water samples from stratified locations, which are due to differences in density resulting from temperature, dissolved solids, or turbidity.

(10) Where there are suspected point (e.g. wastewater treatment plants) and non-point (e.g. feedlots) pollution sources; (a) upstream of the discharge point and (b) downstream of the discharge point.

(11) Generally for small streams less than 20 feet wide, a sampling site should be selected where the water is well mixed. In such cases, a single grab sample taken at mid-depth at the center of the channel is adequate to represent the entire cross-section.

(12) When several locations along a stream reach are to be sampled, they should be strategically located:

- At intervals based on time-of-water-travel, not distance;
- At the same locations if possible, when the data to be collected will be compared to a previous study;

- Whenever a marked physical change occurs in the stream channel;
- To isolate major discharges, as well as major tributaries

(13) There should be at least three sampling sites for each classified section of the river but more monitoring stations may be established as necessary. If a very long stretch of the river has only one classification, at least three monitoring sites should be established; one each at the downstream, midstream and upstream sections or one monitoring station for every 5 kilometers may be designated. Samples may be taken at any accessible point representing each river section.

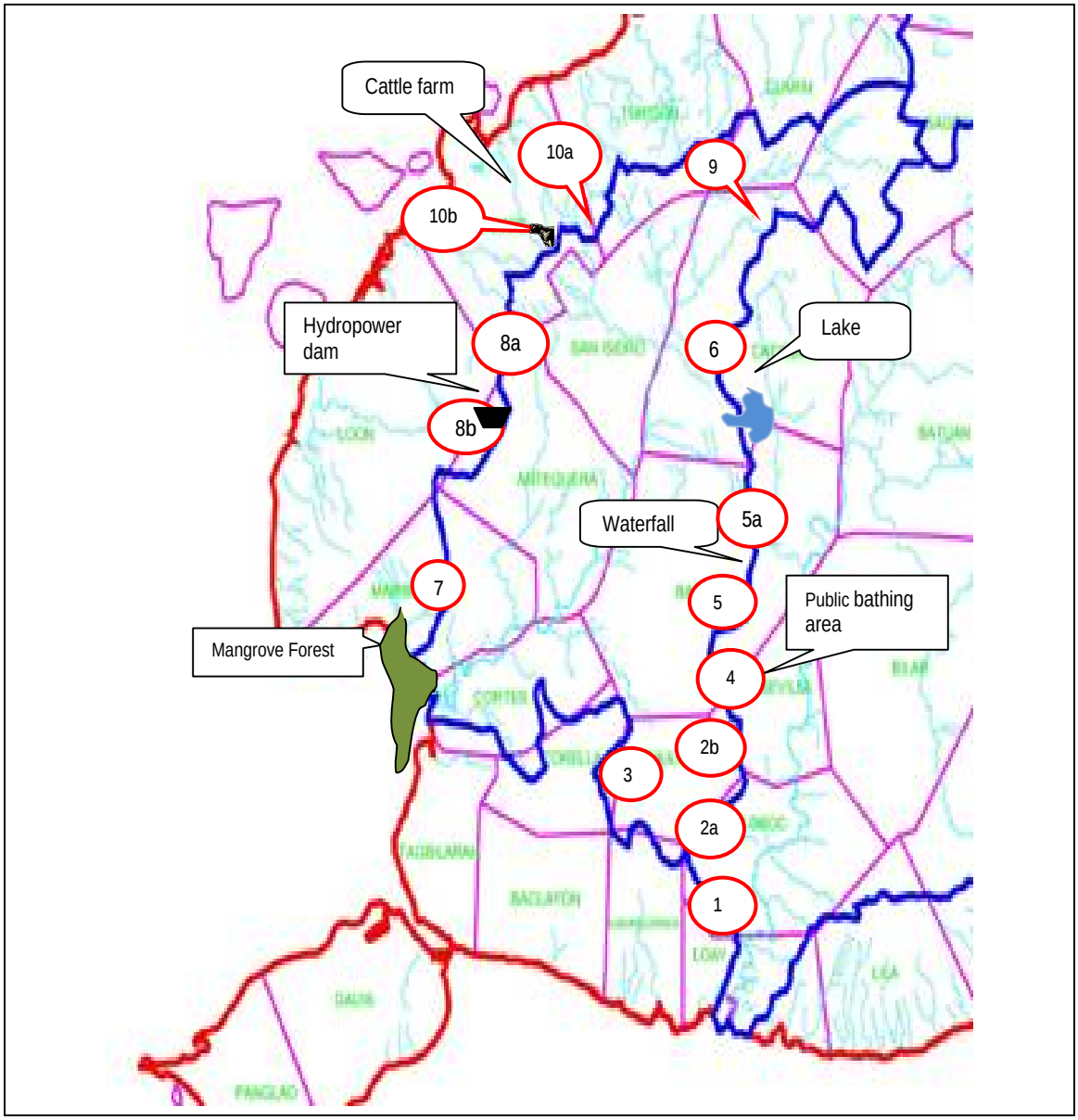


Figure 3.1 Theoretical Sampling Stations in a River

If monitoring stations have already been established by earlier studies or assessment activities, the same stations may be used for future studies if they could meet the objectives of monitoring.

After selecting the monitoring site, indicate its description. General description should include name of water body, location (sitio, barangay, municipality, province), and geographical coordinates (if GPS is used). Specific description (optional) describes how far the location is from the nearest bridge, tributary stream, or landmark. The description may include how far the sampling point is from the shore or bank.

Draw site sketches which show roads, buildings, trees and other landmarks not shown on topographic quadrangles. This will facilitate locating the site in future monitoring activities. Alternatively, take photographs of the selected sampling site, if possible, where there are naturally occurring landmark. The photograph of the exact monitoring location can be superimposed on the topographic or thematic map of the river or stream. Suggested method of photo documentation is discussed in detail in Section 6.6.

The identified monitoring stations should be indicated in a scaled map as a dot (●), a circle (**o**), or an (**x**) and assigned an identification number. This will enable field personnel to easily find the stations and also allow the data to be digitized into a computer database. Refer to Figure 3.2 for an example of selected monitoring stations identified on a scaled map and to Figure 3.3 for the thematic or schematic map of the same monitoring stations.

3.5.2 Sampling Point and Depth in Rivers and Streams

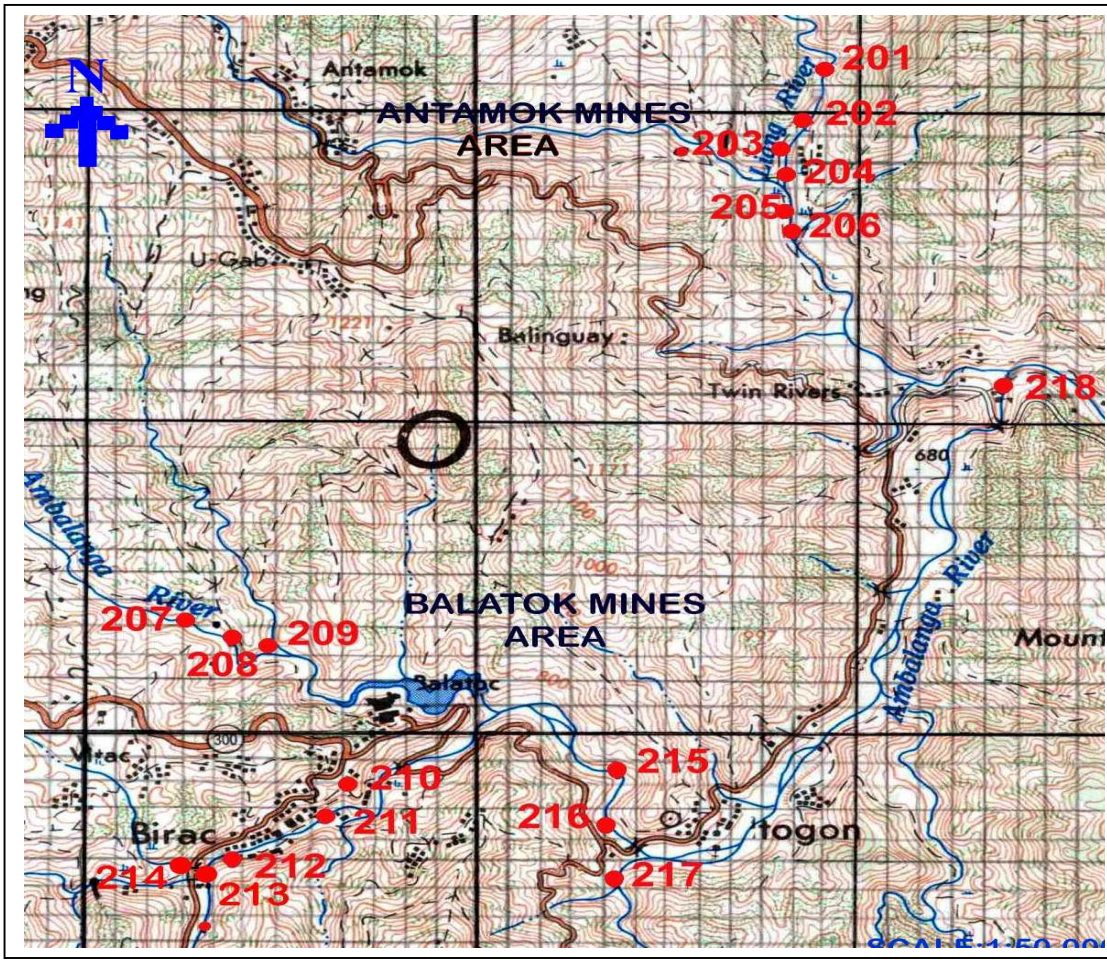
In shallow rivers and streams (<2.5meters) one grab sample collected from the center of the stream can be considered representative of the river or stream water quality.

In deeper waters (>2.5 meters) depth integrated sample can better represent the river or stream water quality.

If it is judged that saline or thermal stratification occurs, a minimum of two samples should be collected, one from the surface and another approximately 0.5 m from the bottom. Water samples may also be collected from the top, middle and bottom of the water column.

Where the river is wide and it is judged that there is a big difference in water quality between the left and right banks, samples can also be taken from the left and right banks, at a point representative of the water quality of the river.

Refrain from taking samples at or near man-made structures (e.g., dams, weirs) as the samples may not provide representative data because of unnatural flow patterns, unless necessary for specific studies.



Liang / Antamok Rivers	Ambalanga River
Sta. 201 – 50 meters upstream from BC-BAGO spillway	Sta. 207 –50 meters upstream from Pink Tunnel
Sta. 202 – BC BAGO spillway	Sta. 208 – Pink Tunnel
Sta. 203 – Filter drain	Sta. 209 – 50 meters downstream from Pink Tunnel
Sta. 204 – 50 meters downstream from Filter drain	Sta. 210 – Effluent from BC-BAGO Diversion Tunnel
Sta. 205 – Colbath tunnel	Sta. 211 – 50 meters downstream from Sta. 212
Sta. 206 – 50 meters downstream from Colbath tunnel	Sta. 212 – Acupan drain tunnel
	Sta. 213 – Camp 6 creek
	Sta. 214 – Surong Creek
	Sta. 215 – Downstream of P-II Dam
	Sta. 216 – Effluent from L-2300
	Sta. 217 – Effluent from L-1300
	Sta. 218 – Mambolo Bridge, Ambalanga River

Source: Mines and Geosciences Bureau (MGB)

Figure 3.2 Selected Monitoring Stations Indicated on a Scaled Map

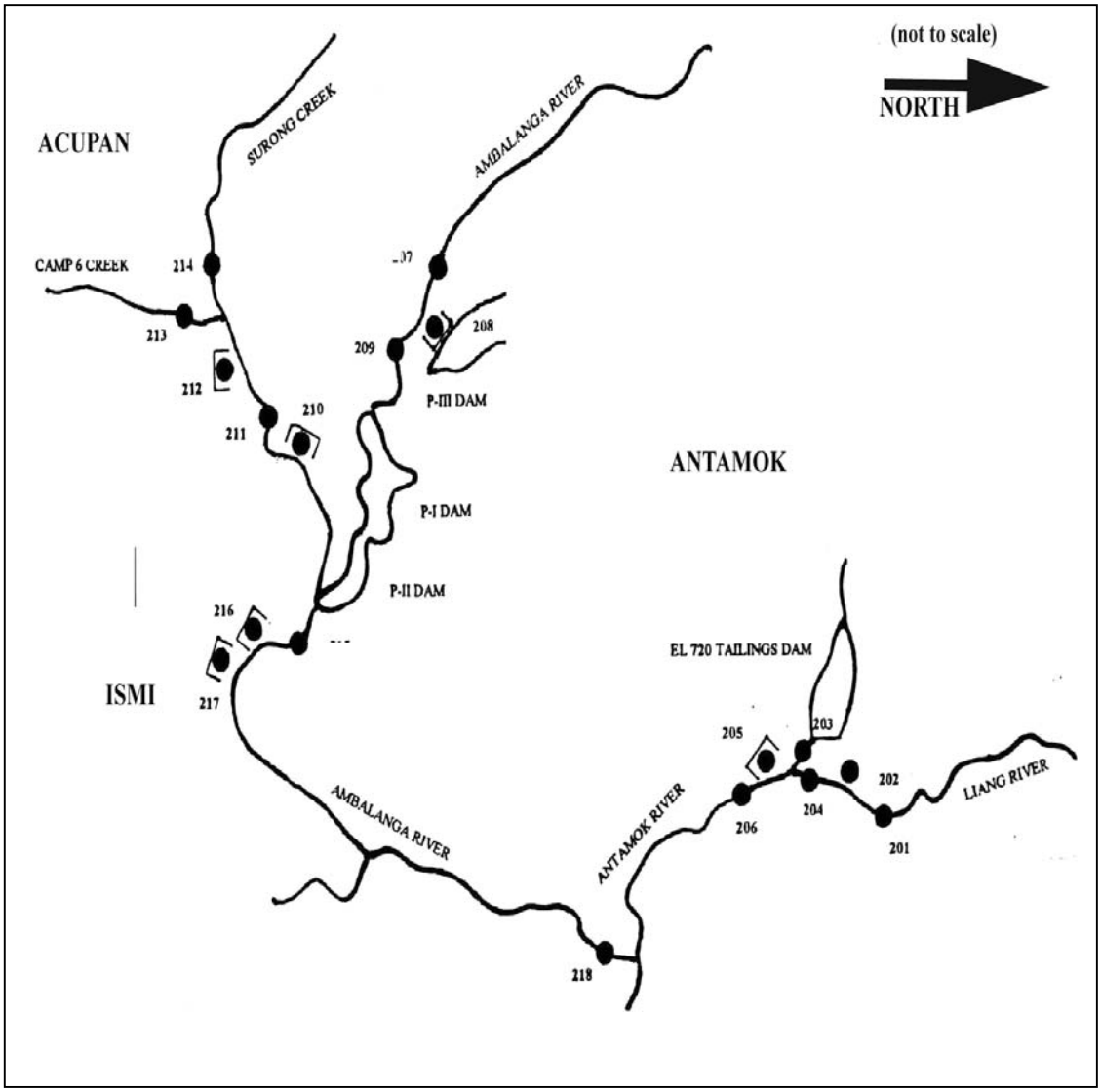


Figure 3.3 Schematic Sketch of the Selected Monitoring Stations

3.5.3 Monitoring Stations in Lakes, Ponds and Similar Water Bodies

The number of monitoring stations on a lake, pond, or impoundment will vary according to the objective of the monitoring and on the size and shape of the reservoir.

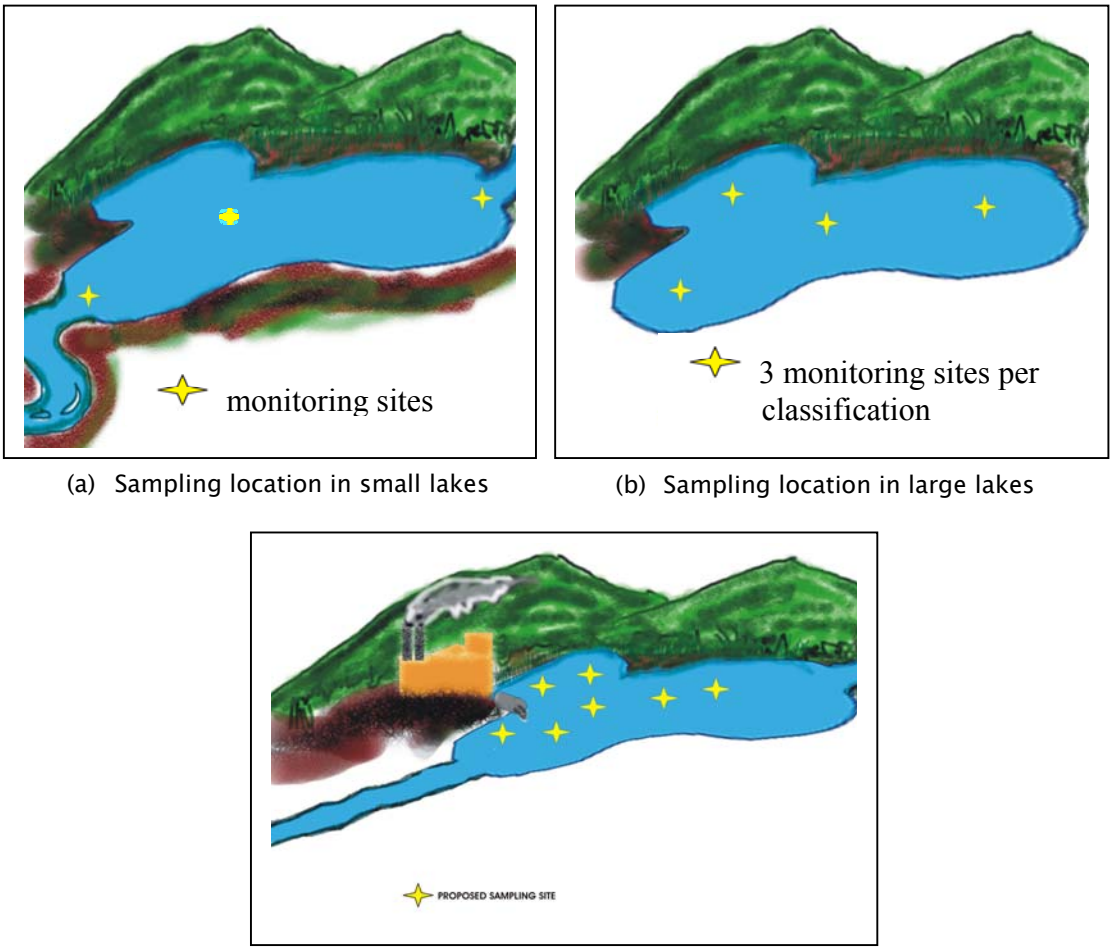
As a general rule, samples should be taken from each section of a lake which can be regarded as homogeneous water mass. Three (3) monitoring stations should be established per lake classification.

In ponds and small impoundments (less than 4m deep) a single vertical composite at the deepest point is usually sufficient to represent the water quality. For lakes with a surface area of less than 30 square kilometers and which have more or less circular or regular configuration three sampling stations to be located at the center would be sufficient. Larger lakes may require more monitoring stations. Each classified section of the lake should have at least three (3) monitoring stations.

For example, five sampling stations were set up by the LLDA within the main lake area of Laguna Lake. The lake has three (3) bays, (West Bay, Central Bay and East Bay) that converge towards the South. Each of the bays and the converging point has a sampling station plus one station was set up near the inflow point from Pasig-Marikina River. In addition, monitoring stations were established at strategic locations along the Pasig- Marikina River which have great influence on water quality and inflows into the lake.

A preliminary survey of the major points of possible discharge of pollutants into the lake and other major natural and anthropogenic factors that might influence lake water quality may be good enough for initial identification of monitoring stations. Study of the collected information should give indications as to the most suitable areas for sampling for specific purposes and checks on one or two points in these areas should demonstrate their value. In selecting stations it should be borne in mind that the time taken and the labor involved in sampling at a lake station is greater than the sampling of a river.

Figure 3.4 is an illustration of theoretical monitoring stations in lakes based on the discussions above.



(a) Sampling location in small lakes

(b) Sampling location in large lakes

(c) Point source impact

Figure 3.4 Theoretical Example of Monitoring Stations in Lakes

3.5.4 Sampling Point and Depth In Lakes, Ponds and Similar Water Bodies

In ponds, small impoundments and small lakes where the depth is less than 4m, a single vertical composite at the deepest point where oxygen deficit is likely to be greatest should be sufficient, unless the salinity profile indicates the presence of a halocine (salinity stratification). In such case, samples should be collected from each stratum.

For depths between 4m and 8m, collect one sample from the surface (between 0.1m to 0.5 m) and one sample approximately 0.5m from the bottom. For much deeper lakes, water samples can be collected at increments of three (3) meters using a Van Dorn (or similar type) horizontal sampler.

3.5.5 Monitoring Stations in Coastal and Offshore Waters

The monitoring sites at beaches should be representative of the complete bathing beach area. For beaches less than one kilometer in length, three monitoring sites per beach may be sufficient. For beaches that are more than one (1) km long more sampling sites may be needed. They would normally be spaced 300 meters apart and fixed permanently for the season.

For regular monitoring, sampling should be done during normal tide conditions so that the sampling site can be more or less fixed. Sampling should be undertaken at the same period of day.

If there are fresh water inflow sources to the coastal areas, monitoring stations should also be established near the outlet of such sources.

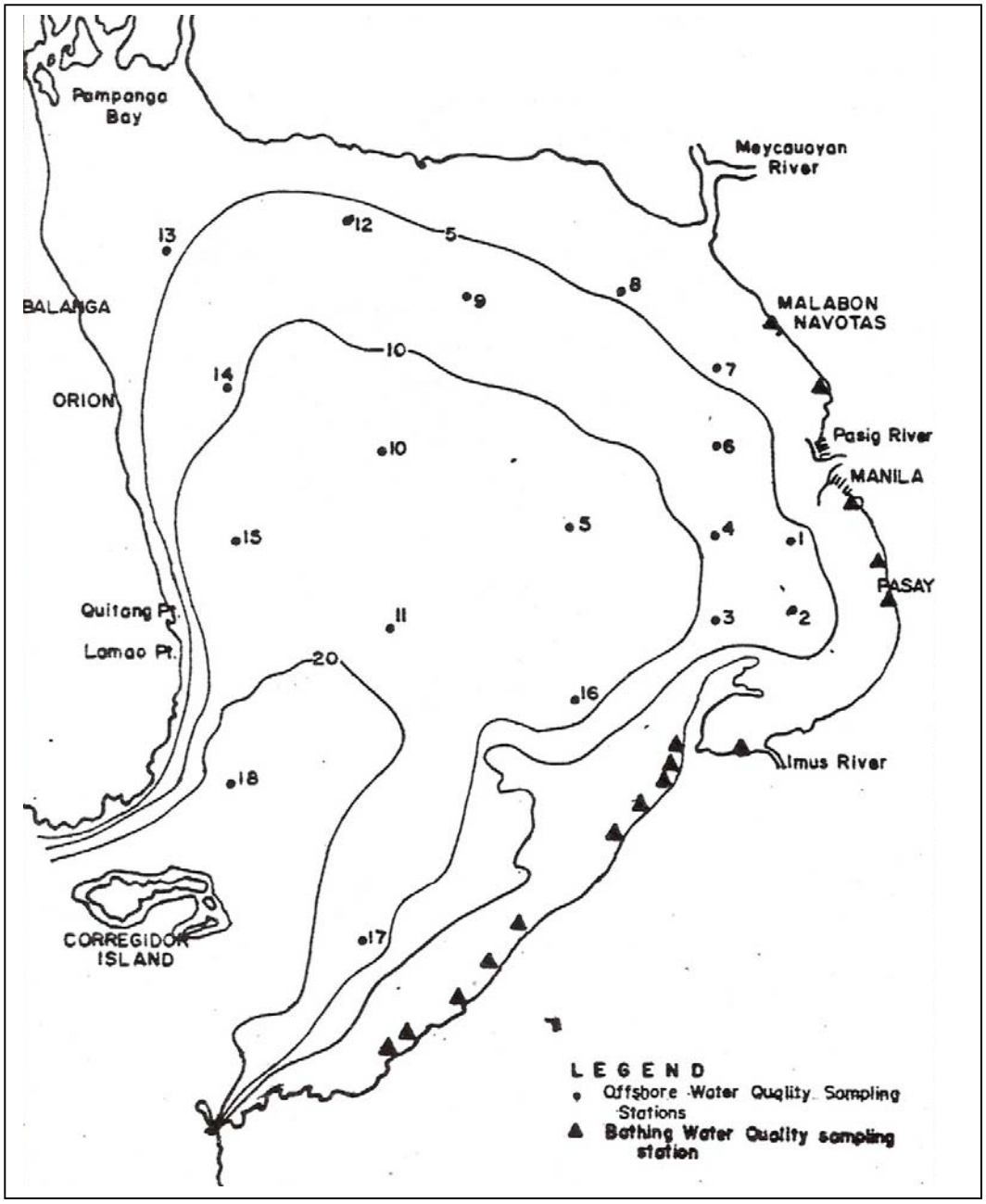
Offshore monitoring stations would normally be established by dead-reckoning (DR) method verified by GPS or by using magnetic compass and radar fixes. Stations should be established such that the different bathymetric profiles are well-represented, i.e., along 5m, 10m, 20m and 30m depths and considering possible sources of pollution, e.g., industries and sewage outfalls.

3.5.6 Sampling Point and Depth in Coastal and Offshore Waters

For regular beach monitoring, samples are usually taken within locations representative of the common bathing areas. Surface grab sampling is appropriate in areas where the depth is less than 4m. Samples for fecal coliform bacteria may be collected just below the surface (0.1-m).

In offshore areas with depth of between 4m to 10m, one sample can be taken at the surface (0.10m-0.50m), one (1) at the middle layer and one at near-bottom depth (0.5-1 m above the seabed). In much deeper areas, samples can be collected at depth increments of 5m using a Kemmerer or Van Dorn sampler.

Figure 3.5 is an example of monitoring stations established for coastal and offshore monitoring. This is a map of the monitoring stations of the Manila Bay Monitoring Program (1986) of the former National Pollution Control Commission (now Environmental Management Bureau). The monitoring stations consisted of 15 sites for bacteriological sampling and beach surveillance and 18 off-shore monitoring stations. Note that in addition to the monitoring stations in the beach areas, bacteriological stations were also established near the river outlets of Pasig, Parañaque and Imus Rivers.



Source: NPCC/Environmental Management Bureau

Figure 3.5 Coastal and Offshore Monitoring Stations of the Manila Bay Monitoring Program, 1986.

3.6 Water Quality Parameters for Measurement

The parameters to be monitored should be specified. Choose the parameters according to the objective of monitoring. For purposes of classification for instance, the classification guidelines recommend minimum test parameters for rivers, lakes and coastal and offshore waters considering the beneficial uses.

The objectives of the monitoring program, the available resources and the budget limitations primarily dictate the parameters that will be monitored. The sampling plan should describe these parameters and the reasons for their selection.

It is not practical to measure all water quality parameters in any one monitoring program. The best approach is to develop a list of parameters that meet the project goals and budget limitations. This may not be easy if there is no existing information on the water body and the types of water quality problems it may have. This is why it is useful to conduct preliminary survey of local water quality problems and possible pollution sources.

For instance, where there is occurrence of algal bloom or fish kills, it is necessary to analyze DO, temperature, nitrates and phosphates. When assessing the impacts of a sewage treatment facility the parameters may include coliform bacteria, ammonia, BOD and heavy metals. If sampling near an oil refinery analysis should include petroleum oil byproducts and metals.

3.7 Timing and Frequency of Monitoring

The plan should describe the intended timing and frequency of monitoring. The frequency of monitoring would depend on the monitoring objective. The timing should consider the effect of temporal variations on water quality.

The sampling plan should describe how often sample will be taken and at what times of the year as water quality changes with the seasons.

Except as needed for special studies, it is not advisable to take samples when it is raining, within 24 hours after a heavy downpour or when the water level is at high stage. In these conditions, the water sample will not be representative.

The recommended parameters, frequency and duration of sampling according to the objective of monitoring are shown in Table 3.1.

Table 3.1 Recommended Parameters, Frequency and Duration of Sampling

Objective of Monitoring		Parameters	Sampling Frequency (Mininum)	Minimum Duration of Monitoring
1	Classification	Primary parameters	Quarterly[1]	1 year
2	Reclassification[2]	Primary	10 monthly sampling in a period of one year	3 consecutive years
		Secondary[3]	Quarterly	3 consecutive years[4]
3	Trend monitoring	Primary	10 monthly sampling in a period of one year	3 consecutive years[5]
		Secondary	Quarterly (every 3 mos.)	3 consecutive years
4	Designation of Non-Attainment Areas (NAA)	All relevant parameters	(a) ten monthly sampling in a period of one year within the last two years, or (b) quarterly sampling within the last two years (except for parameters requiring more frequent sampling based on the DENR water quality guidelines)[6]	1 year for monthly monitoring; 2 years for quarterly monitoring
5	Monitoring for ECC compliance	Selected/ specific to project or site condition; parameters prescribed in the EMoP or ECC	As prescribed in the EMoP or in the ECC	As prescribed in the EMoP or in the ECC
6	Monitoring to identify causes and sources of water-related problems	Selected / specific to situation	High, will depend on impact area and parameter	very short (days-weeks)
7	Monitoring for baseline data and scientific studies	Primary	Once a month for 12 months	1 year
		Secondary [7]	Once a month for 12 months	1 year
8	Other purposes	Selected based on objective	As necessary depending on objective	< 1 year

[1] Minimum of three (3) sampling sites per water body classification.
[2] It is not necessary to undertake separate monitoring if trend monitoring is being conducted. Data from trend monitoring may be used.
[3] Important secondary parameters specific to the water body as identified by the EMB-RO or the agency conducting the monitoring
[4] Data from trend monitoring may be used.
[5] Monitoring may be continued afterward or may be resumed later as necessary.
[6] Data from trend monitoring may be used
[7] Selected parameters specific to the water body as identified by the EMB-RO or monitoring agency

3.8 Water Quality Sampling and Test Methods

Typically, more than one sampling strategy or approach is necessary when several types of contaminant are being monitored, and most sampling plans employ a combination of sampling strategies. Some sampling techniques, methods and procedures are described in Chapter IV.

The intended method of analysis should be indicated in the plan, including the methods for measurement of depth, width, water discharge and water levels, and should always be related to the objectives of monitoring.

Selection of test method should be coordinated with the laboratory as it will depend primarily on available equipment, reagents and apparatus. On the other hand, sampling procedures, containers and preservation techniques should conform to the selected laboratory method. Provided the selected method is recognized by the EMB, it would be acceptable.

For consistency and comparability of results, it is advisable to use the same procedure throughout the study or monitoring period. If it becomes necessary to change the method, the reason should be briefly explained in the report.

3.9 Coordination with the Laboratory

Close coordination with the laboratory is extremely important. Coordination with the laboratory should be undertaken during the preparation of the monitoring plan and before leaving for sampling.

- The laboratory should be informed of the parameters proposed for analysis and the number of samples to be collected so that the laboratory could prepare appropriate containers, reagents, equipment and apparatus to be used in sampling.
- The laboratory should be informed if there is intention to conduct on-site measurements or field testing so that the necessities can be prepared.
- The laboratory should be informed of the estimated time the samples will reach the laboratory.

3.10 Quality Assurance and Quality Control

The QA/QC procedures that will be observed during sampling, transport, handling, preservation and laboratory analysis should be

specified in the plan. The recommended QA/QC procedures are discussed in detail in Chapter V.

3.11 Budget for the Monitoring Activity

It is essential to consider how much will be spent during the course of the monitoring activities. Such allocation should include the cost for equipment (rental, maintenance or purchase), field materials and supplies (i.e. logbooks, personal protective equipment, etc.), transportation and/or fuel allowance, sampling and on-site testing, laboratory supplies and other incidental costs.

CHAPTER IV
SAMPLING AND FIELD TEST METHODS AND TOOLS

4.1 Introduction

This Chapter provides an overview of the different methods and tools available for field sampling and field tests. Each method has advantages and disadvantages. It is important to understand the limitations of each method to help the planner make the right judgment in selecting the method that meets the objectives of the water quality monitoring.

4.2 Types of Sample

There are two types of water sample: grab sample and composite sample.

4.2.1 Grab Sample

A grab sample is a single water sample collected at one time from a single point[1]. A grab sample represents only the composition of the water at the time and place the sample was collected.

Grab sample can be discrete or depth-integrated. A discrete grab sample is taken at specified sampling station, depth and time while a depth-integrated grab sample is collected over a pre-determined part of the entire depth of the water column at specified sampling station and time.

Depth-integrated samples may be obtained either by continuously sampling the total column of water from the surface to just above the sediment, or by discontinuously taking grab samples from representative depths and then mixing them together. The latter is particularly appropriate for deep waters.

However, in order to choose representative depths and to achieve meaningful integration, knowledge of thermal stratification of the water body is necessary.

Grab sampling is suitable when:

- analyzing situations at specific sites (e.g. maximum density of coliform bacteria at a bathing beach).

[1] Philippine National Standards for Drinking Water 2007, DOH-AO No. 2007-0012. The 2007 PNSDW is available in the DOH website: www.doh.gov.ph

- analyzing for unstable parameters that have to be measured right away or on site, e.g., Dissolved Oxygen (DO), temperature, pH, Total Dissolved Solids (TDS), salinity, etc.
- a snapshot of water quality at a particular instant is desired
- the characteristics of the waters are known to be relatively constant over time
- collecting samples to be analyzed for parameters that could be adversely affected by compositing process.

4.2.2 Composite Sample

The Philippine National Standards for Drinking Water (PNSDW) of 2007 defines composite sample as a series of individual grab samples taken at different times from the same sampling point and mixed together. A composite sample may also be a number of grab samples of equal or weighted volumes mixed in one container.

There are different types of composite sample.

(1) *Fixed Volume Composite Sample*. In a fixed volume composite, both the time interval and the size of sample remain constant. This is used when the flow rate of the water does not vary more than 15% of the average flow.

(2) *Time Composite Sample*. This is collected by mixing samples of equal volume collected at regular time interval.

(3) *Flow-Proportioned Composite Sample.* The volume of sample collected is a proportion of the flow volume. A flow-proportioned sample can be collected by keeping the time interval constant and varying the sample volume with the changing water flow.

(4) *Depth-Integrated Composite Sample.* This is collected in pre-determined depths of the water column in equal sample volumes and mixed in one container.

Composite samples are preferred when:

- assessing the total concentration of a substance or pollutant in water (e.g. total phosphorus potentially available for phytoplankton growth) or the population of an organism (e.g. the size of a bacterial population).
- the variables to be assessed are unevenly distributed.

4.3 Sampling Methods

4.3.1 Manual Grab Sampling

Manual sampling is a technique used for collecting grab samples for immediate on-site field analysis. Manual sampling is preferred over the use of automatic equipment over extended periods of time, especially when it is necessary to observe and/or note unusual conditions.

The more commonly used grab sampling methods are described below.

4.3.1.1 Direct Sampling with the Sample Container

Sampling may be done using the sample container which may be a wide-mouthed glass, plastic container, BOD bottle or vial with cover. This sampling method is appropriate when:

- sampling wadable waters
- the water sample will be collected only from the surface
- the sample to be brought to the laboratory does not require filtration

The condition of the water body should be checked first before choosing this method. As a rule of thumb,

> Water is wadable when the water level is below the knee or just slightly above the knee. Furthermore, the water should not show signs of significant pollution from sewage or industrial discharges.

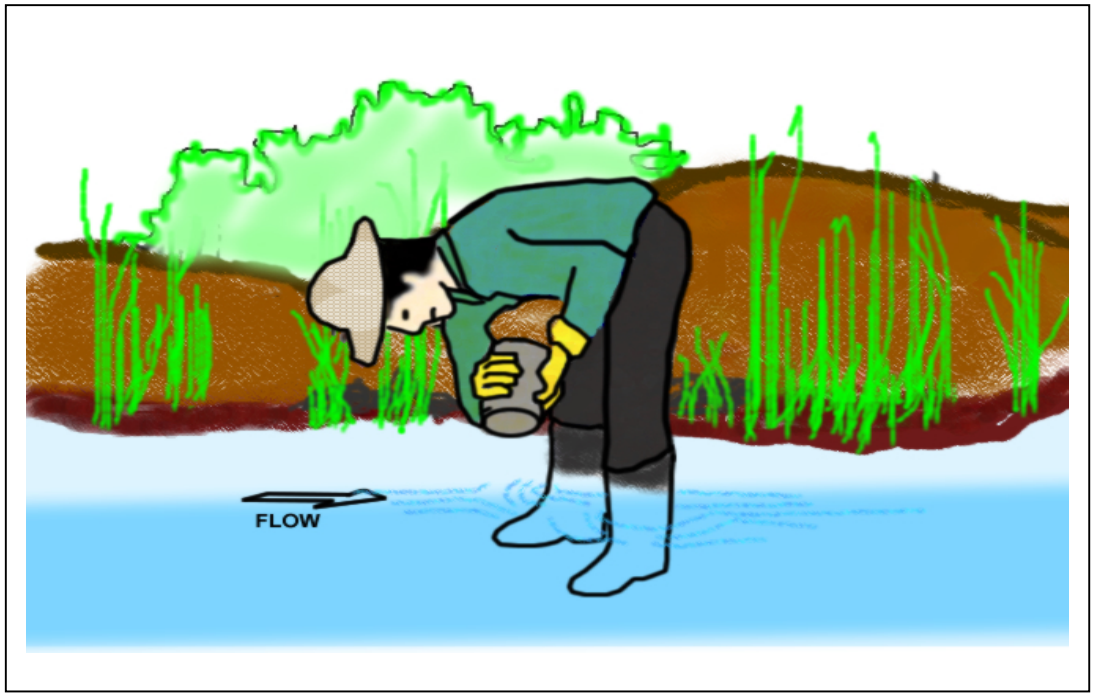
The sampling procedures are as follows. (Please take note of the recommended QA/QC procedures in Chapter 5 and safety measures in Section 6.2.3 during the sampling.)

(1) Put on protective gloves and wading boots.
(2) Wade into the water to the center of the river channel where the water is deepest and current has the greatest velocity. Face upstream and wait until the plume of sediment has been carried away or has settled. See Fig. 4.3.1 (a).
(3) Rinse the container at least three times with the river water, throwing the used water downstream of the sampling location.
(4) Lower the sample container into the water face down. Hold it with one hand on each side to a depth at least 4 inches below the surface or halfway to the bottom of the stream. See Fig. 4.3.1 (b). Do not touch the inner part of the container. If the stream is very

shallow, lower to a depth just above the stream bed but do not touch or disturb the stream bed with the container.

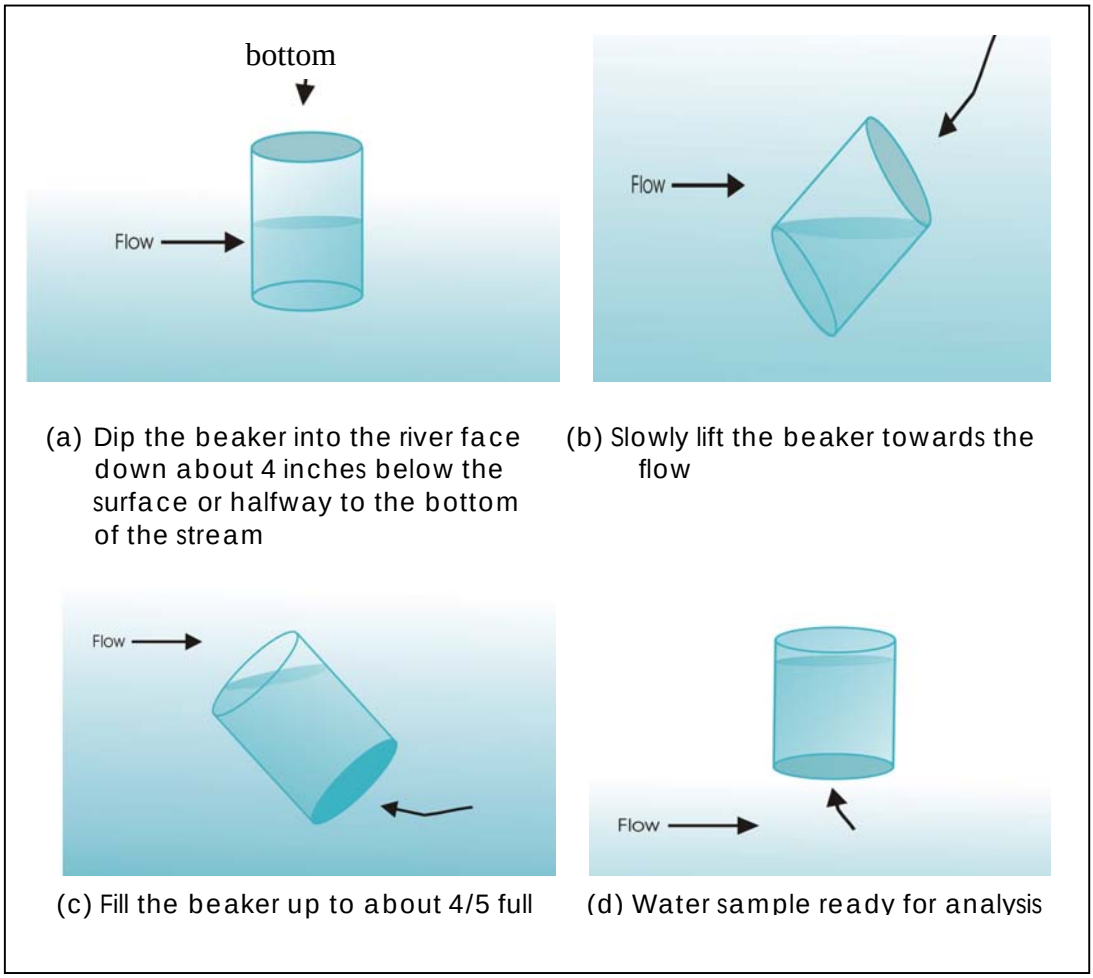
(5) Slowly lift the container towards the flow. Fill it to about 4/5 full. Enough space should be left to allow for addition of preservative, if necessary, and to allow for mixing the sample.

(6) Cap or cover the container and bring the sample to the working area for the succeeding steps.



Source: Adapted from Water Quality and Sampling Procedures, State of Washington

Fig. 4.3.1 (a) Proper Position in Taking Water Sample in Wadable Waters



Source: Adapted from Water Quality and Sampling Procedures, State of Washington

Fig. 4.3.1 (b) The Procedure for Collecting Samples in Wadable Waters

The above sampling procedure does not apply to DO, BOD and bacteriological analysis. The recommended sampling procedures for these parameters are discussed in Section 6.5.2, Section 6.5.4, and Section 6.5.5, respectively.

The recommended samplers for deep waters are described below.

4.3.1.2 Sampling with DO Sampler

A typical DO sampler is shown in Fig. 4.3.2(a). It is a 30cm long metal tube of about 10 cm diameter with a threaded removable cap at one end and sealed at the other. It has a bracket where a 300-ml BOD bottle is placed with the top of the bottle 2 - 3 cm below the top of the sampler. The sampler cap has a tube extending from its underside

down into the BOD bottle when the cap is in place. The upper end of this tube is open and flush with the outside face of the sampler top. A second tube in the sampler cap is flush with the inside face and extends upwards for about 8 - 10 cm. This second tube is sometimes incorporated into the frame to which the lowering rope is fastened.

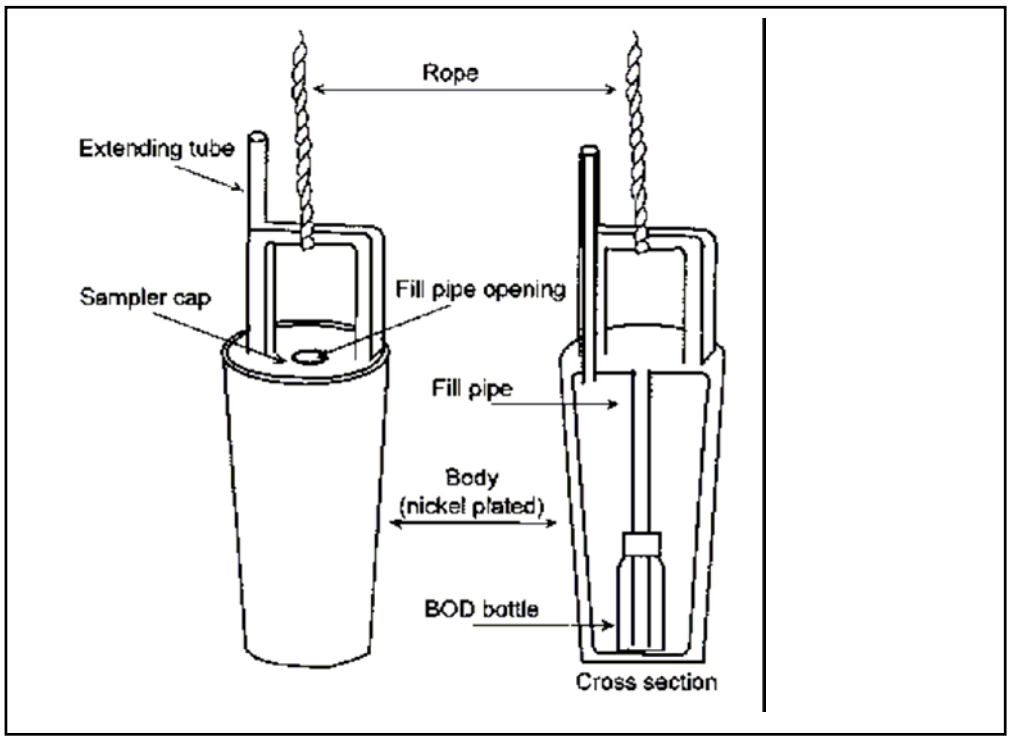


Fig. 4.3.2(a) A DO Sampler

The sampler should be lowered quickly to the desired sampling depth to obtain representative sample. If a sample needs to be taken from deeper areas, inflow can be prevented by putting a cork or similar device, which can be removed when the desired depth is reached. When the sampler is pulled up, the cap is removed and a ground-glass stopper is placed in the neck of the BOD bottle before it is taken out of the sampler.

Another type of DO sampler is shown in Fig. 4.3.2(b). This sampler can be improvised and is used as follows:

(1) Remove the stopper from the gray sampler lid. Lift the wire lid retainer up and away from sampler. Remove the lid with inlet tube attached and slide it up the rope bridle.

(2) Remove the cap of the DO bottle and insert into the inner chamber of the sampler. Place the thermometer in the outer chamber positioning the scale such that it can be read clearly.

(3) Replace the lid of the sampler and insert the inlet tube into the BOD bottle. Snap the wire retainer into the grooves on the lid. Press the plastic stopper into the center inlet hole.

(4) Attach weights to the large snap ring at the bottom of the sampler. Clip the nylon line to the loop at the top of the rope bridle with a snap clamp. The sampler is now ready for use.

(5) To take sample from a bridge, lower the sampler down at the center of the river, stopping just when the brass fastener (between the sampler bridle and the calibrated line) is at the water surface. This allows for collecting water samples 1 meter below the water surface.

(6) Remove the stopper by quickly pulling the line. Allow water to overflow and flush. The water sampler is filled when bubbles will no longer appear. It will take about one minute.

(7) Retrieve the sampler and read the temperature through the clear sampler body. Record the water temperature on the data sheet.

(8) Place the sampler on a flat surface. Release the wire lid retainer and remove the plastic lid with the inlet tube attached, sliding it up the rope bridle.

(9) Remove the BOD bottle from the inner chamber and carefully set aside for the DO test. Remove the thermometer and place in a location that does not receive direct sunlight, to take the air temperature.

(10) The water from the outer sampler chamber may be collected into a sample bottle and used for analysis of parameters other than DO and bacteria.

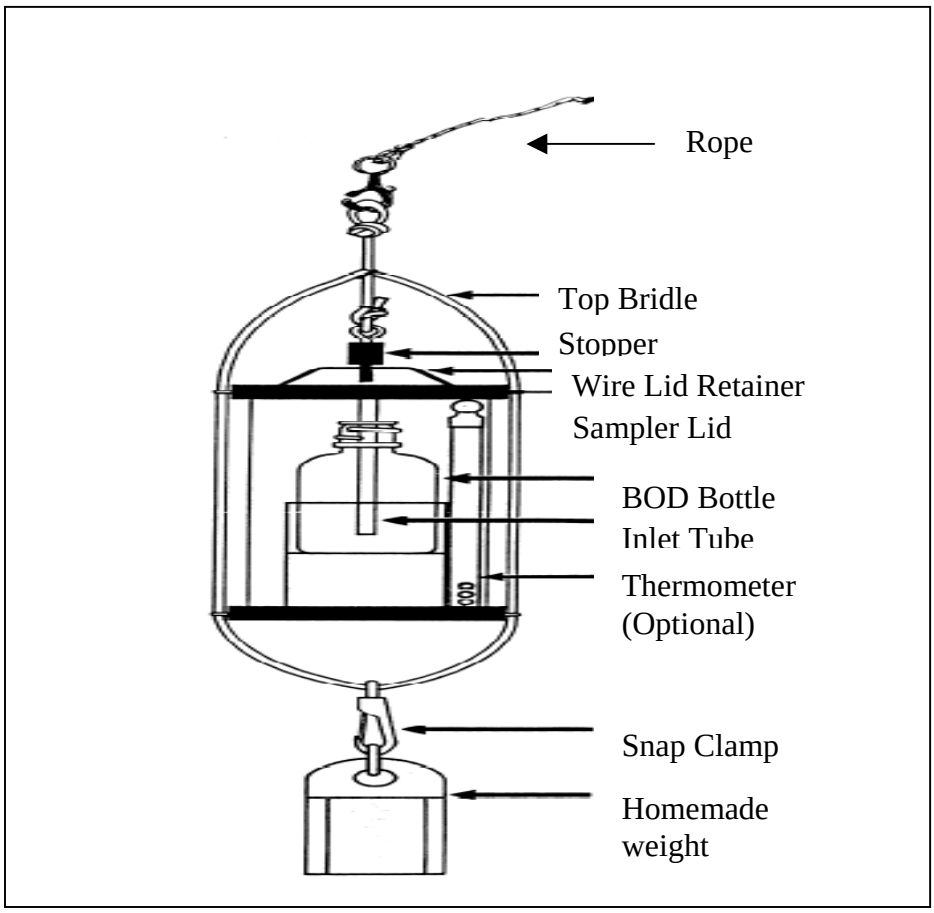


Fig. 4.3.2 (b) Another Type of DO Sampler

4.3.1.3 Sampling with Intermediate Container

It is advisable to use an intermediate container (e.g., bucket, beaker, wide-mouthed bottle) to collect a grab sample if any one of the following conditions exists:

- if the water is too deep for wading
- if the water is significantly polluted and direct contact is not advisable
- if the laboratory provides pre-preserved sample containers

Intermediate devices also prevent unnecessary contamination of the outer surface of the sample bottle, which would otherwise result from direct immersion in the source.

The more common intermediate sampling devices are described below.

(1) Dip/Pond Sampler

With an intermediate device such as the dip/pond sampler, (Fig. 4.3.3) samples can be obtained at distances as far as 3 m (10 ft) from the edge of the source, preventing the sampler from having to contact the source physically.

The intermediate container may be an unpreserved sample container, beaker, bucket, pond sampler or dipper. The construction of this container and any additional equipment required to access the sample location (e.g., extension arms, poles) must be appropriate for the parameter to be analyzed. The decontamination of this equipment must also be appropriate for the parameter to be analyzed and for the make of the equipment. Dippers and pond samplers can be either reused or discarded.

The pond sampler consists of an adjustable clamp attached to the end of a two- or three-piece telescoping aluminum or fiberglass pole that serves as the handle. The clamp is used to secure the container.

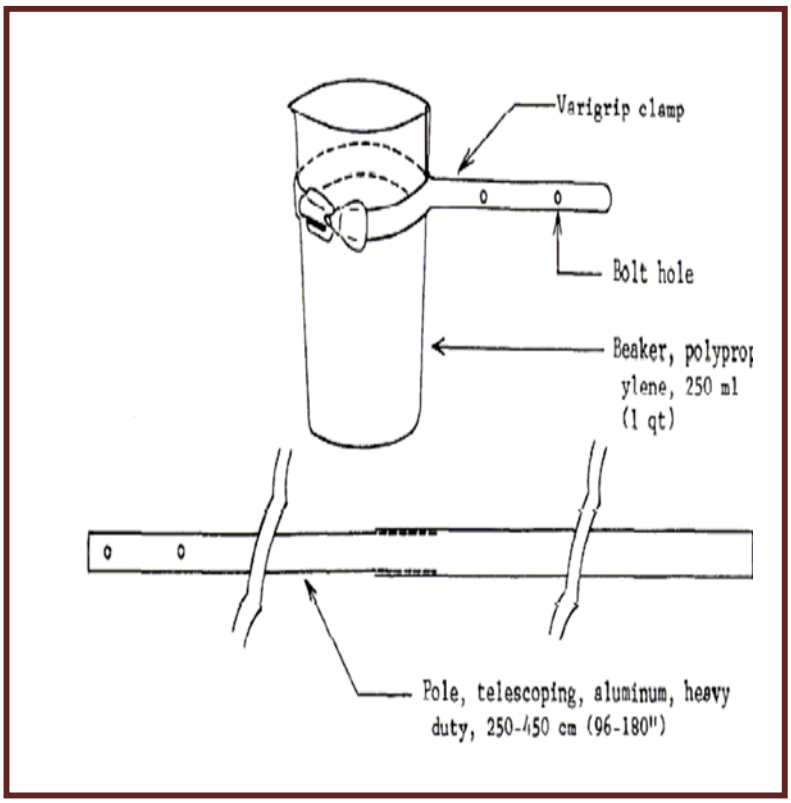


Fig. 4.3.3 A Pond Sampler

The procedures for taking grab samples using a dipper or pond sampler are as follows:

(a) Locate the center of the stream.

(b) Attach the extension arm to the sampler so that the length would be sufficient to reach the sampling site.

(c) Dip the container face down into the water about 4 inches below the surface or halfway to the bottom of the stream.

(d) Slowly lift the container towards the flow and fill it up to about 4/5 full.

(e) Slowly pull the container toward the bank, taking care not to spill the contents.

(f) Transfer the water sample to the pre-preserved sample container then cover. The sample is ready for the succeeding steps.

(2) Kemmerer Sampler

Many of these samplers are constructed of plastic and rubber that preclude their use for all volatile and extractable organic sampling. Some newer devices are constructed of stainless steel or are all Teflon or Teflon-coated, making them acceptable for all water quality parameters without restriction. Horizontal type collection devices are capable of collecting water at discrete depths.

The vertical Kemmerer (Fig. 4.3.4) designs can collect samples from an integrated depth. In the open position, water flows easily through the device. Once the device is lowered to the desired depth, a messenger is dropped down the sample line, tripping the release mechanism and closing the container. In the closed position, the bottle is sealed at the top and bottom, isolating the sample during retrieval.

Follow the procedures below if Kemmerer sampling is selected.

(a) If the water is too deep for wading, check if it is deep enough for a Kemmerer bottle. Lower the Kemmerer into the stream, if it did not touch the bottom when the top is submerged, the Kemmerer can be used.
(b) Lock the Kemmerer sampler open and, while holding the messenger in one hand, lower the sampler from the top of the bridge until the sampler is totally submerged, the top part approximately 4 inches below the water surface.
(c) Release the messenger, sending down the line to close the Kemmerer sampler.

(d) Pull the sampler back up.

(e) Transfer the water sample to a beaker and then to the pre-preserved sampler container. Cover. The sample is now ready for the succeeding steps.

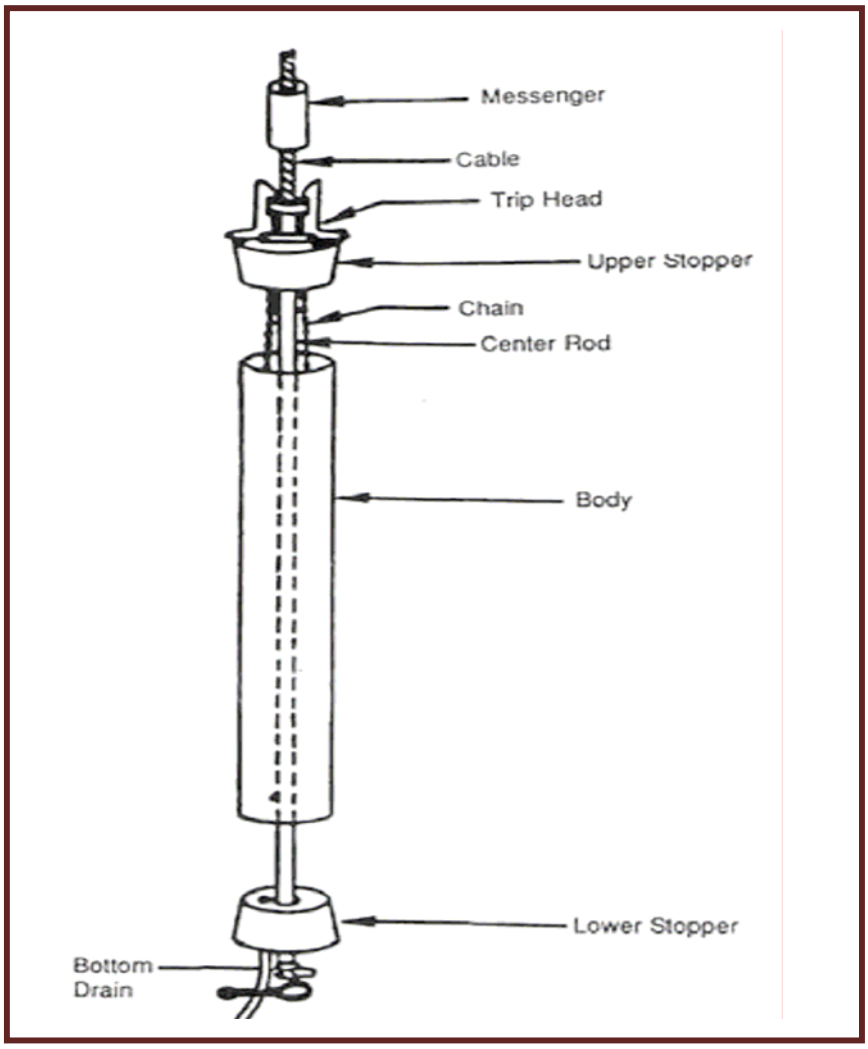


Fig. 4.3.4 A Kemmerer Sampler

(3) Van Dorn sampler

The Van Dorn Sampler (Fig. 4.3.5) is suitable if collecting discrete samples at depths 2.0 m or greater The vertical configuration of the sampler is made of acrylic plastic material so that it can be used for sample removal.

A horizontal configuration of the Van Dorn Bottle, as shown in Figure 4.3.6, should be used when samples are to be taken from the bottom, at the sediment-water interface or when samples are required from a

narrow band of the depth profile. Sampler volume ranges from 2.0 to 16.0 liters.

The procedure for using the Van Dorn is similar to that of the Kemmerer sampler.

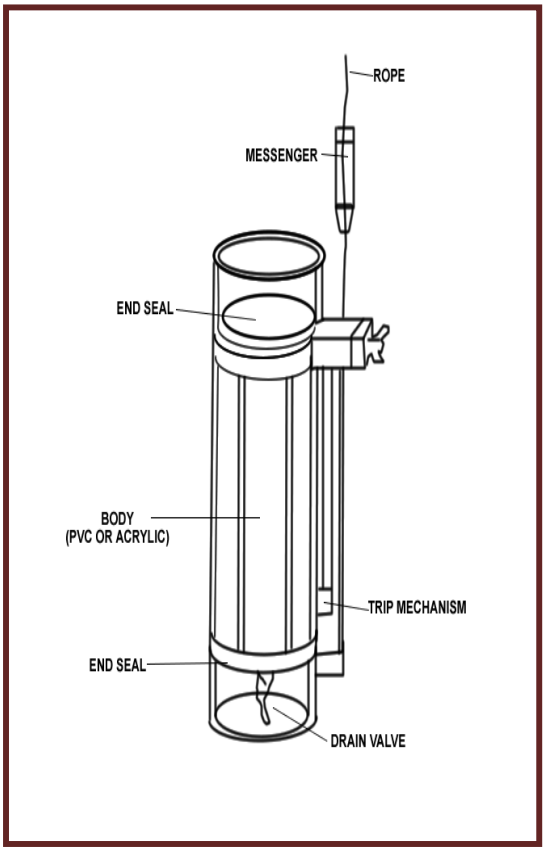


Fig. 4.3.5 A Vertical Van Dorn Sampler

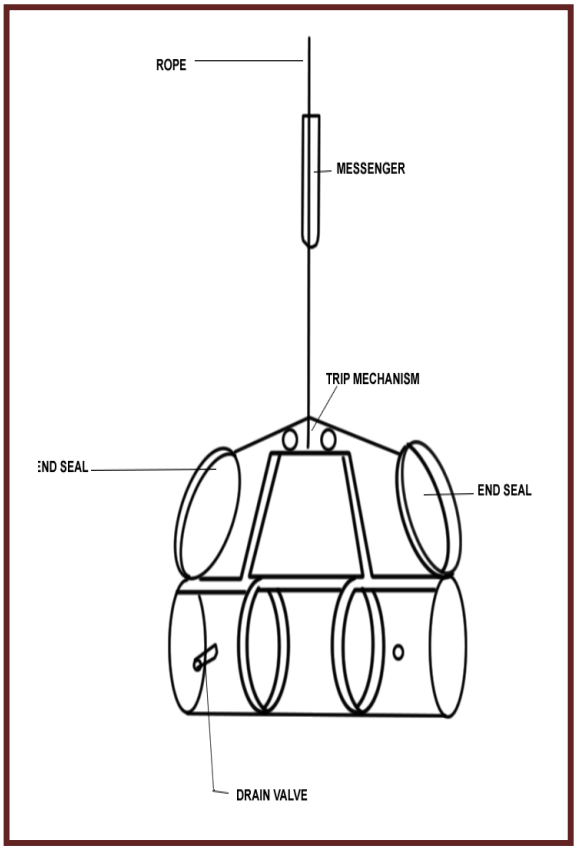


Fig. 4.3.6 A Horizontal Configuration of the Van Dorn Sampler

If a Kemmerer, Van Dorn, etc., sampler is used, slightly shake the sampler before pouring out the sample to make sure that suspended solids are kept in suspension and mixes with the water when transferred

(4) Sampling Iron

The sampling iron or multipurpose sampler (Fig. 4.3.7) is suitable for taking samples in flowing streams or rivers. It is a weighted platform attached to a rudder and equipped with clamps for holding sample bottle. The rudder allows it to maintain position in the flowing water. The platform has rings at the top and bottom where ropes are attached.

One end of the rope is attached at the top ring. A friction release device connected between the rope and the bottom ring holds the bottle in an inverted position when lowered down the river.

If sampling near the surface, the sampler is simply immersed in the water until filled then pulled back up. In deeper areas, the sampler is lowered in an inverted position and then restored to the upright position when the required depth is reached.

The advantage of the sampling iron is that the sample container can be used directly to collect the sample and does not have to be transferred to another container for shipment in the laboratory. However, samples taken with this sampler cannot be used for dissolved oxygen determination.

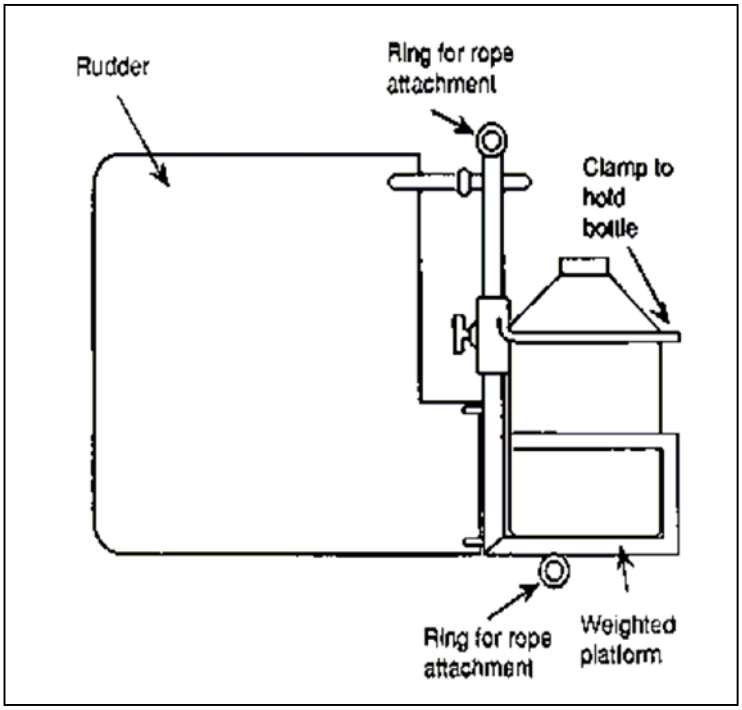


Fig. 4.3.7 A Sampling Iron

(5) Weighted Bottle

The weighted bottle (Fig. 4.3.8) can be used to obtain representative samples from a specific depth. The sampler consists of a glass bottle, a weighted sinker, a bottle stopper, and a line that is used to lower and raise the sampler during sampling. This sampler is more desirable than the Van Dorn in some sampling situations because of its glass construction.

Once the sampler is lowered to the desired sampling depth, the stopper is opened, and the bottle is filled and retrieved to the surface. The weighted bottle closes once the sample is collected.

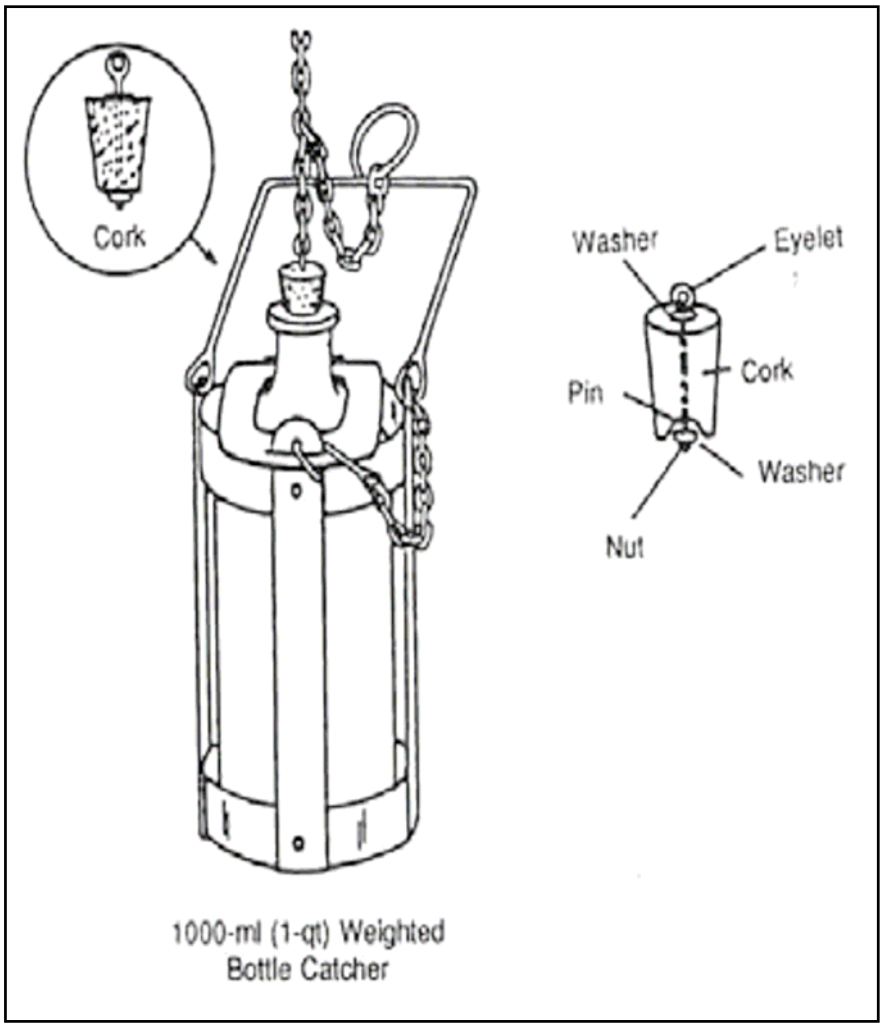


Figure 4.3.8 A Weighted Bottle

4.3.1.4 Sampling with Depth Grab Samplers

Mid-depth samples or samples taken at a specific depth can approximate the conditions throughout the entire water column. Mid-depth samples can be taken using the Kemmerer or Van Dorn samplers. Certain construction material may preclude their use for certain parameters. If volatile or extractable organics are to be collected, all related components (stoppers, etc.) must be constructed of inert material.

4.3.2 Automatic Sampling

An automatic water sampler can automatically sample water at fixed intervals. Its advantage is that it can keep water sample in store for a considerably long time for further analysis. Its drawbacks include the cost and the requirements for maintenance.

An automatic water sampler must be installed at a point in a river, stream or creek which has a potential source of pollution source and thus requires monitoring of the water quality to verify if the source is polluting the water.

4.4 Flow Measurement Methods

Stream flow or discharge is the volume of water that moves over a designated point over a fixed period of time. It is often expressed as cubic meter per second (m^3/s).

The flow of a stream is directly related to the amount of water moving off the watershed into the stream channel.

Stream flow measurement is required in stream quality monitoring for the computation of mass flow or mass balance of the different water quality parameters.

The most common methods of measuring stream flow are briefly discussed below. The use of each method is dependent on the type of field information that can be gathered using available equipment.

4.4.1 Velocity-Area Method

This method involves the measurement of the area of the cross section of a river and the mean velocity of water flowing through it, discharge is the product of the two measurements. The area of the cross section is determined by means of soundings at a number of verticals on a cross section and measurement of distance of these verticals from a reference point on the bank. Velocity is determined using a current meter, shown in Fig. 4.4.1.

If the stream current velocity is high, the meter will not hang vertically below the point of suspension but will be carried downstream by the current. This will result to longer line paid out than the true vertical depth and the meter is higher than indicated. If the angle between the line and the vertical is about 12^o, the error will be about 2%. Wherever possible, bridges are used as the measuring station.

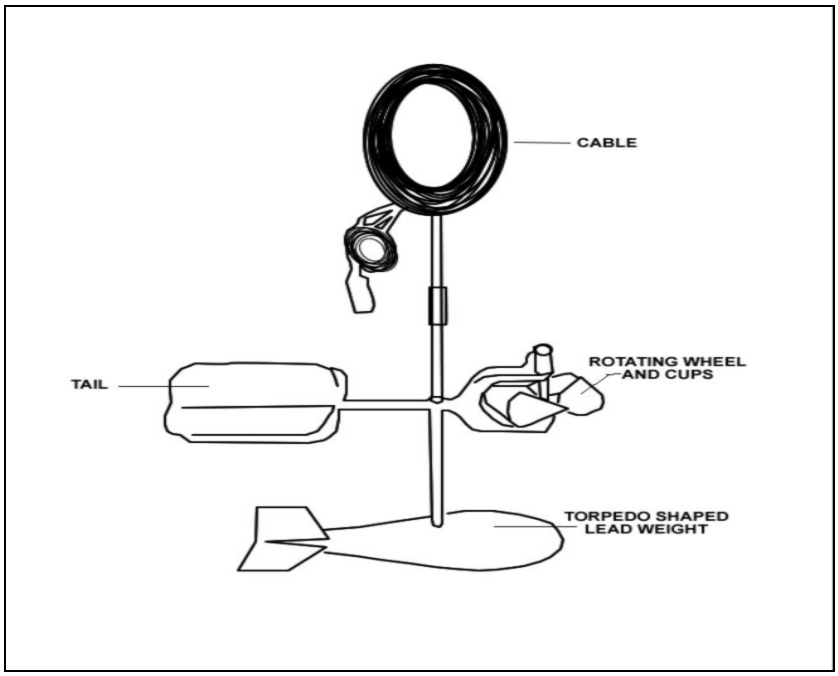


Fig. 4.4.1 A Current Meter

4.4.2 Float Method

One simple method of estimating flow in a specific area or reach of a stream is the float method. It uses a float (any object that floats, e.g., guava, santol, orange, ping-pong ball, pine cone, etc.) to measure stream velocity. Flow is calculated by the equation:

$$\textbf{Flow} = ALC/T$$

Where:

A = Average cross-sectional area of the stream
= stream width multiplied by average water depth

L = Length of the stream reach measured

C = A coefficient or correction factor (0.8 for rocky-bottom streams or 0.9 for muddy-bottom streams). This allows for correction for the fact that water at the surface travels faster than that near the stream bottom due to resistance from gravel, cobble, etc. Multiplying the surface velocity by a correction coefficient decreases the value and gives a better measure of the stream's overall velocity. (0.85 is commonly used if there is uncertainty in the uniformity of stream bottom surface)

T = Time, in seconds, for the float to travel the length of L

The procedures for flow measurement using the above methods are discussed in more detail in Chapter VIII.

4.5 Analytical Methods

4.5.1 Field Test Kits

Field Test kits (Fig. 4.5.1) are easy to use and require very little training or equipment. The methods may vary but most require adding tablets or pre-measured chemical to a 5- to 10-milliliter water sample. The chemical reacts with the water sample, causing it to change color after a short while. The concentration of the chemical being measured is shown by the intensity of the color.

Fig. 4.5.1 A Field Test Kit

Field test kits are useful for educational monitoring and as a quick way to identify gross water quality problems but are not appropriate for studies designed to measure changes in water quality or to check if a water body is meeting water quality guidelines because they are not precise and accurate.

For example, a DO test kit can tell if the DO is below 8 mg/l, but cannot tell if it is 5, 6, or 7 mg/l. It is also difficult to get repeatable results as different people will see different colors depending on their eyesight and the amount of light.

4.5.2 Meters and Probes

Meters and probes, also called “water quality checker” (Fig. 4.5.2) are portable battery-powered instruments with a probe that can be dropped into a stream to get a digital water quality reading. These instruments are relatively easy to use, and are moderately expensive. Once purchased they can be used over and over, and in the long run are cheaper than test kits if measuring a lot of samples. These types of instruments are available for a few water quality parameters, including dissolved oxygen, pH, temperature, salinity and conductivity.

These instruments are accurate if they are calibrated frequently in the laboratory. Calibration is done by checking the meter against a sample with a known concentration of the parameter to be analyzed (this kind of sample is known as a **standard solution**). If the instrument reading is in error, the instrument is adjusted to match the correct value. Calibration should be done using a range of standard solution concentrations, to ensure that the instrument reads both low and high concentrations correctly.

Fig. 4.5.2 Meters and probes

A big advantage of meters and probes is that they can be used directly in the water body, thus avoiding errors that occur when samples are handled. For instance, when collecting DO sample, care must be taken not to trap extra air bubbles in the sample bottle. The main drawback is that good field instruments are not available for most chemical parameters, including coliform bacteria, nitrates, phosphates, metals, pesticides, herbicides, solvents, and petroleum by- products. In scientific studies these must be measured in the laboratory.

4.5.3 Laboratory Methods

There are many laboratory methods, but the one thing they all have in common is the requirement for specialized training and equipment. Laboratory analysis is needed when the water quality parameters being studied cannot be measured with field instruments, and when high level of accuracy is required.

A few methods such as titration for dissolved oxygen can be done in a simple laboratory. However, measurement of metals and toxic chemicals require special procedures (e.g., AAS, GC, ICP, HPLC), which are expensive and available only in specialized private, government, and university laboratories.

For the field personnel, the important thing to know about these methods is how the sample should be handled. Laboratory methods all have very specific ways in which the sample must be treated. Many require that the sample be put on ice and analyzed within a few hours. Some require that a chemical fixative be added to the sample immediately after it is collected. Others need special sampling bottles

made from a specific type of material. In all cases it is important to avoid contamination. Laboratories usually supply clean sample bottles, and will tell the field personnel how to handle the samples.

For DENR-sanctioned monitoring activities, cooperating laboratories must be recognized by the DENR and their methods must conform to the procedures of EMB. If using analytical methods other than those described in the approved laboratory methods, approval of the EMB must first be secured.

CHAPTER V
QUALITY ASSURANCE AND QUALITY CONTROL

5.1 Introduction

This chapter explains the various QA/QC indicators and how they are used in ambient water quality monitoring. It describes quality control procedures that are necessary to develop information which can be used to evaluate the quality of analytical data. QA/QC terms are defined and explanations on why, when and how QA/QC samples are taken or analyzed are provided.

QA/QC procedures should be incorporated into any monitoring activity. If deviation from the procedures becomes necessary as a result of unforeseen field events, then justification for the deviations must be documented in the field book. Alternative or new procedures not covered in this manual or in the EMB-approved laboratory method must be submitted to the EMB and approved before implementation.

The need to observe QA/QC procedures during any sampling activity is emphasized to ensure that samples are neither contaminated nor altered due to improper handling.

5.2 Sources of Error

Water quality monitoring involves a lot of steps and there is potential for error at each of these steps. The major sources of error are measurement error, sample handling error, and natural variability.

Measurement error results because none of the methods (field kits, field instruments, or laboratory analysis) provide perfect water quality measurements. Measurement error can not be eliminated but can be reduced by instrument calibration, proper training, and equipment maintenance.

Another source of measurement error is the method's detection limit**.** As chemical concentration approaches zero accurate measurements are more difficult to obtain. If the concentration can not be detected by the method, it does not mean that the chemical is not present in the water. Most likely the concentration is less than the detection limit. The result should be reported as the detection limit with a less-than symbol (for example, lead concentration is <0.01 mg/L).

Sample handling error could be caused by contamination of the sample during the sampling or due to contaminated equipment or container, or because air is trapped in the sample bottle when it was

closed after sampling. Improper storage and transportation of the sample are other sources of handling error. This kind of error can be minimized by closely following proper handling procedures.

Natural variability is often the biggest source of imprecision. When measuring water quality, only a small part of the water body is being sampled. Different portions of the water body may have different water quality characteristics than what is measured in the sample. Likewise, the water quality would differ according to seasons. Natural variability is a basic feature of any water body and cannot be controlled. The best approach is to minimize variability by taking as many samples as can be afforded and by taking samples on the same time of day and at different seasons.

5.3 Quality Control Methods

5.3.1 Equipment Calibration and Maintenance

All equipment used in the field must be maintained according to the manufacturer's recommendations. Each of the field instruments must be checked and examined before sampling to ensure that the equipment works properly. For some equipment (e.g., DO meters, temperature meters, pH meters) specific preventive maintenance schedule and calibration procedure are required.

Spare parts such as batteries, probes, standard solutions, glassware, etc. should be kept on hand. Spare parts for instruments used each day in the field should be taken along in the vehicle.

Dirty or soiled sampling equipment can contaminate a sample and adversely affect its representatives. *Equipment must be cleaned thoroughly after each sampling day* by washing with a strong, phosphate-free detergent and thoroughly rinsing with tap water followed by rinsing with deionized water and allowed to air dry thoroughly. After drying, the equipment should be placed into sealed plastic bags until needed. (Note: latex gloves should be worn during all phases of equipment cleanup.) Plastic beakers used to collect the samples should be washed daily.

If multiple samples at multiple sites are to be collected with the same piece of sampling equipment during a particular sampling trip, the equipment should be rinsed at each site immediately prior to the collection of the first sample. This is accomplished by first rinsing with water from the same source as the water being collected for the sample. However, care must be taken so as not to disturb the water to be sampled.

5.3.2 Field Data Form and Chain of Custody of Samples

Whenever project personnel collect water sample for analysis, all associated field data and descriptive information must be recorded on the Field Data Form (Refer to **Attachment 5.1**). This form must be completely filled out.

All field and laboratory generated samples and data must be handled in an orderly and consistent manner so as not to compromise their integrity. This procedure is termed sample and/or data chain of custody. Chain of custody (COC) is defined as the unbroken trail of accountability that ensures the physical security of samples, data and records. A COC form is shown in **Attachment 5.2**.

For each set of samples, including duplicate and blank samples submitted to the laboratory for analysis the sample collector must fill out and submit a COC form from the laboratory. The COC must contain information on the project, the station, the date and time when the sample was collected and the parameters for analysis.

Each sample submitted for analysis must have the appropriate label.

Upon receipt of the sample(s) submitted, the laboratory personnel should check the sample labels against the information written on the form. If there are any discrepancies the laboratory should inform the sample collector or the organization's quality assurance representative. The laboratory then assigns a log number to the set of samples and returns a copy of the form to the sample collector or authorized personnel of the monitoring agency. The original copy is kept by the laboratory for their records.

5.3.3 Quality Control Checks

5.3.3.1 Field Quality Control Samples

The test results of quality control samples taken in the field reflect the precision and accuracy of the entire process, from sample collection to analyses. Below is a brief description of field quality control (FQC) samples that should be collected when appropriate.

(1) Equipment Blank (EB)

An Equipment Blank is a type of field blank used to determine if contamination has been introduced through contact with sampling equipment or to verify effectiveness of equipment cleaning procedures.

Laboratory water free of analyte is transported to the site and processed through the sample collection device, preserved if necessary and returned to the laboratory for analysis. Laboratory water should not be stored for future use, a hold time of one week is recommended.

EB should be processed whenever contamination is suspected, with each analytical batch or every 20 samples. Corrective action for contamination detected in equipment blanks is addressed by laboratory users evaluating data.

(2) Field Blank (FB)

A Field Blank is used to determine if interferences are present in the field environment. This would include contamination from sample bottles, storage, transport and sample preparation.

A FB is usually laboratory de-ionized water that is transported to the sampling site, opened to the contaminated environment, and processed as a sample (filtration, preservation, etc.). One FB should be submitted with each analytical batch or every 20 samples or whenever contamination is suspected. Contamination detected in field blanks would need to be evaluated by both field and laboratory personnel.

(3) Filter Blank or Cartridge Blank (CB)

A Cartridge Blank is used to determine if interferences are introduced during the filtration or sampling process. Laboratory water is used to rinse the filter and filtration apparatus. At least one CB should be processed with each sample batch or whenever contamination is suspected.

(4) Trip Blank (TB)

A Trip Blank is routinely used when sampling for volatile organic compounds. Volatile organic compounds are most susceptible to this type of contamination. The laboratory supplies samplers with a VOC vial containing acidified analyte-free water. The vial is transported to the sampling site and returned to the laboratory without being opened. Sample contamination from penetration of the Teflon cap by halogenated solvents during transport or at the site can be detected with a TB. TBs are logged into the data management system and are assigned a sample ID number.

(5) Field Duplicates (FD)

Field Duplicates (duplicate sample, replicate sample) are two separate samples collected at the same time and placed under identical circumstances and treated exactly the same throughout field and laboratory procedures. Results give a measure of the precision associated with sample collection, preservation and storage as well as with laboratory procedures. Field duplicate data provide the best measurement of precision from sample collection through analyses.

FD should be taken on 5% of the sample volume. Duplicates are logged in as individual samples and can arrive at the laboratory as "blind" duplicates if the laboratory user desires.

> A field duplicate should not be confused with a split sample.

(6) Split Samples (SS)

Split samples are aliquots of samples taken from the same sample container after thoroughly mixing or compositing the sample. They are analyzed independently and are used to document intra- or inter-laboratory precision. SS may also be used by program personnel to request matrix spike analysis for tests requiring two separate samples.

(7) Blind Sample (BS)

A Blind Sample is a sample submitted to the lab for analysis, the composition or origin of the sample is known to the submitter but unknown to the analyst. A BS can be a duplicate sample, blank, proficiency sample, or an interlab comparison sample.

Table 5.1 summarizes the application of the different field quality control methods.

Table 5.1 Different Field Quality Control Measures and their Interpretation

Method	Requirement	Acceptance Limit[1]	Corrective Action
Pre-cleaned Equipment Blank (EB)	If contamination is suspected: 1 per sampling trip if equipment is not cleaned in the field, and 1 per quarter per project (For Autosampler, collect 1 EB each time intake tubing is replaced) or 1 every 20 samples	>Method Detection Limit (MDL)	Qualify associated samples up to 5 times the contamination level. Investigate equipment cleaning, analyte-free water and container, sample bottles, environmental conditions, preservatives, shipping, etc.
Field Blank (FB); Filter or Cartridge Blank (CB); Trip Blank (TB)	When contamination is suspected. 1 per sampling trip if no EB is collected or 1 every 20 samples	>MDL	Qualify associated samples up to 5 times the contamination level. Investigate environmental conditions, sample bottles, analyte-free water and container, preservatives, shipping, etc.
Field Duplicate (FD) or Replicate Samples (RS)	Varies per project: at least one per quarter or 1 every 20 samples	< 20 % RPD or RSD*	Qualify affected samples. Investigate collection procedure, sample bottles, equipment cleaning, etc.
Split Samples (SS)	Varies per project: as needed	<20 % RPD or RSD*	Qualify affected samples. Investigate laboratory analyses. Then, evaluate splitting techniques.
*Relative Percent Difference (RPD) is used when comparing two results and Relative Percent Standard Deviation (RSD) is used when comparing three or more results.			

Note: Adapted from www.qasr_sec_03_2005. Water Quality Field Sampling, Quality Assurance Requirement, December 2005.

[1] If the result of laboratory analysis of the sample for the specified Q C method is greater than the MDL, it indicates that contaminant is not present and the test results are acceptable.

5.3.4 Prevention of Sample Contamination

The quality of data generated in a laboratory depends primarily on the integrity of the samples that arrive at the laboratory. Consequently, the field personnel must take the necessary precautions to protect samples from contamination and deterioration.

There are many sources of sample contamination. The following are some basic precautions to be observed:

(1) Field measurements should always be made on site or on a separate sub-sample which is then discarded. They should never be done on the water sample to be submitted to the analytical laboratory.

(2) Sample container, new or used, must be cleaned according to the recommended methods.

(3) Only the recommended type of sample container for each parameter should be used.

(4) Water sample containers should be employed for water samples only. Containers that have been used in the laboratory to store concentrated reagents should never be used as sample containers.

(5) Preservatives should be freshly prepared and dispensed with using clean glassware.

(6) Recommended preservation methods must be followed. When preserving samples, the possibility of adding the wrong preservative to a sample or cross-contamination of the preservative stocks should be minimized by preserving, in one operation, all the samples for a particular parameter.

(7) The inner part of sample containers and caps should not be touched with bare hands, gloves, mitts, etc. Do not put anything in the sample bottle except the water sample and recommended preservatives.

(8) Sample containers must be kept in a clean location, away from dust, dirt, fumes and grime. Vehicle cleanliness is important minimize contamination.

(9) Sample containers which have been sterilized for microbiological sampling must remain sterile until the sample is collected. If the sterile heavy-duty paper or aluminum foil has been lost or if the top seal has been broken, do not use the bottle.

(10) All foreign objects, especially metal objects must be kept out of contact with preservatives and water samples.

(11) Specific conductance should never be measured in sample water that had earlier been used for pH measurements. Potassium chloride diffusing from the pH probe alters the conductivity of the sample.

(12) Samples must never be left to stand in the sun; they should be stored in a cool, dark place; ice chests are recommended. Keep the empty bottles in the coolers for additional cleanliness.

(13) Samples must be submitted to the laboratory as promptly as possible. The sample must reach the laboratory early enough such that the recommended holding time for the parameter to be analyzed is not exceeded, taking into account the necessary preparatory activities prior to laboratory analysis.

(14) All sampling instrument, equipment, containers, supplies and materials to be used in sampling should be packed properly in clean containers before leaving for the site.

5.4 Personnel Qualification and Training

Water quality monitoring activities should always be undertaken under the direction and supervision of persons in authority who have the right educational background, experience and qualification in water quality monitoring.

All personnel involved in data collection and water sampling activities must have the necessary skills to perform their duties and must have demonstrated understanding of the use and calibration of field equipment, sampling procedures, monitoring forms and the various quality assurance and quality control methods, otherwise they can undertake sampling and related activities only in the company, direction and supervision of a qualified officer or supervisor.

Thus, field personnel must be trained on every aspect of water quality monitoring before assigning them to water quality sampling and related activities.

The training must include expectations on ethical behavior and data integrity. An effective training program should include actual field sampling exercises with an experienced sampler. During this training period, under the guidance of the trainer, the trainee should perform all aspects of field activities, including preparations for travel, maintenance of equipment, calibration, sampling, collecting QC samples, and completing the necessary water quality field sampling documentation, under the direction and supervision of experienced staff. Training procedures, training records, and demonstration of capabilities must be documented indicating the specific field task, date

of training, and proper signatures. Qualification should be backed up by certification that the personnel had passed the required training.

CHAPTER VI
AMBIENT WATER QUALITY SAMPLING

6.1 Introduction

This Chapter outlines the procedures for collecting representative samples from surface water bodies. It describes the necessary preparatory activities, the minimum QA/QC requirements for sample and field data collection, and the step by step sampling procedures. The main objective is to ensure that acceptable field methods and QA/QC procedures are followed when performing water quality assessments to ensure integrity and reliability of outcome. While the methods are prescribed, they are not meant to stifle professional judgment as field conditions and a host of other factors may necessitate deviation from the monitoring plan or normal practice.

6.2 Preparatory Activities

The head of the monitoring team must ensure that necessary preparations were undertaken before the field work. Each member of the monitoring team should clearly understand his role and his duty to ensure the integrity of all field analyses and of the water samples to be brought to the laboratory for analysis. The following form part of the preparatory activities.

6.2.1 Travel Order and Travel Plan

Whether the monitoring team or personnel belongs to a government or a private institution, the members must secure a travel order and prepare a travel itinerary before embarking on field work.

The travel order would ensure that the activity is recognized by an approving official and each team member is authorized to travel. A travel order will protect the team members in the event an untoward incident happens during the travel period or during the actual sampling activity.

A travel itinerary will give the office an idea of the location of the monitoring team at all times. This will facilitate contacting, communicating with or locating the team in times of need.

Plan the route ahead. If monitoring the water body for the first time, obtain a road map, check for possible routes and select the best route. This can be skipped if at least one member of the team or the driver is familiar with the sampling sites.

6.2.2 Preparation of Sample Containers, Supplies and Materials

6.2.2.1 Types of Sample Container

Normally, clean sample containers for specific parameters to be analyzed can be requested from the laboratory. Sample containers are best provided by the laboratory to ensure that sufficient volume of samples are obtained for the planned analyses and that the containers have been properly cleaned and provided with stabilizing preservatives if necessary. Figure 6.2 below shows the different types of sample containers.

(a) Amber and clear glass jars (b) amber glass jugs (c) wide-mouthed

(d) vials (e) plastic bottles (f) BOD bottles

Figure 6.2 Sample Containers

If laboratory-prepared containers could not be obtained, make sure that the right type, sufficient number and properly cleaned sample containers are ready before leaving for sampling.

- Ensure that there are enough containers to hold all the samples to be collected for the specific parameters to be analyzed and for the required number of analysis per parameter.

- Inspect all containers and covers for cracks and chips and for cleanliness. Do not use containers with visible defects or discoloration.

- Do not use containers that have been used for storage of chemicals or other liquids. All containers must be decontaminated according to recommended procedure.

- The analyses to be performed on the sample dictate the type of sample containers. Plastic containers offer the advantage of being less likely to break than glass but are not appropriate for certain parameters.

- For microbiological analysis, strong, thick-walled, glass sample bottles with a minimum capacity of 120 ml are recommended. The bottles should have screw caps of a type that will maintain an effective seal even after having been autoclaved many times.

Table 6.1 lists the appropriate sample container and the recommended cleaning procedure for specific parameters to be analyzed.

6.2.2.2 Cleaning of Sample Containers

Inadequately or inappropriately cleaned sample container may contaminate the sample, thus great care must be taken in cleaning. Clean the containers (whether glass, plastic or amber), and new ones according to the step-by-step procedures described in Table 6.1.

Table 6.1 Sample Containers for Specific Water Quality Parameters and Recommended Cleaning Procedures

Parameter to be Analyzed	Recommended Container[1]	Cleaning Procedures
1. Organochlorine pesticides, PCBs and organo-phosphates	1,000 ml amber glass with Teflon-lined cap	Rinse three times with tap water, once with chromic acid[2], three times with organic-free water, twice with washing acetone, once with special grade[3] acetone, twice with pesticide grade hexane and dry (uncapped) in a hot air oven at 360^{o}C.
2. Phenols and Phenolic substances	1,000 ml amber glass with teflon-lined cap	Rinse three times with tap water, once with chromic acid[2], three times with organic-free water, twice with washing acetone, once with special grade[3] acetone, twice with pesticide grade hexane

		and dry (uncapped) in a hot air oven at 360^{O}C for at least 1 hour
3. Arsenic, Barium, Cadmium, Hexavalent Chromium, Cobalt, Copper, Iron, Lead, Manganese, Nickel, Zinc	500-1,000 ml Polyethylene (depending upon number of metals to be determined)	Rinse three times with tap water, once with chromic acid[4], three times with tap water, once with 1:1 nitric acid and then three times with distilled water in that order
4. Mercury	100 ml glass	Rinse three times with tap water, once with chromic acid[2], three times with tap water, once with 1:1 nitric acid and then three times with distilled water in that order
5. Acidity, Alkalinity, Calcium, Chloride, Color, Fluoride, pH, Potassium, Sodium, Specific conductance, Sulfate, Turbidity	1,000 ml Polyethylene	Rinse three times with tap water, once with chromic acid[2], three times with tap water, once with 1:1 nitric acid and then three times with distilled water in that order
6. Ammonia Nitrogen, nitrate, nitrite Total Nitrogen	250 ml Polyethylene	Rinse three times with tap water, once with chromic acid[2], three times with tap water, and three times with distilled water, in that order
7. Phosphorus, total	50 ml glass	Rinse three times with tap water, once with chromic acid[2], three times with tap water, and three times with distilled water, in that order
Notes: (1) Teflon containers can also be used to replace either the recommended polyethylene or glass containers (2) Chromic acid - 35 ml saturated $Na_2Cr_2O_7$ per liter reagent grade conc. H_2SO_4 (3) Special grade acetone - pesticide grade when GC analysis to be performed, UV grade for LC analysis (4) Chromic acid should not be used if the sample will be analyzed for chromium		

6.2.2.3 Cleaning of Sampling Equipment

Sampling equipment that has been used at one site must be properly cleaned and decontaminated before use at the next sampling site.

Follow the procedures below to clean the sampling equipment:

(1) Brush with a solution of water and phosphate-free detergent

(2) Rinse well with tap water until free of detergent

(3) Sampling equipment for total solids and pH analyses must be rinsed at least three times with distilled or de-ionized water

(4) Sampling equipment for nitrates and phosphorous analyses must be rinsed with 10% HCl then rinse at least three times with distilled or de-ionized water

(5) Sampling equipment for DO, BOD and bacteria analyses must be rinsed at least three times with distilled or de-ionized water. If distilled or de-ionized water is not available, clean chlorine-free water may be used.

(6) During sampling, rinse several times with the water to be sampled before getting the final sample.

6.2.2.4 Packing Materials and Transport Containers

Prepare sufficient size and quantity of packing materials and transport containers to hold all the samples securely during transport to the laboratory. The following are recommended:

(1) Prepare separate transport containers for bacteriological analysis. Samples for bacteriological analysis must be packed separately from samples for analysis of other parameters.

    It is advisable to pack together all samples for similar analysis in one sample container to prevent cross contamination. For instance, if six (6) samples will be taken for every parameter, pack the sample containers for DO and BOD analysis together, the samples for nitrate analysis together, the samples for metal analysis together, etc.

(2) Transport containers should be made of sturdy materials; should be suited for ice packs; and able to protect sample containers and samples from heat, dust, and breakage during travel. Heavy-duty plastic coolers are durable and would last

longer. Heavy-duty ice chests and ice chests with wooden support are also suitable.

(3) Samples for BOD and bacteriological analyses require rapid cooling and need cold water in addition to ice or ice packs. Thus, the transport container for the samples should be leak-proof.

(4) Bottles containing samples for bacteriological analysis should be placed in clear plastic bags to protect them from external contamination.

(5) The coolers or ice chests should be double lined (a bag within a bag) with unused and untreated heavy weight trash bags. After samples and ice are placed in a doubled bag, seal each bag with a knot or by gathering the top of the bag, folding it over, and securing with filament tape.

(6) Additional packing materials (e.g., foam peanuts) may need to be placed in between sample bottles to avoid breakage during transport. However, care must be taken not to mix the ice and water with the packing materials. Do not mix foam peanuts with ice.

(7) "Blue ice" or other types of commercial, refreezable containers are not recommended. The use of dry ice or other substances that have a freezing point below $0^{O}C$ is also not recommended as this may cause sample containers to freeze and can result in ruined samples and/or broken sample containers.

6.2.2.5 Field Books/Field Data Form/Chain-of-Custody Forms

Prepare a field record book and sufficient number of field data forms (FDF) and chain-of-custody (COC) forms.

The field book should be hard-bound. Do not use loose sheets of paper for recording field observations. Field books should not be discarded but stored for future reference because they represent data in original form and sometimes, later become invaluable.

The FDF is needed to record all field data and descriptive information about the sampling site. The standard FDF of EMB is shown in **Attachment 5.1**. This form should be used and properly filled out for sampling activities done under the auspices of EMB.

The COC is a form that contains information on the project, the station, the date and time when the sample was collected and the analysis requested. It is an unbroken trail of accountability that ensures the physical security of a sample and includes the signatures of those who handled the sample. The standard COC form of EMB is shown in **Attachment 5.2**. This form should be used and properly filled out for all samples taken under the auspices of the EMB.

The same forms may be adopted by other monitoring groups, modified as necessary to suit specific requirements.

6.2.2.6 Checklist of Requirements

The checklist in Table 6.2 may be used to verify if all necessary preparatory works have been undertaken and all materials, equipment and supplies for sampling are available.

Remember to double check if all necessary equipment, materials, supplies and reagents are in the transport vehicle before leaving for field work.

Table 6.2 Checklist for Preparatory Activities, Materials Equipment and Supplies

1. Paperwork
- ___ Travel order and itinerary
- ___ Inventory/survey of sampling stations
- ___ Topographic map and/or thematic map of water body to be monitored indicating monitoring stations and landmarks
- ___ Road map (if monitoring for the first time)
- ___ List of samples required at each sampling station

2. Coordination
- ___ Institutional coordination for travel arrangements, sampling arrangements (e.g., boat hire) and transport of samples (if requiring transport by air or sea)
- ___ Notification to the laboratory on the expected date and time of arrival of samples
- ___ Laboratory has been provided with the list of parameters to be analyzed on site including the list of QA/QC methods based on sampling plan
- ___ Verification of local weather conditions and feasibility of travel

3. For documentation
- ___ Pens (not pencil, not sign pen), clip board
- ___ Sample labels

___ Field notebook
___ FDF, COC, Other forms (e.g., Garber index, survey forms)
___ Camera with film, digital camera or recorder for photo documentation
___ GPS

4. For sampling

___ Sample bottles and covers, preservatives, labels, marker pens, trash bags, wash bottles, field laboratory wares (pipette, beakers, Erlenmeyer flask, etc)
___ Sample containers/transport containers and ice packs
___ Ambient Water Quality Monitoring Manual
___ Filtering apparatus, filter paper (if required)
___ Samplers/sampling equipment inc. extension poles if needed

5. For flow measurements

___ Meter stick (for depth measurements)
___ Current meter/float
___ Flow-measuring bobber/20 meter nylon line or rope
___ Measuring tape
___ Calculator
___ Stop watch
___ Flow record form

6. For Safety

___ First-aid kit
___ Rubber gloves, or disposable vinyl gloves, boots, etc.
___ Material safety data sheet (MSDS)
___ Waterless hand wash or hand wipes
___ Wader/wading boots
___ Raincoat (during rainy season)
___ Life vest (for off-shore sampling)

7. Transportation

___ Vehicle with sufficient capacity for personnel, supplies and equipment
___ Road-worthiness of vehicle. Check battery, lubrication, coolant, windshield washer
___ Sufficient fuel for the trip (either in the tank, fuel container or availability of gasoline stations along the route
___ Availability of spare tire, jack, wheel wrench, early warning device, tool kit and flashlight

8. Double-check

___ Equipment calibration
___ Itinerary against travel details on inventory
___ Accessories for equipment and meters (including cables, chargers and spare batteries) and consumables

6.2.3 Safety Considerations

One of the most important considerations in water quality monitoring is the safety of the field personnel. If possible, field personnel should be trained on safety procedures and should be given safety instructions. Safety precautions can never be overemphasized.

The following are some basic safety rules for the field personnel:

If the surroundings and/or the condition of the waters to be sampled do not look safe, stop the activity and leave the site. Do not risk your life; it is more important than the data!

If preparing for field work, remember to:

- Get at least one partner. Do not travel alone. A team of three or four people is better. It is best if at least one team member has first aid training.
- Obtain an approved travel order and travel itinerary. One copy of the documents should be on file in the office. Bring a copy and leave a copy in the house. Leave also all the members' mobile numbers.
- Do not leave without an ID. Office ID is best. If possible, ID should contain the name and contact number of persons to contact in case of emergency.
- Listen to the weather report. Do not travel if severe weather is predicted.
- Always inform at least one family member of the travel destination, and expected date of return.
- Have a first aid kit handy. Know any important medical conditions of team members (heart conditions or allergic reactions, e.g., to insect bites).
- Wear protective clothing - field shoes, boots, cap, safety goggles, gloves.

In the field:

- Check maps, site descriptions, or directions to ensure that the team is at the proper site.
- Get information from the local folks on the safety and conditions of the water body. Better yet, get assistance of the local folks in getting to the site and during the actual sampling activity. Abort sampling if a storm occurs while at the site.
- If wading must be done in a stream suspected of being significantly polluted, wear waders and rubber gloves.
- Do not attempt to cross streams that are swift and above the knee in depth.
- Never wade in high waters. Do not monitor if the stream is at flood stage unless required for specific studies, in which case, extra precautions must be taken.
- Watch out for dogs, farm animals, wildlife (particularly snakes), and insects such as bees or wasps.
- Never drink the water from the stream or lake or any nearby water body even if it is clear and looks clean. Better bring your own water. Wash hands with antibacterial soap after monitoring.
- Take extra care when walking in the stream. Rocky-bottom streams can be very slippery and may have deep pools; muddy-bottom streams are also dangerous. If one must cross the stream, use a stick as guide and to probe for deep water. One or two or the member(s) should wait at the bank to assist if the other member falls.
- Do not walk on unstable stream banks. Disturbing these banks can accelerate erosion and might prove dangerous if a bank collapses. Disturb streamside vegetation as little as possible.
- If sampling from a bridge, be aware of passing traffic. Never lean over bridge rails unless you are firmly anchored to the ground or the bridge with good hand/foot holds.

When using chemicals:

- Prepare labels and clean equipment before getting started.
- Avoid getting chemical reagents on the skin, eye, nose or mouth. Never use fingers to stopper a sample bottle (e.g., when shaking a solution). Wear safety goggles when performing any chemical test or handling preservatives. Wear masks over nose.
- Study chemical cleanup and disposal procedures. Wipe spills as they occur. Return all unused chemicals to the laboratory for safe disposal. Close all containers tightly after use. Do not switch container caps.

Do not expose chemicals or equipment to extreme temperature or direct sunlight for a long time.

6.3 Water Sampling

6.3.1 Locating the Sampling Site

If not one member of the team has been to the sampling site before, use the topographic map or the thematic map prepared under Section 3.3.1 and/or a road map to locate the sampling station indicated in the sampling plan. Check the thematic map for landmarks (e.g., bridges) or use the GPS to facilitate locating of the sampling site.

6.3.2 Basic Considerations in Sampling

- Remember and follow as far as possible the safety tips in Section 6.2.3
- Always collect samples starting downstream going upstream.
- Take extra care to avoid disturbing sediments in the immediate sampling area.
- Collect the samples in accordance with the sampling plan. Collect the specified number of samples per site from the specified sampling point and depth.

6.4 On-Site Measurements

6.4.1 Measurement of pH

(1) Materials, Reagents and Apparatus

- Water Quality Checker or pH meter and probe
- 2 liter plastic beaker or clean plastic container
- Extra supplies needed for maintenance of probe
- Integrated depth sampler (for deep waters)
- Extension pole (optional)
- Field data sheet to record results

(2) Procedure

(a) Direct Measurement

In wadable waters, pH can be measured by dipping the water quality checker or probe directly into the river.

(Note: If the meter comes with instructions for use, it is better to follow the manufacturer's instructions).

(i) Calibrate the meter following the manufacturer's recommended procedures for field calibration.

(ii) Put on waders or waterproof boots and gloves. Locate the main current of the stream or river.

(iii) With the meter turned on to pH mode, remove the storage cap from the probe. Lower the probe at least 4 inches below the water surface or halfway to the bottom if in a shallow stream. Wait for the meter reading to stabilize then read the measurement.

(iv) Turn the meter off. Rinse the probe/electrode with distilled water, and put back the storage cap.

Figure 6.4.1 Direct measurement of Temperature, pH and Dissolved Oxygen in wadable waters using meter and probe (water quality checker)

Source: EMB-Caraga Region

(b) In Non-wadable waters

If the probe cannot be lowered into the stream or river or lake, depending on the situation, water sample can be collected using the sample container, a dip sampler or integrated depth sampler.

(i) Collect the water samples in accordance with the recommended procedures in Section 4.3.1.1 for sampling directly with the sample container or in Section 4.3.1.2 for sampling with intermediate container.
(Note: Take note of the suitability and limitation of each sampling method in selecting the method to use)
(ii) Transfer sufficient volume of sample into a wide-mouthed sample container or beaker.
(iii) With the meter/probe turned on, remove the storage cap from the probe. Dip the meter/probe in the sample.
(iv) Wait for the meter reading to stabilize then read the measurement.
(v) Record and then turn the meter off. Rinse the probe/electrode with distilled water and replace the storage cap.

6.4.2 Measurement of Dissolved Oxygen

(1) Materials, Reagents and Apparatus

<u>If Using a Water Quality Checker or DO Meter and Probe</u>

- Water Quality Checker or DO meter and probe
- Operating manual for the water quality checker or the meter and probe
- Extra membranes and electrolyte solution for the probe
- Extra batteries for the meter
- Extension pole
- Field data form to record results

<u>If Using the Modified Winkler Method</u>

- Labels for sample bottles
- Field kit and instructions for DO testing (if using test kits)
- DO sampler or home-made sampler to collect deep-water samples
- 300 mL capacity BOD incubation bottles with tapered ground glass pointed stoppers and flared mouths (1 for each site)
- Pipettes with elongated tips capable of transferring 2.0 mL of reagent.

- Manganous sulfate solution
- Alkaline potassium iodine-azide solution
- Concentrated sulfuric acid, 1:1
- 0.025 N sodium thiosulfate standard titrant
- Titrator or buret
- FDF to record results
- 200 mL-graduated cylinder, 250-mL Erlenmeyer flask, magnetic stirrer (if titration will be done on-site)
- Extension pole, golfer's ball (as needed)

Reagents except for the concentrated sulfuric acid must be prepared in the laboratory in accordance to the procedures prescribed by the EMB-DENR.

(2) Procedure:

(a) Direct Measurement

1. In wadable waters, DO can be measured by dipping the water quality checker or DO meter and probe directly into the river, in much the same way as the pH meter.

   (i) Calibrate the meter and probe immediately before use.

   (It is recommended to follow the manufacturer's instructions). Once the DO meter is turned on, wait for 15 minutes before calibrating. Do not turn the meter off until the sample is analyzed. If the meter is working properly, it can be used for on-site DO measurement.

   Check the cable connection between the probe and the meter. Make sure that the probe is filled with electrolyte solution, that the membrane has no wrinkles, and that there are no bubbles trapped on the face of the membrane. Field check of the meter's accuracy can be done by calibrating it in saturated air according to the manufacturer's instructions. Alternatively, measure a water sample that is saturated with oxygen, as follows.

   (NOTE: This procedure can be used also for testing the accuracy of the Winkler method.)

   - Fill a 1-liter beaker or bucket with tap water. (A gallon jug with water can be used for this purpose.) Mark the bottle number as "tap" on the lab sheet.
   - Pour this water back and forth into another beaker 10 times to saturate the water with oxygen.

- Use the meter to measure the water temperature and record it in the water temperature column on the FDF.
- Find the water temperature of the "tap" sample in Table A.3, Annex A. Use the meter to compare the DO concentration of the sample with the maximum concentration at that temperature in the table. The sample should be within the 0.5 mg/L If it is not, repeat the check and if there Is still an error, check the meter's batteries and follow the troubleshooting procedures in the manufacturer's manual.

(ii) Put on waders or waterproof boots and gloves. Locate the main current of the stream or river.

(iii) Place the probe in the stream below the surface.

(iv) Set the meter to measure temperature, and allow the temperature reading to stabilize. (This will take at least 1 minute) record the temperature on the FDF.

(v) Switch the meter to read DO. Record the DO level on the PDF then turn the meter off. Rinse the probe with distilled water.

2. If it is not possible to wade in the water, an extension pole may be used to get the probe to the proper sampling point. Simply secure the probe to the end of the extension pole. Poles may be improvised to make them collapsible and easy to transport. These can be used for the other tests also.

(i) Locate the main current of the stream.

(ii) Follow steps (iii) to (v) above.

(b) Indirect Field Measurement (Meter and Probe Method)

1. If the probe cannot be lowered into the stream or river or lake, depending on the situation, water sample can be collected using a sample container. Collect the water samples in accordance with the procedures below, Fig. 6.4.2.

(i) Carefully wade into the stream. Stand facing one of the banks; do not stand upstream of the bottle. Make sure that the water is deeper than the sample bottle, i.e., it can be reached with both arms underwater.

(ii) Remove the cap of the sample bottle. Lower the bottle into the water slowly, pointing it downstream, until the lower lip of the opening is just submerged.

(iii) Allow the water to fill the bottle very gradually, avoiding any turbulence (which would add oxygen to the sample). When the water level in the bottle has stabilized (it won't be full because the bottle is tilted), slowly turn the bottle upright and fill it completely. Keep the bottle under water and allow it to overflow for 2 or 3 minutes to ensure that no air bubbles are trapped.

(iv) Cap the bottle while it is still submerged. Lift it out of the water. Look around the "collar" of the bottle just below the bottom of the stopper. If air bubble is present, pour out the sample and try again. *An air bubble will produce false, high readings.*

(v) In a clean work area near the bank, uncap the bottle and place the probe below the surface.

(vi) Follow steps (iv) to (v) of the direct measurement procedure above for measuring the DO level using the meter and probe.

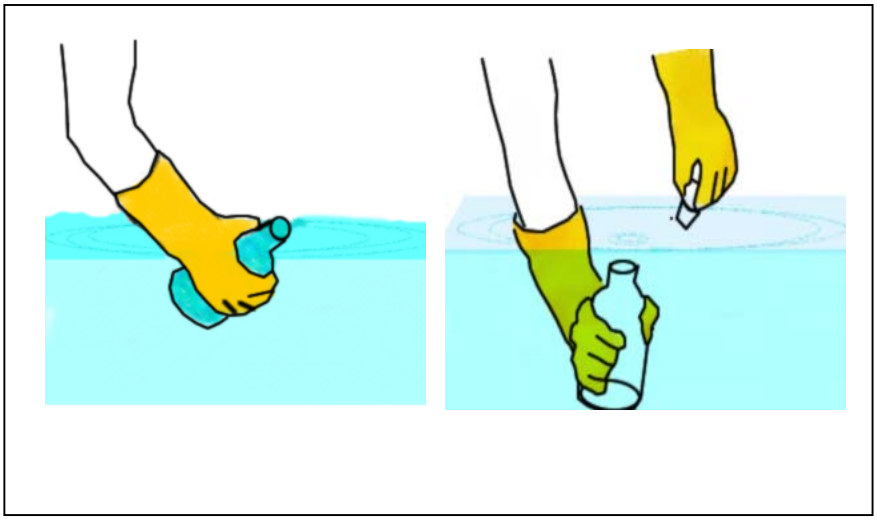


Figure 6.4.2 Collecting Water Sample for DO Test

2. If the water is deep enough for a DO manual grab sampler, sampling can be done from a bridge or watercraft.

(i) Follow the sampling procedures corresponding to the sampler as discussed in Section 4.3 of the manual.

(ii) Follow steps (iv) to (v) of the direct measurement procedures above for measuring the DO level using the meter and probe.

(c) Indirect Field Measurement (Modified Winkler Method)

The Modified Winkler Method involves filling a sample bottle completely with water (no air is left to bias the test). The dissolved oxygen is "fixed" using a series of reagents that form an acid compound that is titrated.

Pre-measured reagents come with DO kits.

Titration involves the drop-by-drop addition of a reagent that neutralizes the acid compound and causes a change in the color of the solution. The point at which the color changes is the "endpoint" and is equivalent to the amount of oxygen dissolved in the sample. The sample is usually fixed and titrated at the sample site.

Three types of titration apparatus can be used with the Modified Winkler Method: droppers, digital titrators, and burets. The dropper and digital titrator are suitable for field use. The buret is commonly used in the laboratory.

1. Depending on the condition of the water body, samples can be collected either by using a BOD bottle according to the procedures in Section 6.4.2(b) above or according to the procedures in Section 4.3 for manual grab sampling with a Kemmerer or Van Dorn sampler. In case of the latter, samples must be transferred to the BOD bottle, taking care to avoid introduction of oxygen while transferring.

2. Fix" the sample immediately following the directions in the DO kit. Remove the stopper and add the fixing reagents to the sample.

3. Immediately insert the stopper so as not to trap air in the bottle and invert several times to mix. This solution is caustic. Rinse immediately. An orange-brown flocculent precipitate will form if oxygen is present.

4. Wait a few minutes until the floc in the solution has settled. Invert the bottle again several times and wait until the floc has settled. This ensures complete reaction of the sample and reagents. The sample is now fixed, and atmospheric oxygen can no longer affect it.

5. If the sample will be taken to the laboratory, it can be stored in the cooler for up to 8 hours before titration in the laboratory.

6. If titration will be done in the field with an eye dropper or syringe, follow the manufacturer's instructions.

7. If using a digital titrator, follow the steps below:

   (i) Select a sample volume and sodium thiosulfate titration cartridge for the digital titrator corresponding to the expected dissolved oxygen concentration according to Table 6.4. In most cases, the 0.2N cartridge and the 100-mL sample volume are used.

Table 6.4 Sample and Titrant Volume for Winkler Titration

Expected Range of DO	Sample Volume	Titration Cartridge	Digit Multiplier
1-5 mg/L	200 mL	0.2N	0.01
2-10 mg/L	100 mL	0.2N	0.02
10+ mg/L	200 mL	2.0N	0.10

   (ii) Insert a clean delivery tube into the titration cartridge.
   (iii) Attach the cartridge to the titrator body.
   (iv) Hold the titrator with the cartridge tip up. Turn the delivery knob to eject air and a few drops of titrant. Reset the counter to 0 and wipe the tip.
   (v) Use a graduated cylinder to measure the sample volume (from the "fixed" sample in the 300-mL BOD bottle) according to Table 6.4.
   (vi) Transfer the sample into a 250-mL Erlenmeyer flask, and place the flask on a magnetic stirrer with a stir bar. If you are in the field, you can manually swirl the flask to mix.
   (vii) Place the delivery tube tip into the solution and turn the stirrer on to stir the sample while turning the delivery knob.
   (viii) Titrate to a pale yellow color.
   (ix) Add two dropperful of starch indicator solution and swirl to mix. A strong blue color will develop.
   (x) Continue to titrate until the sample is clear. Record the number of digits required. (The color might reappear after standing a few minutes, but this is not a cause for

concern. The "first" disappearance of the blue color is considered the endpoint.)

(xi) Calculate mg/L of DO = digits required x digit multiplier (from Table 6.4).

(xii) Record the results in the appropriate column of the data sheet.

Note: Some water quality guideline values are expressed in terms of percent saturation. To calculate percent saturation of the sample:

- Find the temperature of the water sample as measured in the field.
- Find the maximum DO concentration of the sample at that temperature as given in Table A.3, Annex A.
- Calculate the percent saturation, by dividing the actual DO by the maximum DO concentration at the sample temperature.
- Record the percent saturation in the appropriate column on the FDF.

(8) Return the FDF to the laboratory

(9) If the samples will be sent to a laboratory, make sure that all the necessary information for each site are recorded on the FDF, especially the bottle number and corresponding site number and the time the samples were collected. Submit both the samples and FDF to the laboratory.

(d) Laboratory Analysis (Modified Winkler Method)

If titration can not be done on site, the sample can be "fixed" in the field and then sent to the laboratory for titration. This is preferable when sampling under adverse conditions or to reduce the time spent in collecting samples. It is also a little easier to titrate samples in the laboratory, and more quality control is possible because the same person can do all the titrations. In this case, follow the procedures for “fixing” as directed by the laboratory, or the procedures below:

(1) Using separate pipettes, add 2.0 mL manganous sulfate solution followed by 2.0 ml of the alkaline iodide-azide solution well below the surface of the liquid, stopper with care to exclude air bubbles, and mix well by inverting the bottle several times. If white precipitate is formed, there is no need to continue analysis, as this means that DO is zero.

(Note: *Some of the sample will overflow as chemicals are added, but sufficient amount of the oxygen-reacting chemicals will fall to the bottom of the bottle. The overflow assures that when the sample bottle is closed, air will not be trapped inside*.)

(2) When the precipitate settles, leaving a clear supernatant above the settled precipitate, shake again.

(*Wait until all precipitate has settled because incomplete reaction would produce false low readings*).

(3) When settling has produced at least 200 mL of clear supernatant, carefully remove the stopper and immediately add 2.0 mL of concentrated sulfuric acid using another pipet and allowing the acid to run down the neck of the bottle.

(4) Re-stopper and mix by gentle inversion until the reagent and the precipitate have dissolved. *This may take a few minutes.* A clear- yellow (low DO) to brown orange color (high DO) will develop, depending on the oxygen content of the sample.

Following completion of this step, contact between the water sample and the atmosphere will not affect the test results. The succeeding step can be done in the laboratory.

(5) Titrate with thiosulfate solution to a pale straw color using another pipette. Add 1.0 – 2.0 mL of starch solution and continue to titrate to the first disappearance of the blue color.

Each ml. of thiosulfate titrant used is equivalent to 1.0 mg DO when the entire bottle contents are titrated.

If duplicate samples will be collected, label the duplicate bottle with the correct code, which should be determined prior to sampling by the laboratory supplying the bottles. Use the same procedure for collecting a sample for titration by the Modified Winkler method.

6.4.3 Measurement of Temperature

(1) Materials, Reagent and Instruments

- Thermometer or probe
- 2 liter plastic beaker or clean plastic container
- Extra supplies needed for maintenance of probe
- Integrated Water Sampler
- Extension pole (optional)

(2) Procedure

(a) In wadable waters, temperature can be measured by dipping the thermometer or probe directly into the river. The procedures are the same as in Section 6.4.1(2)-(a).

If the pH probe is capable of reading temperature, simply record the temperature displayed in the pH probe while getting the pH measurement.

If a different thermometer or probe is used, use the same procedure as in Section 6.4.1 (2) except that the thermometer is used instead of pH meter. If using a thermometer, allow at least one minute for the reading to stabilize. If possible, try to get the temperature reading with the thermometer bulb beneath the water surface. If it is not possible, quickly remove the thermometer and read the temperature before it changes to air temperature.

(b) If wading is not possible, direct reading may still be done with the aid of an extension pole. Tape the thermometer to an extension pole and dip into the water at least 4 inches below the surface or halfway to the bottom of shallow stream. Read the temperature quickly before it changes to the air temperature.

(c) If collecting samples using intermediate container, follow the sampling procedures in Section 4.3.1.2 for the selected method. Place the thermometer or probe in the plastic beaker containing the water sample. Wait for the meter reading to stabilize then read the measurement and record in the field data sheet.

If there is intention to do horizontal or vertical temperature profiling, make sure that all the points where measurements will be taken can be reached safely before even trying to do the profiling.

6.5 Collecting Samples for Laboratory Analysis

6.5.1 Sampling in Rivers and Streams

Basic Considerations

(1) Get samples from the main stream, not from the stream banks. Water from the stream bank is usually stagnant and retains much of the pollutant from upstream drainage channel or the debris carried along during high flows. Never sample stagnant water.

(2) Flow is well mixed at the outside curve of the stream making it a good choice for sampling.

(3) In shallow rivers, grab sampling technique is appropriate. Samples may be collected either by using a beaker, dipper, or a manual grab sampler depending on the condition of the selected sampling site.

(4) If the sample matrix is homogeneous, the grab sampling method is effective. If homogeneity is not apparent based on flow or vertical variations (this should never be assumed) then use other collection methods.

(5) The use of unpreserved sample containers as direct grab samplers is encouraged, since the same container can be submitted for laboratory analysis after preservation. This procedure reduces sample handling and eliminates potential contamination from other sources (e.g., additional sampling equipment, environment, etc.). Use of pre-preserved sample containers is discouraged as the collection method may dilute the concentration of preservative necessary for proper sample preservation.

(6) If possible, use the actual sample container provided by the laboratory for collecting samples to be analyzed for petroleum oil, VOCs, and microbiological samples. This procedure eliminates the possibility of contaminating the sample with an intermediate collection container.

6.5.1.1 Sampling in Wadable Waters

(1) If collecting a grab sample directly into the sample container:

(i) Prepare a clean surface to work if preservation is required.

(ii) Slowly submerge the container, mouth or opening first, into the water.

(iii) Invert the bottle so that the mouth is upright and pointing towards the direction of water flow (if applicable). Allow the water to run slowly into the container until filled.

(iv) Return the filled container quickly to the surface.

(v) Pour out a few milliliters of sample out of the bottle, away from and downstream of the sampling location. This procedure allows for addition of preservatives and so that the sample can be shaken just before analysis. Do not use this step for volatile organics or other analytes where headspace is not allowed in the sample container. Also for DO and BOD

samples where introduction of air into the water sample should be avoided.

(vi) Add preservatives and cap securely, gently mix and securely cap container, label and place on wet ice (if cooling is required).

(vii) Fill out the FDF and COC form.

(2) If sampling using a dipper attached to a pole, submerge the container mouth first. Follow steps (ii) to (vii) above.

(Note: This procedure is recommended if the water to be sampled has doubtful quality or visibly polluted).

6.5.1.2 Sampling from a Bridge

Sampling can be done from a bridge if the selected site is not accessible and there is no better alternative.

Sampling can be done using any sampler described in Section 4.3, as appropriate for the parameter to be analyzed. The procedures for sampling are as described in Section 4.3.1.2.

Care must be taken to ensure that the activity will not obstruct traffic. Park the sampling vehicle a few meters away from the bridge or approaches. If leaning over bridge rails make sure you are firmly fastened to the ground or the bridge with reliable hand or foot holds.

(1) Materials, Reagents and Apparatus

- Water Quality checker
- Kemmerer, Van Dorn, multisampler or DO sampler with rope marked at 0.5-meter depth intervals and a messenger
- Plastic or glass beaker or similar container
- Rubber gloves
- 250, 300, 500, 1000 ml sample bottles, depending on the parameters to be analyzed. Use the recommended bottle for coliform bacteria, petroleum oil, AVFO and DO samples
- Acid for sample preservation, unless the bottles contain acid or preservative already (the laboratory can provide pre-preserved sample bottle or preservation can be done on site)
- Coolers with ice
- Field notebook or FDF and COC form
- Thermometer

(2) Procedure

(a) Stream Sample Collection

(i) Put on the gloves

(ii) Check whether the stream is deep enough for the selected sampler.

(iii) Follow the steps in Section 4.3.1.2 for the appropriate procedure for the selected sampler.

If the volume of water in the sampler is insufficient to fill all sample bottles, repeat the procedures for sample collection, each time filling the beaker until enough water is obtained to fill the needed sample bottles.

(iv) Add preservatives in accordance with instructions from the laboratory as appropriate for the parameters to be analyzed. If a preservative was added, indicate this in the label unless the bottles are pre-labeled for the appropriate tests and are pre-treated with preservative in the laboratory. If this is the case, skip this step.

(v) Mix the sample well by inverting.

(vi) Fill out the FDF and COC form.

(vii) Place the samples in a cooler on ice for transport to the laboratory. Make sure that the temperature is maintained to $4^{o}C$ until the samples reaches the laboratory.

(viii) Collect additional water as needed to fill bottles for blank or duplicate samples.

(ix) Label required number of sample bottles to be collected at the site (sample site, date, time, parameters, preservative, name or initials of person/s collecting the sample) as described in Fig. 6.7.1.

(b) Stream Duplicate Sample Collection

For QA/QC check, one set of field duplicate sample is generally collected with every 20 samples collected. Collect the duplicate samples in the same manner as the stream sample. Label each duplicate sample as described in Fig. 6.7.2

(c) Stream Blank Sample Collection

One field blank sample should be collected at least with every 20th stream sample. Follow the steps below for collection of blank sample:

(i) Using deionized water, triple rinse the sampler and the collection beaker.

(ii) Fill each bottle with deionized water from the sampler and collection beaker.

(iii) Preserve each sample appropriately and according to the parameters which are to be measured in the corresponding 20th stream samples.

(iv) Label each blank sample container as described in Fig. 6.7.3.

(v) Place the sample in a cooler on ice for shipment to the laboratory.

(vi) Fill out the FDF and COC form.

6.5.1.3 Sampling from a Watercraft

A boat or raft will be required for deep sites where bridge or other access does not exist. Try to maneuver the boat into the center of the main current to collect the water sample.

When sampling from a boat or watercraft, take samples near the bow, and going up the current.

Sampling can be done using any sampler described in Section 4.3, as appropriate to the parameter to be analyzed. Follow the procedures described in 6.6.1.2 both for the water sample, duplicate sample and blank sample collection.

6.5.2 Sampling in Lakes

Lake samples must be reflective of the whole lake. To be representative, samples must be taken at appropriate depths. Consider the following in determining the appropriate number of samples to be collected per sampling site:

- For lakes, reservoirs or wetlands with depth less than two meters to four meters, a sample taken at the center or the deepest section would be sufficient.
- For lakes that are deeper than four meters, determine whether the lake is thermally stratified from the temperature/dissolved oxygen profile.
    - If the lake is not stratified collect three samples from each sampling site, one at the surface, one at mid-depth, and the last sample one meter off the bottom.

- If the lake is thermally stratified, collect three samples; the first one should be collected at the surface (epilimnion), the second one located one meter below the thermocline (top of hypolimnion) and the last sample one meter off the bottom (bottom of hypolimnion) In some cases, an additional sample can be collected just above the thermocline (bottom of epilimnion).

(1) Materials, Reagents and Apparatus

- Kemmerer, Van Dorn, multi-sampler or DO sampler with rope marked at 0.5-meter depth intervals and a messenger
- Plastic or glass beaker or similar container Rubber gloves
- 250, 300, 500, 1000 ml sample bottles. Depending on the parameters to be analyzed. Use the recommended bottle for coliform bacteria, petroleum oil, AVFO and DO samples (The laboratory can provide pre-preserved sample bottle or preservation can be done on site)
- Acid for sample preservation, unless the bottles contain acid or preservative already
- Coolers with ice
- Field notebook or FDF and COC form

(2) Procedure

(a) Field (Lake and Reservoir) Sample Collection

(i) Anchor the raft or boat before sampling. Put on the gloves.

(ii) Rinse the sampler three times with the water being sampled prior to collecting each sample.

(iii) Follow the procedure in Section 4.3.1.2 for the sampling procedure for the selected sampler.

If the volume of water in the sampler is insufficient to fill all sample bottles, repeat the procedures for sample collection, each time filling the beaker until enough water is obtained to fill the needed sample bottles.

(iv) Add preservatives in accordance with instructions from the laboratory as appropriate for the parameters to be analyzed. If a preservative was added, indicate this in the label unless the bottles are pre-labeled for the appropriate tests and are pre-treated with preservative in the laboratory. If this is the case, skip this step.

(v) Mix the sample well by inverting.

(vi) Fill out the FDF and COC form.

(vii) Label each sample bottle properly as shown in see Fig. 6.7.1.

(viii) Place the samples in a cooler on ice for transport to the laboratory. Make sure that the temperature is maintained to 4^{O}C until the samples reach the laboratory.

(ix) Collect additional water as needed to fill bottles for blank or duplicate samples.

(b) Field Duplicate Sample Collection

One set of field duplicate sample is generally collected with every 20 samples collected.

Collect the duplicate samples in the same manner as the stream sample. The duplicate sample must be collected immediately after the collection of the 20th water column sample. Label the sample as described in Fig. 6.7.2.

(c) Field Blank Sample Collection

One field blank sample should be collected at least with every 20th water column sample. Follow the steps below for collection of blank sample:

(i) Using deionized water, triple rinse the sample bottle and the collection beaker.

(ii) Fill each bottle with deionized water from the sampler and collection beaker.

(iii) Preserve each sample as appropriate for the parameters to be measured in the corresponding 20 stream samples.

(iv) Label each blank sample container as described in Fig. 6.7.3.

(v) Place the sample in a cooler on ice for shipment to the laboratory.

(vi) Fill out the FDF and COC form.

6.5.3 Sampling in Coastal and Offshore Waters

In beaches or coasts, samples may be taken by grab sampling following the same procedures in 6.4 for on-site measurements and the procedures in Sections 6.5.1.1 for parameters other than DO and volatile organics.

In deep areas, samples may be taken by boat or watercraft following the appropriate procedures in Section 6.4 for on-site measurements or those in Section 6.5.2 for parameters to be analyzed in the laboratory.

(1) Materials, Reagents and Apparatus

- Water checker
- Kemmerer, Van Dorn or DO sampler with rope marked at 0.5-meter depth intervals and a messenger
- Plastic or glass beaker or similar container Rubber gloves
- 250, 300, 500, 1000 ml sample bottles. Depending on the parameters to be analyzed. Use the recommended bottle for coliform bacteria, petroleum oil, AVFO and DO samples (The laboratory can provide pre-preserved sample bottle or preservation can be done on site)
- Acid for sample preservation, unless the bottles contain acid or preservative already
- Coolers with ice
- Field notebook or FDF and COC form

(2) Procedure

(i) Anchor the raft or boat before sampling. Put on the gloves.

(ii) Rinse the sampler three times with the water being sampled prior to collecting each sample.

(iii) Follow the procedure in Section 4.3.1.2 for the appropriate sampling procedure for the selected sampler.

(iv) If the volume of water in the sampler is insufficient to fill all sample bottles, repeat the procedures for sample collection, each time filling the beaker until enough water is obtained to fill the needed sample bottles.

(v) Add preservatives in accordance with instructions from the laboratory as appropriate for the parameters to be analyzed. If a preservative was added, indicate this in the label unless the bottles are pre-labeled for the appropriate tests and are pre-treated with preservative in the laboratory. If this is the case, skip this step.

(vi) Mix the sample well by inverting.

(vii) Fill out the FDF and COC form.

(viii) Label each sample bottle properly as shown in see Fig. 6.7.1.

(ix) Place the samples in a cooler on ice for transport to the laboratory. Make sure that the temperature is maintained to 4^{O}C until the samples reach the laboratory.

(x) Collect additional water as needed to fill bottles for blank or duplicate samples.

(b) Field Duplicate Sample Collection

One set of field duplicate samples is generally collected with every 20 samples collected.

Collect the duplicate samples in the same manner as the stream sample. The duplicate sample must be collected immediately after the collection of the 20th water column sample. Label the sample as described in Fig. 6.7.2.

(c) Field Blank Sample Collection

One field blank sample should be collected at least with every 20th water column sample. Follow the steps below for collection of blank sample:

(i) Using deionized water, triple rinse the sample bottle and the collection beaker.

(ii) Fill each bottle with deionized water from the sampler and collection beaker.

(iii) Preserve each sample as appropriate for the parameters to be measured in the corresponding 20 stream samples.

(iv) Label each blank sample container as described in Fig. 6.7.3.

(v) Place the sample in a cooler on ice for shipment to the laboratory.

(vi) Fill out the FDF and COC form.

6.5.4 Sampling for Specific Analysis

6.5.4.1 Sampling for BOD Analysis

BOD measurement requires taking two samples from any one sampling site. One is analyzed immediately for DO, and the second is fixed at the site and sent to the laboratory for incubation in the dark at 20^{O}C for 5 days then analyzed for the remaining DO after the 5-day incubation period. The difference in oxygen levels between the first test and the second test, in mg/L, is the 5-day BOD.

(1) Materials, Reagents and Apparatus

The materials, reagents and apparatus needed for BOD analysis are the same as those for DO analysis (refer to Sec 6.4.2) except that additional black or brown BOD bottle is required for the second sample to be delivered to the laboratory for incubation. If a black/brown BOD bottle is not available, simply wrap a clear BOD bottle with a black electrical tape.

(2) Procedure

The first part of BOD analytical procedures consists of the same steps as the DO analysis in Sec. 6.4.2 except that at each site, a second sample is collected in the same manner as the first using a black/brown BOD bottle. This second sample will be incubated in the laboratory after fixing at the site.

In taking samples, follow the procedures in Sec. 6.4.2 with these additional considerations:

- Label the second bottle (the one to be incubated) clearly so that it will not be mistaken for the first bottle.
- Record the information for the second bottle on the FDF.

The succeeding steps are done in the laboratory[1]. Usually, the first bottle for DO is analyzed just before storing the second sample bottle in the dark for 5 days at 20^0C. After 5 days, the second bottle is tested for DO using the same method that was used for the first bottle. The BOD, expressed in mg/L, is calculated using the following equation:

$$BOD = DO_1 - DO_2$$

Where: DO_1 is the dissolved oxygen before incubation, in mg/L
DO_2 is the dissolved oxygen after 5-day incubation, in mg/L

Collect field duplicates and field blanks for every 20^{th} sample following the procedures described in Section 6.5.1 for rivers/stream samples, Section 6.5.2 for lakes and similar water bodies and Section 6.5.3 for marine and coastal waters.

[1] The above explanation is meant to give an overview of the BOD analytical procedures. If it does not totally conform to the approved DENR laboratory procedures, the DENR procedures should always prevail.

6.5.4.2 Sampling for Bacteriological Analysis

(1) Materials, Reagents and Apparatus

Any reused sample containers and glassware to be used in sampling and analysis must have been rinsed and sterilized at 121^{O}C for 15 minutes using an autoclave.

- Sterilized sample bottles with cover and seal to indicate that they have been sterilized. Bottles should be pre-numbered at the laboratory for the specific site to be sampled.

- BOD Sampler
- Beakers
- FDF and COC

(2) Procedure

(i) Collect the samples following the steps described in Section 6.5.1 for rivers/streams, Section 6.5.2 for lakes and similar water bodies and Section 6.5.3 for coastal and offshore waters.

(ii) Collect field duplicates and field blank samples for every 20th sample collected following the procedures described in Section 6.5.1 for rivers/streams, Section 6.5.2 for lakes and similar water bodies and Section 6.5.3 for coastal and offshore waters.

(iii) Place the sample on ice, keep temperature to 4^{o}C and transport immediately to the laboratory for analysis.

(iv) Fill out the FDF and COC form and label the samples.

Remember to wash hands thoroughly after collecting samples suspected of containing fecal contamination. Take care not to touch eyes, ears, nose or mouth until after washing hands.

6.5.4.3 Sampling for Petroleum Oil and AVFO Analysis

(1) Materials, Reagents, Apparatus

- Wide-mouthed glass bottle container with cover (not plastic) to hold sample
- Glass beakers
- Glass sampler
- FDF and COC

(2) Procedure

(i) Water samples for petroleum oil and AVFO are collected in the same manner as samples for general analysis except for the specific requirements for glass containers and samplers. Collect the samples following the steps described in Section 6.5.1 for rivers/streams, Section 6.5.2 for lakes and similar water bodies and Section 6.5.3 for coastal and offshore waters.

(ii) Collect field duplicates and field blank samples for every 20th sample collected following the procedures described in Section 6.5.1 for rivers/streams, Section 6.5.2 for lakes and similar water bodies and Section 6.5.3 for coastal and offshore waters.

(iii) If the sample container is not pre-treated, fix the sample in the field with sulfuric acid to a pH <2 or place the sample on ice bucket, keeping temperature to 4^{O}C. Transport immediately to the laboratory for analysis.

(iv) Fill out the FDF and COC form and labels the samples.

6.5.4.4 Sampling for Analysis of Color

(a) Visual Comparison: Platinum-Cobalt Method (Field Method)

(1) Materials, Reagent and Apparatus

- Calibrated glass color disks
- pH meter
- Filter

(2) Procedure

(i) Collect samples in clean glassware.

(ii) Measure the pH and record in the field data sheet. Refer to procedure for measuring pH.

(iii) Filter the sample.

(iv) Compare the color of the filtered water with the glass disks held at the end of metallic tubes containing glass comparator tubes filled with sample and colorless distilled water. Match the color of sample with the color of the tube of clear water plus the calibrated colored glass when viewed by looking toward a white surface.

Calculate color units by the equation:

$$\text{Color} = \frac{A \times 50}{B}$$

Where:

A = estimated color of a diluted sample and
B = mL sample taken for dilution.

Round off results to whole numbers and record:

Color Units	Record to nearest
1-50	1
51-100	5
101-250	10
251-500	20

(b) Spectrophotometric Method

Portable spectrophotometers can be used for analysis in the field. The accuracy and procedures vary depending on the equipment. If using such equipment, it is advisable to follow the procedures prescribed by the manufacturer.

6.6 Sampling and Analysis of Other Common Water Quality Parameters

6.6.1 Secchi Disk Transparency

The Secchi Disk (Fig. 6.6.1) is the only equipment used to determine a lake's transparency. It consists of weighted circular disk approximately 20 cm in diameter fastened to a 10-meter chain or rope marked off at 10cm intervals. The disk is marked with black and white alternating quadrants and must be heavy enough to sink easily. The rope must be made of a non-stretchable material. (The rope must be periodically checked with a measuring tape as it may shrink following several wet-dry cycles).

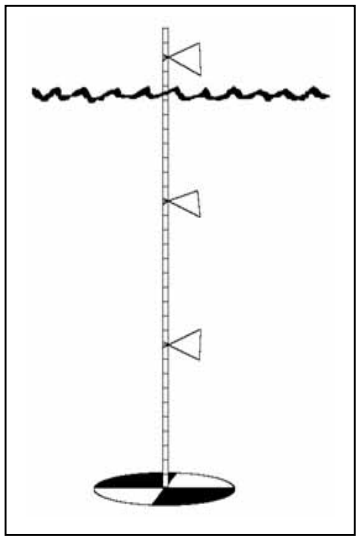


Fig. 6.6.1
A Secchi Disk

(1) Materials, Reagents and Apparatus

- Secchi disk
- Field Data Form

(2) Procedure

To minimize interferences that can obstruct visibility, observations with a Secchi disk should be made during midday, without sunglasses and away from the shady side of the boat/raft or shady part of the lake. The observer should look as close as possible to the water to minimize glare.

a. Measurement is done from a boat or a raft. For stability, anchor the boat or raft.

b. Slowly drop the Secchi disk down until it is barely visible. Record the depth of the Secchi disk at this point.

b. Drop the Secchi disk farther down and bring it up to the depth that it is barely visible. Record the depth of the Secchi disk at this point.

c. Repeat the above procedure and average the two readings for the final Secchi disk depth.

d. Record the Secchi disk calculation on the FDF and on the COC form.

6.6.2 Total Dissolved Solids

(1) Materials, Reagents and Apparatus

- Conductivity meter/TDS probe
- Beaker or wide mouthed jar
- FDF

(2) Procedure

(a) Using conductivity/TDS meter

(i) Calibrate the instrument according to the manufacturer's instructions. It is better to follow the manufacturer's instructions for using the instrument, otherwise, use the following procedures.

(ii) Rinse the probe with de-ionized water after calibration.

(iii) Set the meter to the TDS mode.

(iv) In wadable water, simply dip the instrument into the water to be tested, following the same procedures as that for salinity and conductivity measurement. Read and record the meter reading in the field data form. Rinse the probe with de-ionized water before each sample measurement, and then follow the manufacturer's instructions for temperature compensation.

(v) In non-wadable waters, obtain samples in accordance with the procedures described in Section 6.5.1 for rivers/stream samples, Section 6.5.2 for lakes and similar water bodies and Section 6.5.3 for marine and coastal waters. Transfer about 250 mL of the sample in a beaker. Dip the probe into the water following the same procedures as (iii) above. and read and record the meter reading in the FDF.

6.6.3 Salinity

(1) Materials, Reagents and Apparatus

- Conductivity meter/probe with platinum graphite electrode type cell with temperature sensor or salinimeter;
- FDF

(2) Procedure

(i) Calibrate the instrument according to the manufacturer's instructions using one calibration standard, either standard seawater or a KCl solution, as applicable. The acceptance criterion for initial calibration or a calibration check is that the instrument reading must be within ± 5% of the standard value. Use standard seawater (S = 35) when measuring salinity in the open ocean or estuaries with a predominance of seawater. Potassium chloride may be used in estuarine waters with low salinity (S = 0 – 40).

(ii) Rinse the probe with de-ionized water after calibration.

(iii) In wadable waters, simply dip the probe into the water to be tested, following the same procedures as that for temperature measurement. Read and record the meter reading in the FDF. Rinse the probe with de-ionized water before each sample measurement, and then follow the manufacturer's instructions for temperature compensation. Salinity should be reported with only one decimal figure.

(iv) In non-wadable waters, obtain samples in accordance with the procedures described in Section 6.5.1 for rivers/stream samples, Section 6.5.2 for lakes and similar water bodies and Section 6.5.3 for marine and coastal waters. Transfer about 250 mL of the sample in a beaker. Dip the probe into the water following the same procedures as (iii) above and read and record the meter reading in the FDF.

6.6.4 Specific Conductance

(1) Materials, Reagents and Apparatus

- Conductivity meter/probe with platinum graphite electrode type cell
  With temperature sensor;
- KCl standard solution for calibration
- FDF and COC

Reminder:

Specific conductance should never be measured in sample water that had earlier been used for pH measurements.

(2) Procedure

To ensure accuracy of method, follow the manufacturer's instructions for the particular brand of specific conductivity meter to be used.

For most brands, the procedures are as follows:

(i) Make sure the instrument is set up to measure *Specific Conductivity*, not Conductivity. Perform zero calibration if required by the instrument.

(ii) In wadable water, simply immerse the conductivity probe or sensor at the selected sampling point. Make sure you follow the precautions for wading.

(iii) Allow the conductivity instrument to stabilize;

(iv) Measure the water temperature (if necessary for manual temperature compensation) and record the temperature;

(v) If the meter is equipped with manual temperature compensation, adjust the conductivity meter to the water temperature per manufacturer's instructions;

(vi) If the conductivity meter has a set of positions that multiply the reading by powers of ten in order to measure the full range of potential conductivities, set this dial to the correct range in order to take a reading;

(vii) Record the sample conductivity measurement reading in the FDF.

(viii) Rinse off the probe with de-ionized water. Follow the manufacturer's instructions for probe storage between each use.

(ix) For in-situ measurements at depth or with flow through cells, follow the same procedure as above as well as the manufacturer's instructions. Immerse the probe at the desired depth, wait for stabilization of the reading, and record the value.

6.7 Labeling of Water Samples

Each sample for laboratory analysis must have a label to properly identify it. Label format can be prepared in the office beforehand and filled out in the field after the sample has been collected. It must be ensured that labels are waterproof and will not be damaged if stored in the ice cooler or during transport and storage.

If waterproof labels are not available, alternatively, the sample container can be marked indicating the water body being monitored, the sampling station and the sample number. In addition, the label format should also be filled out. The information indicated in the sample container should also be indicated in the label format to facilitate identification when it reaches the laboratory. The filled out label form should be pasted on the sample container before submitting the sample to the laboratory.

The following are examples of sample and FQC labels:

Name of Waterbody: Pasig River		
Station ID No. PR-01	Sampling Site 1	Description: Sample
Date Sampled: Sept. 7, 2007 Time: 10:10 a.m. Sampled by: E.B.M.		
Preservation Done: ☐ None ■ Ice to 4°C ☐ Nitric ☐ Sulfuric ☐ Other		
For Analysis of :	Fecal coliform	

Figure 6.7.1 Example of Sample Label

Name of Waterbody: Pasig River		
Station ID No. PR-01	Sampling Site _1_	Description: Duplicate Sample
Date Sampled: Sept. 7, 2007 Time: 10:10 a.m. Sampled by: E.B.M.		
Preservation Done: ☐ None ■ Ice to 4°C ☐ Nitric ☐ Sulfuric ☐ Other		
For Analysis of :	Fecal coliform	

Figure 6.7.2 Example of FQC Sample (Duplicate) Label

Name of Waterbody: Pasig River		
Station ID No. PR-01	Sampling Site _1_	Description: Equipment Blank
Date Sampled: Sept. 7, 2007 Time: 10:10 a.m. Sampled by: E.B.M.		
Preservation Done: ☐ None ■ Ice to 4°C ☐ Nitric ☐ Sulfuric ☐ Other		
For Analysis of :	Fecal coliform	

Figure 6.7.3 Example of FQC Sample (Blank) Label

Care must be taken to ensure that the label will not be damaged by water or chemical spillage during handling and transport. Use a permanent ink marker and a waterproof label, similar to the Figure 6.7.4.

Figure 6.7.4 Labeled and sealed water samples

6.8 Filling out of Water Quality Sampling Field Data Form and Chain of Custody Form

Sample and data chain of custody form must be maintained consistently for all field sampling and laboratory activities.

For each set of samples, field duplicate and field blank sent to the laboratory for analysis, a sample identification form from the analytical laboratory and a COC must be filled out.

Upon receipt of the sample(s) submitted, laboratory personnel should check the sample labels against the information written on the form. If there are any discrepancies, the laboratory may contact the representative of the group that conducted the sampling. The laboratory will assign a laboratory number to the set of samples and returns a copy of the form to the sampling agency. The original copy is kept by the laboratory for records purposes.

6.9 Photo Documentation

If possible, take photographs of the sampling sites and sampling activities.

Site photographs are helpful in identifying sites for future monitoring and could also aid in assessing changes in the water body over time. By photographing fixed stations or monitoring sites on a regular basis, the changes occurring at the site are clearly documented. Take enough photos on the first visit to the site to establish a complete photo record of the site and its surroundings and describe the photo points in detail in the field or record notes. The photos can later be transferred to a computer file and can form part of the report. When included in reports, photos would enable readers who have not been to the site to visualize the site conditions.

Take photographs where there are naturally occurring landmarks such as a large tree or boulder or bridge site. It is better to establish specific points where the photographer will position himself every time photographs are taken (photopoint). For instance, he/she can take photographs from one side of a bridge or culvert during each visit to the site. If there are no naturally occurring landmarks at a given site, a photo point may be established, e.g., with a pile of rocks.

Indicate the date and time photos are taken. Captions are meant to provide brief explanation of where the photo was taken and the condition at the time it was taken.

As far as possible, take photo of the established monitoring station every time sample is taken.

For a surface water station, take two photos; one upstream of the sample point looking downstream at the sample point; and one downstream of the sample point looking upstream at the sample point.

CHAPTER VII
SAMPLE PRESERVATION, STORAGE AND TRANSPORT

7.1 Sample Preservation and Storage

Once samples are taken, they should be delivered immediately to the laboratory for analysis. Delay in the transport of samples to the laboratory could result in errors in the monitoring results. Thus, the route from each sampling station should be worked out beforehand to ensure that the transport of sample takes the shortest time possible.

If samples that were collected for bacteriological analysis will reach the laboratory in less than 2 hours, there is no need to preserve. Simply keep the samples in a cool, dark place. If it would lake longer than 2 hours to reach the laboratory, chill the samples rapidly to about 4^{o}C by placing them in a cold water/ice mixture inside an insulated container as shown in **Figure 7.1**. They should be transported to the laboratory in this condition. If the time between collection and analysis exceeds 6 hours, this condition should be noted in the laboratory report. All other samples that will be sent to the laboratory for analysis should be preserved within 15 minutes after sample collection, unless the water sample containers have been pre-preserved by the laboratory.

If the samples cannot be delivered to the laboratory and analyzed soon after sampling, samples should be preserved. The storage of the samples at a temperature of about 4°C, preferably in the dark, will retard biological activity substantially and minimize change in physical and chemical properties of water samples. If refrigeration is not possible, the collected samples can be packed with ice in an insulated container.

Even if pre-preserved sample containers are used, additional preservative must be available in the field whenever needed. If the sample to be preserved will require filtration, filtration must be done before preservation. Take care not to over-preserve samples. Ask the laboratory for the proper ratio of preservative to sample.

Ensure that the recommended holding time for the parameter to be analyzed is not exceeded by the time the sample reaches the laboratory.

Figure 7.1 Samples Packed with Ice in a Cooler

7.2 Preparation of Samples for Transport

When preparing samples for transport, verify that the number and types of sample bottles match the field logbook and the COC. Each sample bottle should be labeled and filled out with permanent marker.

All comments and notes pertinent to the samples should be placed on the chain-of-custody form and not on the sample labels.

The following do's and don't's should be observed when preparing samples for transport:

DO's	DON'T's
√ Check that each bottle is securely capped to prevent leaking and contamination. √ Pack samples in fresh ice for shipping with the volume of ice at least equal to the volume occupied by samples but preferably twice the volume of ice to samples. The amount of ice necessary will vary depending on the length of time in transit from the field or base to the laboratory and the time of year. During summer, the cooler and the samples should be pre-chilled. √ Keep ice/water and packing materials totally separate. √ Coolers should be double lined (a bag within a bag) with unused and untreated heavy weight trash bags. After samples and ice are placed in a doubled bag, seal each bag with a knot or by gathering the top of the bag, folding it over, and securing with filament tape.	• Do not use tape or paraffin on lids or jars containing organic samples. • Do not send samples chilled with "blue ice" or other types of commercial, refreezable containers. • Do not chill sample container with dry ice or with other substances that have a freezing point below 0^{o}C; this may cause sample containers to freeze and can result in ruined samples and/or broken sample containers. • Do not mix ice/water with packing materials. • Do not mix foam peanuts with ice for shipping. • Do not ship nutrient samples in coolers with samples that have been treated with nitric acid preservative. Contamination from the acids used in sample preservation may create false readings for some nutrient species.

CHAPTER VIII FLOW MEASUREMENT

8.1 Selecting Site for Flow Measurement

Careful selection of sampling site can greatly reduce the amount of work required to get accurate flow measurements.

Following are some basic considerations in selecting site and in taking flow measurements:

- Measure flow from the same location throughout the monitoring period. If location is moved, the new location must be noted and the reasons for moving it must be indicated in the flow data form.
- Weirs, bridges, box or round culverts are good sites for flow measurement. These sites enable flow measurements even during high flows and through relatively narrow space or from above the stream.
- The section of the stream for measurement of flow should be as uniform. Stagnant areas or areas with irregular bottoms, standing waves, or strongly sloping bottoms must be avoided. Areas of turbulent flow such as upstream or downstream of bridges or weirs should also be avoided as turbulence could cause inaccurate measurements.
- The narrowest portions of narrow streams are good measurement sites as velocities are higher and fewer measurements will be required.
- Clean stream reach, with minimum vegetation, rocks or debris is preferable.

Following are procedures for some common methods of taking stream flow measurement if stream gauges or automatic flow measuring devices are not installed.

8.2 Flow Measurement Using Current Meters

8.2.1 In rivers/streams with depths greater than one (1) meter

(1) Equipment:

- A current/velocity meter and a weight large enough to keep the current meter from moving

- A hang cable with headphone. The cable should be marked off every 0.10 meters to permit suspending the velocity meter at desired depths.
- Flow measurement field data form and pen
- A bridge sampler, if necessary, to hold the meter and hang cable
- Stop watch
- Calculator (preferably calculator with programmed depth procedures)

(2) Procedure

To get accurate stream discharge estimates, measurements should be made from a bridge, culvert or other structure.

(a) Mark off the bridge or culvert crossing the stream in meter, before beginning the discharge measurement.

(b) Put the current meter, hang cable, and bridge sampler together. Lower the raising nut on the current meter shaft from the traveling position to the bottom or measuring position.

(c) Record the beginning staff gauge measurement from the bench mark. (Each site should have a permanent bench mark from which levels of streams are recorded).

(d) At the first current velocity measurement increment, 0.1m away from the initial or zero starting point at the water's edge, lower the current meter and weight by letting out the hang cable until the weight touches the water surface.

(e) Set this as the zero on the bridge sampler cable meter or record the level of the hang cable at the top of the bridge.

(f) Lower the meter until the weight hits the stream bottom and record the depth in the depth column on the stream gauge/discharge measurement form.

(g) If the depth is greater than 1m., calculate the 0.2 depth and the 0.8 depth measurements.

(h) Lower the current meter to 0.8 of total stream depth on the cable meter. Start the stop watch and count the number of

revolutions of the current meter, ticks in the headphones, for a time period between 40 and 70 seconds.

Note: The current velocity equation is V = 2.2172R + 0.0267, where R = revolutions/second, for calculating velocity. This equation is valid for measurements involving 5 or more revolutions counted over the 40 to 70 second measuring period.

(i) Record the number of revolutions and measurement time in seconds on the Stream Gauge/Discharge Measurement form.

(j) Set the meter at the 0.2 of total stream depth and repeat steps (h) and (i).

(k) Repeat steps (d) – (j) for each 0.1m increment on the bridge or culvert.

(l) Make sure the hub is raised off the needle bearing anytime the velocity meter is not being used.

(m) Complete all calculations at the end of the stream flow measurement, while personnel are still on site.

(n) At the end of each day the current meter must be cleaned, dried, and oiled according to the standard operating procedures for the meter.

8.2.2 In rivers/streams with depths less than one (1) meter

For the measurement of streams of this size, follow steps (j)–(l) above.

8.3 Flow Measurement Using the Float Method[1]

As discussed in Section 4.5.3, the float method involves calculation of the following equation.

Flow = ALC/T

Where:

A = Average cross-sectional area of the stream (stream width multiplied by average water depth).

[1] Adapted from http:/www.epa.gov.owow.monitoring.volunteer/stream.vms51.html

L = Length of the stream reach measured (usually 6 m)

C = A coefficient or correction factor (0.8 for rocky-bottom streams or 0.9 for muddy-bottom streams). This allows for correction for the fact that water at the surface travels faster than near the stream bottom due to resistance from gravel, cobble, etc. Multiplying the surface velocity by a correction coefficient decreases the value and gives a better measure of the stream's overall velocity.

T = Time, in seconds, for the float to travel the length of L

(1) Materials and Supplies

- A ball of heavy duty rope or a roll of plastic wire or string to be stretched across the stream width perpendicular to shore at two locations.
- Four or more stakes to anchor the string to each bank to form a transect line
- Hammer or stone to drive the stakes into the ground.
- Construction tape measure (at least 6 m)
- Stick to measure depth of water.
- Twist ties (to mark off intervals on the string of the transect line
- Anything that floats (a piece of wood, plastic cap or plastic bottle, a small fruit like an orange, a pingpong ball, etc).
- A stopwatch or hand watch with stopper
- Calculator, pencil with eraser, record form

(2) Procedure

(a) Select a stretch of stream at least 6m long (Refer to Section 8.1 for tips on selecting site). This will represent L in the formula.

(b) Make a transect line across the stream perpendicular to the shore using the string and stakes. Make sure the string is taut and near the water surface. The upstream transect is Transect #1, the transect located 6m downstream would be Transect #2 as shown in Figure 8.3.1.

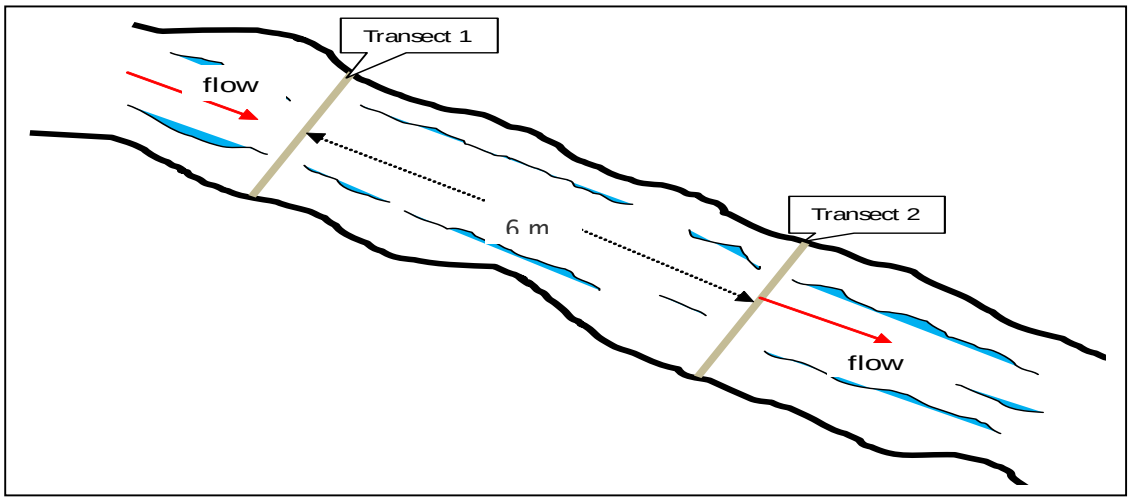


Figure 8.3.1 Setting Transects for Flow Measurement

(c) Calculate the average cross-sectional area

Cross sectional area, A, is the product of a stream width multiplied by the average water depth. To calculate the average cross sectional area for the stream reach, determine the cross sectional area for each transect, add the results together and divide by 2.

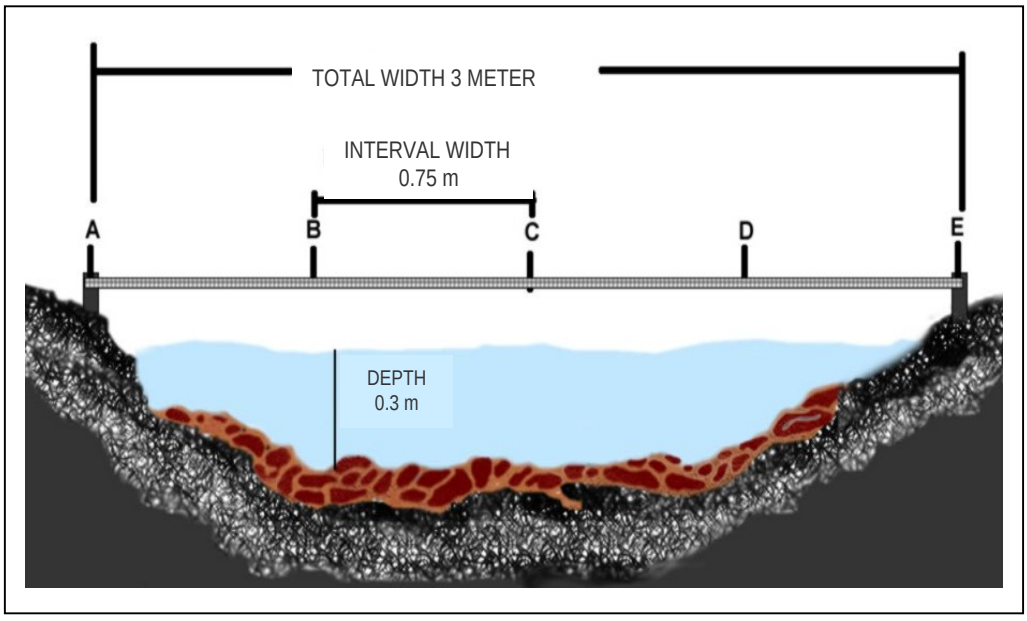


Figure 8.3.2 Measuring the transect cross sectional area

To measure the cross-sectional area:

(i) Determine the average transect depth by marking off equal intervals along the string with the twist ties. The intervals can be one-fourth, one-half, and three-fourths of the distance across the stream. Measure the water's depth at each interval point (Fig. 8.3.2). To calculate average depth for each transect, divide the total of the three depth measurements by 4. (Divide by 4 instead of 3 because the 0 depths that occur at the shores have to be accounted for.)

(ii) Determine the width of each transect by measuring the distance from shoreline to shoreline. Simply add together all the interval widths for each transect to determine its width.

(iii) Calculate the cross-sectional area of each transect by multiplying width times average depth.

(iv) To determine the average cross-sectional area of the entire stream reach (A in the formula), add together the average cross-sectional area of each transect and then divide by 2.

(d) Measure travel time

With a stopwatch, determine the time it takes for an orange (or some other object) to float from the upstream to the downstream transect. An orange is a good object to use because it has enough buoyancy to float just below the water surface. It is at this position that maximum velocity typically occurs.

The person who releases the orange at the upstream transect should position it so it flows into the fastest current. The clock stops when the orange passes fully under the downstream transect line. Once under the transect line, the orange can be scooped out of the water. This "time of travel" measurement should be conducted at least three times and the results averaged--the more trials, the more accurate your results will be. The averaged results are equal to *T* in the formula. It is a good idea to float the orange at different distances from the bank to get various velocity estimates. Discard any float trials if the object gets hung up in the stream (by cobbles, roots, debris, etc.).

(e) Record measurements on the data form and calculate flow. The data form is given in Figure 8.3.3 below.

DATA FORM FOR CALCULATING FLOW

Name of River_____ Station No. _____

Solving the Equation: Flow (F) = $\frac{ALC}{T}$

Where: A = average cross sectional area of the stream; L = length of stream reach measured (usually 6m)
C = coefficient of correction factor (0.8 for rocky bottom streams; 0.9 for muddy bottom streams)
T = time in seconds (s) to travel the length L

A: Average Cross-sectional Area

Transect #1 (Upstream)

Internal Width (m) Depth (m)

A to B = _____ _____ at B
B to C = _____ _____ at C
C to D = _____ _____ at D
D to E = _____ _____ at E (shoreline)
Totals: [ ] [ ] ÷ 4
= Average depth (m) = [ ]

Cross sectional area of Transect # 1
A_1= Total width (m) x Ave. depth (m)
A_1 = [ ] x [ ] = [ ] m^2

Transect #2 (Downstream)

Internal Width (m) Depth (m)

A to B = _____ _____ at B
B to C = _____ _____ at C
C to D = _____ _____ at D
D to E = _____ _____ at E (shoreline)
Totals: [ ] [ ] ÷ 4
= Average depth (m) = [ ]

Cross sectional area of Transect # 2
A_2= Total width (m) x Ave. depth (m)
A_2 = [ ] x [ ] = [ ] m^2

(Cross Sectional Area of Transect # 1 + Cross Sectional Area of Transect No. 2) ÷ 2 = Ave. Cross Sect. Area

A = ([ ] m^2 + [ ] m^2) ÷ 2 = [ ] m^2

L :Length of Stream Reach

[ ] m

C: Coefficient

[ ]

T: Travel Time

Travel Time of Float (s)

Trial 1 = _____
Trial 2 = _____
Trial 3 = _____
Total = [ ] ÷ 3
= Ave. time [ ] s

Flow = $\frac{ALC}{T}$ = $\frac{[\ ] \times [\ ] \times [\ ]}{[\ ]}$ = [ ] m^3/s

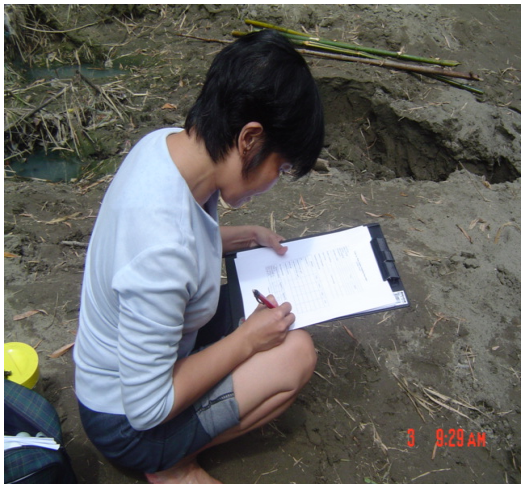
Figure 8.3.3 Data Form for Calculating Flow

(a) Measuring length of stream section

(b) Setting transect lines

(c) Measuring and marking off depth transect sections

(d) Ball released from transect 1 floating towards transect 2. The time (in sec) it takes the ball to reach transect 2 is recorded.



(e) Recording measurements in the data form for flow calculations

CHAPTER IX
DATA STORAGE, TREATMENT AND INTERPRETATION

9.1 Introduction

After completing the sampling activities and the laboratory analyses, the next steps in the monitoring process are the organization, storage, interpretation and analysis of data.

It is important to present the data in a way that readers can make sense out of them otherwise all the monitoring efforts are wasted. Properly interpreted, the data should be able to meet the objectives of the monitoring.

The following sections explain how the monitoring data may be organized, manipulated, presented and interpreted so that they could provide a clear picture of the water quality status of the body being monitored.

Before attempting to tabulate, graph and interpret water quality test results, carefully proof-read and double check data against the original field data form, field notes and laboratory test results. It is also important to ensure that all data for each parameter are expressed in the same unit of measurement.

9.2 Data Storage and Organization

As soon as the field and the laboratory test results are obtained, immediately review for completeness and accuracy. Do not wait longer than one week or so before checking the data because if discrepancies are found too late it is more difficult to rectify.

After confirming completeness and reliability of data, they can be transferred into computer files and organized into **data tables.** Well-organized data tables facilitate data analysis and enable quick identification of data errors.

Again, it is advised to double-check the data table entries against the field data forms and laboratory test results. Common data errors stem from oversights in transferring data from the original report to data tables, or from one table to another. It is thus imperative to carefully proof-read and double check data entries whenever they are being transferred. Consistency in the use of units of measurement should also be checked.

Many data encoders have no knowledge of water quality and could not spot errors, thus it is suggested to have the database checked by a knowledgeable person.

Data storage through database programs is ideal because the information management is centralized and can be easily expanded and shared between users. Users can create and edit data tables and perform queries, analysis, and searches of stored data. The database developer can make data entry easier for encoders by creating entry form templates, and field parameters and ranges that reduce human error.

Development of a database program may require time and resources that many organizations cannot afford but is relatively easy to maintain.

If a database program is not available, the best alternative is a spreadsheet program, e.g., Excel, Lotus, etc. Spreadsheets are not as efficient as databases at storing, manipulating, and managing large data sets but are relatively easy to set up and can also allow manipulations such as calculations, statistics, and graphical analysis. In addition, the users are able to sort and list through data and create custom graphs and charts.

It must be ensured that all the information that would be necessary for interpretation and analysis can be retrieved in many ways. Both the primary and secondary data obtained during the monitoring process should be stored in a hard copy filing system as well as in the computer. It is recommended to keep the survey forms, field data form and laboratory test results on file for at least 5 years to enable cross-checking or reconstruction in the event untoward incident occurs with the computer files.

Water quality data should include the following information:

(1) Basic information about a water body being monitored:

- Name of the water body
- Type of the water body (river, lake, beach, etc.)
- Name of basin and sub-basin
- Station no. or code and location (region, province, municipality or city, barangay) and geographical co-ordinates

Although not necessarily essential for analysis, it is suggested to include a narrative description of the sampling location, the agency

responsible for the monitoring, and the name of the contact person for additional information.

An example of a monitoring station inventory in spreadsheet format is given in Table 9.1.

Table 9.1 Example of Basic Information for Danao River

Project Name: Water Classification Monitoring		**Agency:** DENR-EMB-Region VI **Contact Person**: _____	
Name of Waterbody: Danao River		**Region**: Region 6	
Type: River	**Name of basin/sub-basin**:		
Station No./Code	**Location**	**Coordinates**	
		N	**E**
1	Danao Terminal Port, Brgy. Old Poblacion, Escalante City, Negros Occidental	10°49”084’	123°33”023’
2	Sitio Lawis, Brgy. Langub, Escalante City, Negros Occidental	10°48”087’	123°31”782’
3	Danao Bridge, Sitio. Tanquinto, Brgy. Mabini, Escalante City, Negros Occidental	10°49”291’	123°29”193’
4	Sitio Tapon, Brgy. Jonobjonob, Escalante City, Negros Occidental	10°50”085’	123°28”844’
5	Sitio Minabuno, Brgy. Malasibog, Escalante City, Negros Occidental	10°49”866’	123°27”047’
6	Overflow at Sitio Minauko, Brgy. Libertad, Escalante City, Negros Occidental	10°46”832’	123°29”279’
7	Upstream Malasaging Modular Steel Bridge, Brgy. Libertad, Escalante City, Negros Occidental	10°50”085’	123°28”844’

In database format, all the above information, except the name of the water body and the geographical coordinates is usually indicated by appropriately chosen alphanumeric codes put together in a unique identifier (reference code) for each sampling location, similar to that being used by the Global Environment Monitoring System (GEMS) water quality database (WHO, 1992). In this system, the reference codes are developed to indicate the sample by water body location, type and sub-type of water body, sample type, and analysis type.

Applying the same concept, a similar code may be developed for Philippine waters.

- **Station ID No**.: _____ Monitoring Agency: DENR-EMB-R6
- **Station Name**: **Danao Terminal Port**
- **Coordinates: Longitude: N-** 10º49"084'**; E -** 123º33"023'
- **Location: Region:** 6 **Province**: Negros Occidental
- **Municipality:** Escalante **Barangay:** Brgy. Old Poblacion
- **Type of Monitoring**: Classification **Type of Water Body**: River **Type**: Main River
- Name of Watershed: _____
- Area of watershed (ha): _____ Length of River: 26 km
- Ave. depth (m): _____ Width (m) _____
- Discharge volume (m3/day): _____ Water level (m): _____

(2) Information about the water sample

Another table may be dedicated to describing the type of samples collected at any particular location and other important information at the time of sample collection, including:

- Project identification
- date and time of sampling
- location of sampling
- sample matrix, e.g. grab, depth integrated, composite, duplicate or triplicate, split, spiked or blank
- depth of sampling
- sampling method and/or sampling apparatus
- preservation method
- any other field pretreatment, e.g. filtration, centrifugation, solvent or resin extraction, if any
- name of sample collector

Table 9.2 is a theoretical example of a data table showing the above information for an ECC compliance monitoring program.

Table 9.2 Basic Water Sample Information

Name of Project	**NORTH LAGUNA LAKESHORE FLOOD CONTROL AND DRAINAGE PROJECT**		
Date of Sampling:	December 21, 2005	**Sampled by:**	
Time of Sampling:	10:40 a.m.		
Station No.: Q4	**Location:** Tapayan Bridge, San Juan, Taytay, Rizal		
Name of Water Body:	Napindan River		
Depth of Water (m):	3.8	Depth of sampling from surface	4 in

Weather Condition:	Fair
Odor of Water Sample:	Odorless
Visual Color of Water:	Light green
Observation of Surroundings:	Presence of water lilies, swamp cabbage and small boat along Tapayan river. Presence of informal settlers underneath the bridge
Sample matrix:	Grab water sample **Preservative:** None
Test parameter:	Salinity, pH, Temperature, Conductivity, TDS, DO
Sampling method:	On-site analysis by meter and probe (ion electrode)
Test parameter for Lab	DO, BOD_5. TSS, Turbidity, Total Coliform, Fecal Coliform
Sample Matrix:	Grab sample **Preservation** Chilled to 4°C

(3) Water Quality Test Results

Raw water quality data are usually presented in table form, both for the data obtained in the field and data obtained from the laboratory. The information included in such tables relates to the parameter measured, namely:

- parameter measured,
- location of measurement, e.g. *on-site,* field, field laboratory, or regular laboratory,
- analytical method used, including the instrument used to take the measurement, and
- actual result of the measurement, including the units.

A sample on-site and laboratory test results for the water sample described in Table 9.2 are shown in Table 9.3 below.

Table 9.3 Sample On-site and Laboratory Test Results Summary For Station Q4

Parameter	Unit	Value	Test Method	Where analyzed
Salinity	°/₀₀	0.7	Meter and probe	On-site
pH	--	6.8	Meter and probe	On-site
Temperature	°C	26.9	Meter and probe	On-site
Conductivity	µS/cm	1,414	Meter and probe	On-site
Total Dissolved Solids	mg/L	707	Meter and probe	On-site

Dissolved Oxygen	mg/L	2.8	Meter and probe	On-site
BOD_5	mg/L	3	DO analyzed on site, 2nd part Winkler	DO on-site; Winkler; Authorized laboratory
TSS	mg/L	25	Gravimetric Method	Authorized Laboratory
Turbidity	NTU	20	Nephelometric method	Authorized Laboratry
Total Coliform	MPN/100 mL	$2.3x10^4$	Multiple tube fermentation	Authorized Laboratory
Fecal Coliform	MPN/100 mL	$2.0x10^3$	Multiple tube fermentation	Authorized Laboratory

To facilitate data interpretation, data for various measurement dates (temporal data) or data from various monitoring stations obtained in one sampling date (spatial data) can be presented in one, two or several data tables as explained below.

Data Tables

Data tables may be organized in many ways, depending on the information that one wants to look for. For instance, one table may be created for each sampling location. The rows would show the various water quality parameters, and the columns would show the results for each sampling date as shown in the example Table 9.4(a) to Table 9.4(c) below. These tables are based on monitoring test results for the classification of Manurigao River in Caraga, Davao Oriental (Region XI). (Note: It is advised to indicate exact date of sampling.)

Table 9.4(a) Summary Data Table, Water Quality Monitoring of Manurigao River, CY 2005

Parameter	Station 1								
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Color, PCU	3	<1	1	1	1	1	3	<1	<1
Temp., ^oC	22	26	26	29	27	28	26	28	29
pH	7.4	8	8.2	7.9	7.3	7.9	7.6	8.1	7.6
DO, mg/L	8.7	8.7	8.8	8.5	8.5	7.4	8.1	8.4	7.7
BOD, mg/L	0.8	0.6	0.6	0.5	1.0	0.7	0.8	0.5	0.8
TDS, mg/L	143	171	149	245	195	217	272	425	666
TSS, mglL	7	5	2	<1	1	4	8	5	15
Total Coliform, MPN/100mL	300	170	130	1400	300	300	2200	500	80

Table 9.4(b) Summary Data Table, Water Quality Monitoring of Manurigao River, CY 2005

Parameter	Station 2								
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Color, PCU	3	<1	1	1	1	1	3	<1	<1
Temp., ^{O}C	22	25	24	28	27	27	26	26	28
pH	7.7	8.1	8.2	8.0	7.8	8.0	7.6	8.1	7.9
DO, mg/L	8.8	8.5	8.3	8.6	8.9	7.8	8.4	8.3	7.8
BOD, mg/L	0.8	0.5	0.8	0.8	1	0.4	0.6	0.6	0.9
TDS, mg/L	134	161	144	169	202	166	177	168	176
TSS, mglL	11	2	3	<1	<1	6	4	1	4
Total Coliform, MPN/100mL	110	20	230	330	2400	800	1700	130	40

Table 9.4(c) Summary Data Table, Water Quality Monitoring of Manurigao River, CY 2005

Parameter	Station 3								
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Color, PCU	3	<1	1	1	1	1	3	1	<1
Temp., ^{O}C	21	23	23	26	26	25	25	25	26
pH	7.6	7.9	8.0	7.8	7.7	7.9	7.3	8.0	7.7
DO, mg/L	8.7	8.2	8.6	8.5	8.5	7.4	8.5	8.1	7.8
BOD, mg/L	0.6	0.6	0.8	0.8	1.2	0.6	0.6	0.8	1.2
TDS, mg/L	135	153	158	236	335	416	172	225	246
TSS, mglL	10	3	<1	<1	4	9	3	1	2
T.Coliform, MPN/100mL	9000	40	110	130	230	5000	5000	2400	130

This kind of table shows how the different parameters relate to each other.

Another common method is to create one table for each water quality parameter. Example Table 9.5 shows the DO concentration along Manurigao River from February 2005 to October 2005.

Example Table 9.5: DO Measurements along Manurigao River

Station No.	Dissolved Oxygen in mg/L(CY 2005)								
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1	8.7	8.7	8.8	8.5	8.5	7.4	8.1	8.4	7.7
2	8.8	8.5	8.3	8.6	8.9	7.8	8.4	8.3	7.8
3	8.7	8.2	8.6	8.5	8.5	7.4	8.5	8.1	7.8

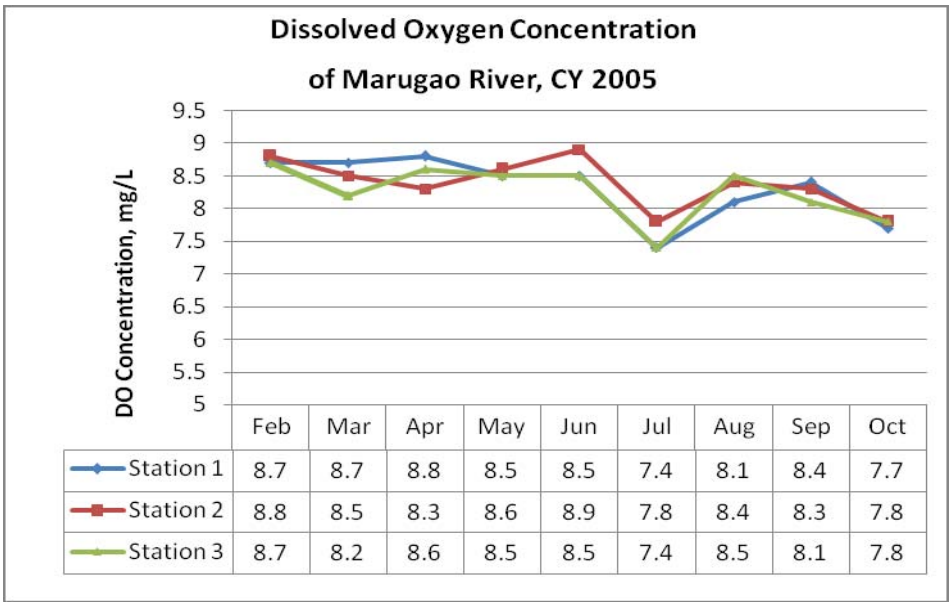
This kind of table shows trend in water quality, such as how a parameter changes over time at one location, or how it changes along the river on a given sampling date.

Based on the examples above, tables can be customized according to the user's needs Tables can be produced by reprocessing and reformatting the data file retrieved for the standard detailed table of WQ test results.

Graphs

With an organized data table, it is now possible to convert data groups into graphs that would enable visualization of trends and correlations among data. Data graphs could be presented in many different ways. The following are some examples.

A **time-history graph** (Fig. 9.1) shows how a physical or chemical parameter changes with time at a sampling location. For instance, the following time-history graph of dissolved oxygen was developed from the data in Example Table 9.5 above:



	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Station 1	8.7	8.7	8.8	8.5	8.5	7.4	8.1	8.4	7.7
Station 2	8.8	8.5	8.3	8.6	8.9	7.8	8.4	8.3	7.8
Station 3	8.7	8.2	8.6	8.5	8.5	7.4	8.5	8.1	7.8

Fig. 9.1 Example of Time History Graph

This graph shows that dissolved oxygen levels dropped in all the three sampling stations in July 2005.

The **spatial-trend graph** (Fig. 9.2) shows how a water quality parameter changes along the river. For instance, the following graph shows dissolved oxygen levels at the three sampling stations of Manurigao River in March 2005, based on the data in Example Table 9.5:

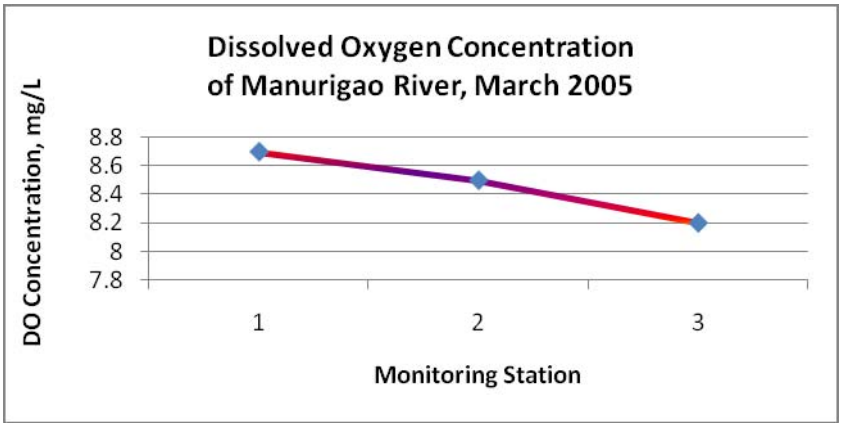


Figure 9.2 Sample Spatial-Trend Graph

The low dissolved oxygen at Station 3 may indicate existence of a pollution source or a condition that may use up DO. The graph also shows that the DO decreases from station 1 to station 3.

A correlation plot shows if a relationship between two physical or chemical parameters exists. For example, based on Example Table 9.4, the DO values can be plotted against the temperature values to see if a relationship exists between them.

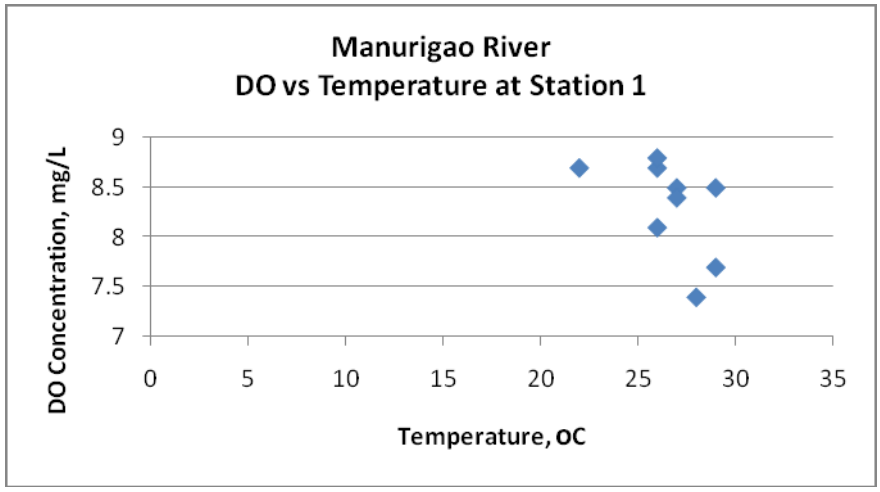


Figure 9.3 Sample Correlation Plot

This plot shows that the DO does not necessarily decrease as the temperature gets higher, probably because the temperature variation is not so wide or because other conditions influence the DO concentration.

9.3 Statistical Analysis

Statistical summary describes large data sets with a few representative values.

Summary statistics are used to present water quality data sets into simpler and more understandable forms, the most common being the mean and median value. Among others, reliable statistical data should be able to provide information on:

- the general water quality at a given site
- whether the water quality is improving or getting worse
- the mass loads of materials moving in and out of water systems
- the sources of pollutants and their scale
- the relationship of the different WQ parameters at given sites
- estimate of future water quality based on past and existing water quality

With inductive statistics, e.g., detecting significant differences, correlations and regressions, the desired information can be obtained from data sets.

The first step in the development of summary statistics is deciding how the data will be organized. Data must be divided into groups, or subsets, that are comparable and can be used to support or refute hypothesis being proven. For instance, to see how the DO concentration in a stream changes with time, data that contain all the analytical results for DO for each sampling event must be grouped together. The average dissolved oxygen for each sampling event then could be calculated and graphed.

The most common statistics are calculated to show **Central or Location Tendency** and **Variability** as discussed below.

Measures of Central or Location Tendency

Measures of Central Tendency are the statistical calculations if one wants to represent a group of data by a single value. This value referred to is the expected or the most-likely value.

The **Arithmetic Mean** or simply **Mean** or the **average value** is the most common measure of location or central tendency. It is the sum of all values divided by the number of values:

$$\text{Mean } (\bar{x}) = (X_1 + X_2 + X_3 + \ldots . X_n) / n$$

Where: X_i = the ith value of the chemical parameter
n = the total number of values

The Mean is very sensitive to outliers or unusually large or low values. Take for example the following data set for fecal coliform from Table 9.4(b).

Table 9.6 (a) Example Table on Application of Arithmetic Mean

Total Coliform, MPN/100mL	110	20	230	330	2400	800	1700	130	40

The Mean of these values is 640 MPN/100ml (100+20+230+330+2400+800+1700+130+40)/9. This mean value passes the guideline values for Class A, Class B and Class C waters. However, assuming that for the same table, the value 2400 was accidentally keyed in as 24000, the resulting table would be:

Table 9.6 (b) Example Table on Application of Geometric Mean

Total Coliform, MPN/100mL	110	20	230	330	**24000**	800	1700	130	40

The Mean of these values, 3040 MPN/100ml exceeds the DENR guideline values for Class AA, Class A and Class B water. The value of 24000 is obviously an outlier in the data set. Given all of the possibilities for measurement error, sampling handling error, and natural variability, the person who checks the data should watch out for outliers or odd figures which can heavily influence the statistical calculations and hence the interpretation of results.

One way to resolve the problem is to calculate the **Geometric Mean**, which is less sensitive to outliers. The Geometric Mean is the nth root of the product of values, where n is the number of samples:

$$\text{Geometric Mean} = (X_1 * X_2 * X_3 \ldots\ldots * X_n)^{1/n}$$

In the example table above, the Geometric Mean is 312 MPN/100ml. In this case, the Geometric Mean passes the DENR guideline value for Classes AA, A and B water.

Another measure of central tendency, the **Median (M)** is the value that has an equal number of values of the data set on either side of it. It is also referred to as the 50th percentile. The Median is not particularly sensitive to outliers. It is a good measure of central tendency in data sets that do not follow a normal bell-curve probability distribution.

To compute M, arrange the data in ascending numerical order. Using the data in Table 9.6(b), the arranged data set would be:

Total Coliform, MPN/100mL	20	40	110	130	230	330	800	1700	24000
	X1	X2	X3	X4	X5	X6	X7	X8	X9

i) If n is odd: $M = (n+1)/2$ order statistics

In the table above, Median ($x1, x2, x3, x4, x5, x6, x7, x8, x9$) = $x5$ = 230

ii) If n is even: M = average {$n/2$)th + (($n/2$)+l)th} order statistics the Median would be: ($x1, x2, x3, x4, x5, x6,$) = ($x3$ + $x4$)/2

As indicated, the Median value in the table above is 230 MPN/100ml.

Measures of Variability

Measures of central tendency describe the most likely value but do not show how the values vary. In the tables below for instance, Set A and Set B both have a Mean value of 230.

Table 9.7 Comparative Table of Mean Values

Set A	143	95	100	70	80	217	250	450	666
Set B	180	245	230	236	260	250	200	225	246

Comparing the mean values of the data sets, it appears they are similar, having similar Mean value. However, on close scrutiny, it can be seen that data set A has wide variability among the individual values while the individual values of data set B are closer to each other. In displaying summary statistics, it is desirable to describe this variability.

The Range, which is the difference between the minimum value and the maximum value, is the simplest measure of variability. It is a crude measure of the spread of the data but is a useful statistic if the data set is very limited. The minimum and maximum values are shown together.

In the example data set for coliform bacteria in Table 9.4(b), the summary statistics can be displayed as follows:

Arithmetic Mean:	3040 MPN/100ml
Geometric Mean:	312 MPN/100ml
Median:	230 MPN/100ml
Range:	20 to 24000 MPN/100ml

Another measure of variability, which is more complicated, is the **standard deviation.** It is calculated from the square of the deviations of each value from the mean.

Standard deviation is a statistical measure of spread or variability. The standard deviation is the root mean square (RMS) deviation of the values from their arithmetic mean. Population Variance is the square of the standard deviation. It is a measure of the degree of spread among a set of values; a measure of the tendency of individual values to vary from the mean value.

Standard deviation is calculated by the following formula:

$$\sigma = \sqrt{\frac{\Sigma\ (x - \bar{x})^2}{n}}$$

Where:

σ = standard deviation.
Σ = the sum of
x = value of sample
$\bar{x}$ = the mean
n = the number of values

For instance, to find the standard deviation of Set B values in Table 9.7, first work out the mean, $\bar{x}$.

$\bar{x}$ = (180+245+230+236+260+250+200+225+246)/9 = 230

Then substract the mean individually from each of the numbers and square the result. This is equivalent to the $(x - \bar{x})^2$ step. The symbol 'x' refers to the values given in the table.

x	180	245	230	236	260	250	200	225	246
$(x - \bar{x})^2$	2522	218	0	33	887	391	913	27	249

Now add up these results, this is the 'sigma' (Σ) in the formula:

- = (2522+218+0+33+887+391+913+27+249)
- = 5242

Divide by the number of values (n), which in this case is 9. This yields 582. And finally, the square root of this is 24.13. Thus, σ = 24.13.

On the other hand, when a set of data (or *samples*) is taken from a certain population, standard deviation must then be expressed in terms of the Sample Variance, where the denominator *n* must be replaced by *n-1*. This allows the computation of standard deviation to eliminate the bias by improving the formula's degrees of freedom.

Grouped Data

When dealing with grouped data, such as the following:

x	180	245	230	236	260	250	200	225	246
f	9	5	14	32	15	6	11	2	9

the formula for standard deviation becomes and the calculation results

$$\sigma = \sqrt{\frac{\Sigma f(x - \bar{x})^2}{\Sigma f}}$$

x	180	245	230	236	260	250	200	225	246
f	9	5	14	32	15	6	11	2	9
$(x - \bar{x})^2$	2522	218	0	33	887	391	913	27	249
$f(x - \bar{x})^2$	22700	1092	1	1068	13301	2347	10047	55	2240

From the data above: $\frac{\Sigma f(x - \bar{x})^2}{\Sigma f} = \frac{52851}{103} = 513$

The square root of this is 22.65. Thus, σ = 22.65.

A **percentile, P** is a value below which falls a given percentage of the observations in the data set. For example, the 80th percentile *P*80 is the value for which 80 per cent of the observations are less than it and 20 per cent greater than it.

Assume that the following are the results of BOD analysis in one monitoring station of Pasig River in 2005 and the Chief of the PCD wishes to find out if the 80th percentile.

Date	BOD, mg/L
01/11/05	38
02/10/05	13
03/10/05	17
04/11/05	15
05/10/05	29
06/11/05	31
07/11/05	30
08/11/05	29
09/12/05	98
10/11/05	5
11/10/05	5
12/12/05	3

To determine the 80th percentile, follow these steps:

(1) Arrange the BOD values from the lowest to the highest then rank.

Date	BOD, mg/L	Rank
12/12/2005	3	1
10/11/2005	5	2
11/10/2005	5	3
2/10/2005	13	4
4/11/2005	15	5
3/10/2005	17	6
5/10/2005	29	7
8/11/2005	29	8
7/11/2005	30	9
6/11/2005	31	10
1/11/2005	38	11
9/12/2005	98	12

(2) Compute the rank (R) of the 80th percentile using the following formula:

$$R = \frac{P}{100}(N + 1)$$

Where: P is the desired percentile (80 in this case)
and N is the number of data (12 in this case).

Therefore,

$$R = \frac{80}{100}(12 + 1)$$

$$R = 10.4$$

If R were an integer, the *80*th percentile would be the number with rank R. But since R is not an integer, compute the *80*th percentile by interpolation as follows:

(a) Define IR as the integer portion of R (the number to the left of the decimal point). For this example, IR=10
(b) Define FR as the fractional portion or R. For this example, FR=0.4
(c) Find the value with Rank I_R and with Rank I_R+1. For this example, this means the value with Rank 10 and the value with Rank 11. The values are 31 and 38.

Date	BOD, mg/L	Rank
12/12/2005	3	1
10/11/2005	5	2
11/10/2005	5	3
2/10/2005	13	4
4/11/2005	15	5
3/10/2005	17	6
5/10/2005	29	7
8/11/2005	29	8
7/11/2005	30	9
6/11/2005	31	10
1/11/2005	38	11
9/12/2005	98	12

(d) Interpolate by multiplying the difference between the scores by F_R and add the result to the lower score.

For this example, this would give:

$$0.4(38-31) + 31 = 33.8$$

Therefore, the 80th percentile is 33.8.

The median and percentiles are often used in water quality assessments to compare the results from measurement stations.
The interpretation of data should be undertaken by professionals who have sufficient background in water quality studies, such as: (i) hydrologists/hydrogeologists, hydrobiologists, chemists, chemical engineers, limnologists, (ii) statisticians or statistical analysts for the data treatment, (iii) professionals from relevant organizations such national government agencies and academe.

CHAPTER X
REPORT PREPARATION

10.1 Introduction

The last step in the monitoring process is the preparation of report. Even if data are correctly interpreted, they will not be useful if they could not be presented in a manner that can be understood by intended readers. The form and level of data presentation is, therefore, crucial. The type of report to produce or publish would depend on the intended reader.

A comprehensive report that contains all relevant data and interpretations would be required by the scientific community and regulatory agencies. On the other hand, heads of local government and the public would be more interested in a simple and brief report or summary report that merely highlights the major findings and contains illustrations for ease of understanding.

10.2 Suggested Outline of Report

A comprehensive water quality monitoring report should include the following:

1. Cover Page

   The cover page should contain the name and address of the organization or entity preparing the report, the title of the report, and the month and year the report was prepared.

2. Table of Contents

   The Table of Contents shows how the report was organized into sections or chapters and in which pages certain topics can be found. The lists of figures, tables, attachments, appendices, annexes, references and definition of terms, if necessary, should be included in the Table of Contents and the pages where these figures, tables, etc. appear should also be indicated.

3. Executive Summary

An Executive Summary highlights the salient parts of the report, and includes a brief description of the waters being monitored, methodology, summary of findings and conclusions or recommendations. The executive summary is usually sufficient for reports to head of offices or agencies.

4. Main Report

The main report should include the following topics in sections or chapters.

(1) Background information

Description of the water body including a short description of its administrative boundaries, physical characteristics as size of drainage area, depth, width, surface area, length, flow direction, general behavior, discharge and general description of land uses, biological health, etc.

Description of the topography, soil type, vegetation cover and the present land uses, and other factors that may affect water quality such as climate, rainfall and wind directions. Estimated vegetation cover/denuded areas (hectare). As much as possible, describe the history of vegetation within and in the immediate vicinity of the river basin or drainage area.

Description of the existing uses or potential uses of the water. If the water has been classified, it is suggested to include information on the existing classification and existing water quality.

A location or vicinity map of the water body should be attached. It is advisable to attach also a map showing the sampling or monitoring stations.

(2). Objective

Description of the objectives of monitoring-both the general objectives and the specific objectives.

(3). Methodology

The methodology should include coverage of the monitoring, description of the sampling site, sampling method, sample containers, preservation and analytical procedure used for each parameter monitored. It should also include the frequency and timing of monitoring and the duration of monitoring. Deviations, if any, from the recommended methods should be explained.

(4). Results and Discussions

The results of monitoring should be presented using tables and graphs, and correlations as appropriate. There are various ways by which results could be presented, as discussed in Chapter X. The choice of schemes would depend on the objective of the report and the intended readers, as well as on the discretion and professional judgment of the person preparing the report. Reports should be presented in formats that are easy to understand. If necessary, photographs can be used to aid in visualization of the site conditions.

(5). Findings and Recommendations

This section summarizes the findings and inferences based on the findings. Depending on the outcome, it may include recommendations for further studies, management interventions, or other actions to protect the existing water quality and uses or to improve water quality to meet the designated uses.

(6). Annexes and Attachments

The filled in survey forms, COCs and documentation of participatory mapping, and minutes of meetings and public consultations shall be attached.

(7). References. References should be properly cited.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ATTACHMENTS

ANNEXES

Attachment 3.1

SAMPLE ONLY
NO TECHNICAL BASIS

WATER QUALITY SAMPLING PLAN

CALBAYOG RIVER

CALBAYOG CITY, PROVINCE OF SAMAR

January 2008

1. Introduction

The Calbayog river system is the main river within the City of Calbayog. It serves as a transport route between Calbayog City and some coastal barangays and functions as the main drainage outlet of practically all surface runoff and liquid discharges from the core area of Calbayog City. Calbayog River does not have existing classification.

2. Monitoring Objectives

A water quality monitoring program is planned to be undertaken to:

- Establish water quality baseline data for Calbayog River.
- To check whether the current water quality conforms to the beneficial uses of the river and proposed classification.

Water quality survey including a survey of pollution sources will be carried out as part of the monitoring plan.

3. Scope of the Monitoring

(1) Sampling of water from selected sites along Calbayog River and selected tributaries. Testing the samples for primary water quality parameters and selected secondary parameters. These include pH, temperature, DO, BOD_5, TSS, chloride, fecal coliform, mineral fat and oil, ammoniacal nitrogen and phosphate.
(2) Survey of both point and non-point sources of wastewater discharges. The following data will be gathered:
    (a) Total area, area of urban section, area of sub-urban section, agricultural section and other land uses
    (b) Population and population projections
    (c) Data on sewage connections and sanitation facilities
    (d) Industries, business, commercial and government establishments and economic activities that may contribute to pollution load to Calbayog River

4. Monitoring Team

The monitoring team consists of the following:
Engr. _____ – Supg. Water Qlty. Specialist (Team Leader)
Ms. _____ – Supervisor (water sampling)
Mr. _____ – Team Member (water sampling)
Mr. _____ _ Team Member/Driver

All the members of the team are experienced and properly trained in water quality monitoring.

5. Monitoring Stations, Sample Timing and Frequency and Sampling Method

(a) Monitoring Station

The following monitoring stations have been identified based on preliminary survey and review of existing data:

Station No.	Name of River	Distance from Mouth, km	Location	GPS Coordinates
1	Calbayog River	0		
2	Calbayog River	3		
3	Calbayog River	6		
4	Nijawan River	Confluence with Calbayog River near the mouth		
5	River No. 3 (Unidentified)	Confluence with Calbayog River 4.2 km upstream from the mouth		

(b) Sample timing, frequency and sampling method.

Water sampling will be undertaken monthly from March 2008 to October 2008. One grab sample will be taken from each sampling station for all parameters for analysis. Sampling will be done using a boat where the river is not wadeable, i.e., Stations 1, 2, and 4. Sampling at station Stations 3 and 5 will be by wading.

6. Analytical Methods

(a) On site measurement

The following parameters will be measured on site using meter and probe (multiparameter checker)

- Temperature
- pH
- DO

(b) Sample Handling and Preservation

The following protocol will be observed for the samples to be analyzed in the laboratory.

Parameter	Volume Requirement (ml)	Container	Preservation	Holding Time
BOD	1,000	P,G	Cool, 4^0C	24 hours
Total Suspended Solids	1,000	P,G	None required	24 hours
N-NH3	50	G	Cool, 4^0C H2SO4 to pH < 2	24 hours
Phosphate	25	P,G	Filter on site Cool, 4^0C	24 hrs
Chloride	50	P,G	Cool, 4^0C	28days
AVFO	1,000	G only	Cool, 4^0C, HCl to pH <2	24 hours
Petroleum Oil	1,000	G only	Cool, 4^0C, HCl to pH <2	24 hours

The water samples for laboratory analysis will be sent to the laboratory as soon as possible. In the absence of complete laboratory facility in Calbayog City, the samples will be transported to Tacloban City EMB Region 8 Laboratory for analysis. Coordination with the Laboratory has been undertaken to confirm the date and time of arrival of samples. Sampling will be timed so that the water samples can be transported at the earliest time in consideration of the limited holding time for some samples.

7. Quality Assurance/Quality Control

Quality assurance will be achieved by closely following the Procedural Manual on Ambient Water Quality Monitoring of the Philippines. A copy of the manual will be brought to the field for reference in case issues arise during actual field monitoring. Field monitoring equipment will be calibrated according to the manufacture's guidelines. Calibrations will also be recorded in the calibration log book. Calibration solutions will be used in accordance with manufacture's recommendations.

Field notebooks will be made available to the monitoring team and kept on file after completion of the monitoring for use in succeeding activities and future reference. Field conditions, field observations, sampling location information and narrative information concerning any special circumstances or corrective action will be recorded in the field notebooks.

Samples will be labeled in the field. Sample location, date of collection, water body name and the initials of the sample collector will be included on sample identification labels. The standard field data form and COC form will be used to record time of sample collection and chain of custody.

Attention will be paid to proper packing of samples to prevent contamination and breakage of sample containers during transport.

8. Data Management And Presentation

   The Team Leader will be responsible for receiving and safekeeping of the data forms and field/ laboratory notebooks, checking for errors in identification, decimal placement, dates, times, units reported and comments. Personnel collecting data will be contacted immediately if there are data gaps or if scheduled sampling times were missed.

   Test results will be evaluated individually by performing appropriate mathematical analysis for precision or accuracy for each sample. The Team Leader will be allowed access to project data and submit reports to data users. All data will be accompanied by quality control information.

   Data will be printed out in lists and graphs with lists checked against original data forms. The Team Leader will be responsible for correcting data entry errors. It is also his responsibility to evaluate the raw data generated by the EMB Region 8 laboratory for appropriate numeric reduction, data quality, and accuracy. All data will be reviewed and reported in units specified at the detection level of the analytical methods used.

   Data analysis will involve calculation of geometric means according to the WQ Monitoring Manual All data will be organized in spreadsheet format, and charts and/or graphs will be generated when needed.

   The monitoring team will compile water quality data and submit the information to EMB Central Office for review.

Prepared and submitted by:

_____
Supervising Water Quality Specialist
Team Leader

Recommending Approval

_____
Chief, Pollution Control Division

Approved:

_____
Regional Director

SITE ASSESSMENT FORM

Name of River/Stream:							
Sampling Station ID No:							
Distance from Previous Station: _____ kilometer _____ meters							
Description of Flow:		Turbulent					
		Silent					
Stages of Flow:		Upstream					
		Downstream					
Average Width of River/Stream at Station (in meters):							
Depth of River at Station (in meters):							
Section 1:	Section 2:	Section 3:	Average:				
Surface Velocity (in meters/second):							
Section 1:	Section 2:	Section 3:	Average:				
Stream Flow rate:							
Nature of River Bottom: (bedrock, sand, clay, silt, gravel, with solid waste, etc.)							
Bank and Riparian Vegetation: (check all that applies)							
		Weeds		Reeds (tambo, etc)			
		vines					
River Classification:		AA		C			
		A		D			
		B					
If unclassified, described current usage:							
		source of water supply					
		recreational (bathing, swimming, etc.)					
		agriculture, irrigation, livestock watering, etc.					
		fishing (propagation & growth of aquatic resources					
Proximity to Common Sources of Contamination (attach photos)							
a. common sources				b. distance from the source			
		settlement area (residential, etc.)		within 500 meter radius			
		Industry (power plant, paper mills.etc)		within 1 kilometer radius			
		agricultural area		> 1 kilometer radius			
		eroded stream banks/landslides/algal growth					
Specify the types of industry closest to the site:							
		Quarrying					
		Smelting					
		manufacturing & processing					
Accessibility to the Site:							
		paved road		dirt road		private property	
		bridge		no access			

Recommendation:

☐ Proposed as a sampling station ☐ Not Proposed

Assessed by: _____

Position: _____

VISUAL STREAM SURVEY

Helpful Hint: To facilitate the survey, it would be very helpful to bring along copy of a topographic map and a GPS to confirm exact survey boundaries. Observations such as conditions of watershed may be noted on the maps as necessary.

I. BASIC INFORMATION

Sampling Station No. _____Name of River: _____

Location: _____
(Barangay, Municipality/Province/Region)

Upstream boundary: _____ Coordinates: _____
(Barangay, Municipality/Province/Region)

Downstream boundary: _____ Coordinates: _____
(Barangay, Municipality/Province/Region)

Total River Length: _____ km Length of stream surveyed: _____ (m)

Date: _____ Time _____ hrs Weather: _____

Survey undertaken by: _____Position: _____

Survey supervised by: _____

II. BANK AND IN-STREAM CHARACTERISTICS

1. **Use of Flood plain**: industrial _____% commercial _____% residential _____% pasture/grassland _____%, woodland_____% others (agriculture) _____% _____% roadway/pavement (Note: Items must sum up to 100%)

2. **Riparian cover**: trees _____% grasses or weeds _____ % bare area_____% paved area _____% , buildings_____% others (bamboo stands) _____% (Note: Items must sum up to 100%)

3. **River bank conditions**: trees _____% grasses or weeds _____% bare area _____% paved area _____% , buildings_____% others _____% (Note: Items must sum up to 100%)

4. **Water flow**: Present conditions: Check as appropriate;

   _____ in channel ____ flooding over banks _____ dry/no flow/pooling

5. **Flow Rate:** _____ m (determined by flow measurements, see Attachment 4)

6. **Tidal Influence**: Is waterway influenced by tides? ____ Yes _____ No; If yes, when? _____ If influenced by tide: Tide was: ____ rising _____ falling

   Tide was: ____ high _____ mid-range _____ low

7. **Bed composition**: silt or mud _____%, sand _____% gravel _____ %

   Cobble (2-10") _____ % boulders >10" _____% bedrock _____ %

8. **Percent embeddedness of cobble substrate** = _____+_____ + _____ + _____+ _____ ÷5 = _____% Some what/not embedded (0-25%) halfway embedded (50%) Mostly embedded (75%) completely embedded (100%)

(Note: Applicable only to riffle areas, not to pools or runs. Fill out only if applicable to stream being surveyed.)

9. **Presence of naturally occurring organic material in stream (good habitat for aquatic organisms)**

Logs or wooden debris: ____ none ____ occasional ____ plentiful

Leaves, twigs, rootmass, etc. ____ none _____ occasional ____plentiful

10. **Alga**e: Percentage of stream bottom covered by visible algae? _____%

close growing (cluster): _____% Filamentous (strands over 2" long) _____

= 100%

11. **Water clarity**: Check all that apply (determine by viewing sample water in a clear container)

_____ turbid: suspended matter in water : _____ sediment ___ blue/green algae _____ (leaves)

_____ tannic: clear water that is naturally stained orange/brown due to organic acids

_____ no staining/no suspended matter

_____ others (i.e., chemical discharge, dyes)

12. **Color of water** (describe) _____

13. **Odor of water** (describe) _____

14. **Bank erosion:**

a. How vegetated is the <u>left</u> bank, looking downstream, for the length of the river reach being surveyed (circle a percentage)

Vegetated bank Bare/eroded bank

<u>100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%</u>

What are the visual indicators used to assess the percentage above? (check all that apply)

____ exposed soil ____ obvious soil loss _____soil covered with vegetation

____ steep slopes (U-shaped banks) ____ gentle slopes

____ exposed roots _____no exposed roots

b. How vegetated is the right bank, looking downstream, for the length of the river reach being surveyed (circle a percentage)

Vegetated bank Bare/eroded bank

100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%

What are the visual indicators used to assess the percentage above? (check all that apply)

What are the visual indicators used to assess the percentage above? (check all that apply)

____ exposed soil ____ obvious soil loss _____ soil covered with vegetation

____ steep slopes (U-shaped banks) ____gentle slopes

____ exposed roots _____ no exposed roots

Indications of human use:

_____

_____

_____

16. **Additional Comments**:

_____

_____

_____

_____

III. AQUATIC BIOTA CHECKLIST (Optional)

1. Wildlife in or around the stream: Check opposite column if present.

Mammals		Reptiles	
Amphibians		Mussels/shells/clams/oysters	
Waterfowls		Crustaceans	

2. Fish in the stream: (Check all that apply)

Sizes	**None**	**Abundant**	**Rare**
Small (1-2")			
Medium (3-6")			
Large (7" and above)			

3. Aquatic plants in the stream (check all that apply)

Plant type	Frequency of Occurrence	Where found		
		Stream Edge	Pools	Near Riffle
Attached plants:	None			
	Occasional			
	Plentiful			
Free-floating plants:	None			
	Occasional			
	Plentiful			

4. Extent of algae in the stream: Are there submerged stones, twigs, or other material in the stream coated with a layer of algae? (Check all that apply)

Color	Frequency of Occurrence	Type of Coating	
		Light	Heavy
Brownish	None		
	Occasional		
	Plentiful		
Greenish	None		
	Occasional		
	Plentiful		
Others			

5. Are there filamentous (string-like) algae?

Color	**None**	**Occasional**	**Plentiful**
Brownish			
Greenish			
Other			

6. Are there detached "clumps" or "mats" of algae floating on the water's surface?

Color	**None**	**Occasional**	**Plentiful**
Brownish			
Greenish			
Other			

7. Stream shade cover: How well is the water surface shaded by vegetation: (Looking downstream). 100% means total shading, 0% means no shading. Encircle based on best estimate.

100	90	80	70	60	50	40	30	20	0

Write down additional comments/observations: _____

_____

_____

_____

IV. LAND USES

1. Identify land uses and activities in the basin area that have the potential to affect water bodies.

(Check all the boxes that apply, describe the location of the activity(ies) and indicate the location on your map. If the activities are frequently occurring, indicate on the note.

Please indicate if you: _____ Surveyed only the area adjacent to the waterbody

_____ Surveyed the entire drainage area

Land Disturbing Activities & Other Sources of Sediment	**Adjacent to Water**	**In Watershed**	**Notes on location & frequency of activity**
Extensive areas disturbed by land development or construction of utilities, roads & bridges	☐	☐	_____
Large or extensive gullies	☐	☐	_____
Unpaved roads near or crossing streams	☐	☐	_____
Croplands	☐	☐	_____
Pastures with cattle access to water bodies	☐	☐	_____
Commercial forestry activities including harvesting and site-preparation	☐	☐	_____
Extensive areas of streambank failure or channel enlargement	☐	☐	_____
Other Agricultural Activities			
Confined animal (cattle or swine) feeding operations and concentrations of animals	☐	☐	_____

Animal waste stabilization ponds	☐	☐	
Poultry houses	☐	☐	
Highways and Parking Areas			
Shopping centers & commercial areas	☐	☐	
Interstate and controlled access highways and interchanges	☐	☐	
Major highways and arterial streets	☐	☐	
Other extensive vehicle parking areas	☐	☐	
Mining			
Quarries with sediment basins in live flowing streams	☐	☐	
Transportation and Motor Vehicle Services			
Truck cleaning services	☐	☐	
Public and private automobile repair facilities	☐	☐	
Car washes and large auto dealers	☐	☐	
Rail or container transfer yards	☐	☐	
Airports with fuel handling / aircraft repair	☐	☐	
Business & Industry, General			
Activities with exterior storage or exchange of materials	☐	☐	
Activities with poor housekeeping practices indicated by stains leading to streams or storm drains or on-site disposal of waste materials	☐	☐	
Heavy industries such as textiles & carpet, pulp & paper, metal, and vehicle production or fabrication	☐	☐	
Dry cleaners / outside chemical storage	☐	☐	
Food & Kindred Products			
Fertilizer production plants	☐	☐	

Feed preparation plants	☐	☐	_____
Meat and poultry slaughtering or processing plants	☐	☐	_____
Construction Materials			
Wood treatment plants	☐	☐	_____
Concrete and asphalt batch plants	☐	☐	_____
Waste Recycling, Movement & Disposal			
Junk and auto salvage yards	☐	☐	_____
Solid waste transfer stations	☐	☐	_____
Landfills and dumps (old & active)	☐	☐	_____
Recycling centers	☐	☐	_____
Drum cleaning sites	☐	☐	_____
Illicit Waste Discharge*			
Sanitary sewer leaks or failure	☐	☐	_____
Overflowing sanitary sewer manholes due to clogging or hydraulic overloading	☐	☐	_____
By passes at treatment plants or relief valves in hydraulically overloaded sanitary sewer lines	☐	☐	_____
Domestic or industrial discharges	☐	☐	_____
Extensive areas with aged/malfunctioning septic tanks	☐	☐	_____
Dry-weather flows from pipes (with detectable indications of pollution)	☐	☐	_____
Streamside areas of illegal dumping	☐	☐	_____

- If found (most likely during stream surveys), these activities should be immediately reported to the local government or EMB regional office.

V. GENERAL WATERBODY AND WATERSHED CHARACTERISTICS

This information may be obtained during the KII.

1. **Note the number of hydrologic modifications on your waterbody:** *structures that alter water flow*

None	_____	Dredge spoils	_____
Dams	_____	Pipes	_____
Bridges	_____	Waterfalls	_____
Others	_____		

2. **Note the approximate length of the stream that is affected by the following:** *if assessing a wetland, lake or pond, some of the following may also affect your waterbody*

Stream culvert	_____ meter or _____ km or _____% of stream length
Stream straightening	_____ meter or _____ km or _____%
Concrete streambank/bottom	_____ meter or _____ km or _____%
Dredging/channelization	_____ meter or _____ km or _____%
Riprap/gabion	_____ meter or _____ km or _____%
Cattle crossing	_____#
Stream crossing *(for vehicles)*	_____#

3. **Note extent of vegetative buffer along the banks*:*** *at a minimum of 5 sites*, at regular intervals (every 250 m in a 1-kilometer section) note the following*

#	**Width in meter**	**Location (Left bank, Right bank or N, S, E, W side of wetland or lake**	**Characteristics and comments**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

4. **Check the categories that best describe the general appearance of the waterbody:**

Litter:

- ☐ No litter visible
- ☐ Small litter occasionally (i.e., cans, paper)
- ☐ Small litter common
- ☐ Large litter occasionally (i.e., tires, pallets, shopping carts)
- ☐ Large litter common

Special Problems:

Spills of chemicals, oil, etc.
Fish kills
Wildlife, waterfowl kills

Erosion:

No bank erosion or areas of erosion very rare; no artificial stabilization
Occasional areas of bank erosion
Areas of bank erosion common
Artificial bank stabilization (i.e., riprap) present

5. **Comments on general waterbody and watershed characteristics:** (e.g. date and size of fish kill, increased rate of erosion evident, litter most evident after storms)
   * Fish kills should be immediately reported to DENR Wildlife Resources Division or to the BFAR.

6. **Summarize notable changes that have taken place since last year (if this is not your first year conducting the Watershed Survey).**

I. PIPE AND DRAINAGE DITCH INVENTORY

In this section, provide information on pipes and drainage ditches found on the banks or in the waterbody. These pipes/ditches can be abandoned or active. Note the information for each pipe or drainage ditch you observe. *Make additional copies as necessary.*

Pipe #	Location	Type	Size	Flow	Waterbody condition	Comments

1. **Number each pipe/ditch** for mapping/locating purposes
2. **Location of pipe/ditch**: note whether in water, bank, near waterbody or other. Describe location.
3. **Identify type of pipe (list all that apply)**: PVC, iron, concrete, galvanized; industrial outfall, sewage treatment plant outfall, storm drain, combined sewer overflow; agricultural field drainage, paddock or feedlot drainage, settlement basin/pond drainage, parking lot drainage unknown, other.
4. **Size**: **measure approximate diameter of pipe:** inches or centimeters
5. **Describe the discharge flow**: Rate of flow: none, intermittent, trickle, steady, heavy
   Appearance: clear, foamy, turbid, oil sheen, color, other
   Odor: none, rotten eggs/sewage, chemical, chlorine, other
6. Waterbody condition: describe the bank/waterbody below pipe or drainage ditch: no problem evident, eroded, sewage litter (e.g. toilet paper), litter (e.g. bottles, cans), lots of algae, other
7. Comments of pipes and drainage ditches: Use this space to explain or expand on information provided on pipes and discharges you have identified above. For example, you may want to identify particular facilities, or discuss in more detail the condition of the waterbody below the discharge. Use separate page if necessary.

KEY INFORMANT SURVEY QUESTIONNAIRE/ PARTICIPATORY MAPPING GUIDE

Characterization of Biophysical Environment

With the use of a topographic map and provincial/municipal/ barangay boundary maps, identify a reference point (e.g., the barangay hall or the place where you are holding the meeting) and from there, mark the landmarks that will be identified from the survey. To facilitate the survey, it is advisable to use local dialect as the medium of communication. Request the key informants to identify the following:

a. The names of barangays and municipalities within the survey area
b. The names of the rivers within the survey area. Which is the principal river, which are the secondary rivers? Where are the river boundaries?
c. Where do the rivers originate? Where do the rivers drain?
d. Approximately how long are the rivers, how wide and how deep? Describe the general physical character of the river and riverine area (e.g, meandering, shallow and wide, deep and wide, rocky bottom, soft bottom)
e. What are the existing uses of the rivers? Identify the points where the uses change.
f. Are there endemic aquatic species? Do the river serve as habitat for wild animals? .
g. Are there protected areas in the locality? Where are the boundaries of such areas? Are there other important /historical landmarks?
h. Are there intake facilities for public drinking water supply? Which areas do these facilities serve?
i. Are there intake facilities for irrigation? What areas do these facilities serve?
j. Are there man-made dams? What are these for?
k. Are there lakes, reservoir, and similar water bodies? What are current uses of such bodies of water?
l. When is the rainy season? Dry season?
m. What are the existing uses of the watershed/river basin area? Where are the boundaries of these uses?
n. Identify and locate on the map: mine sites, quarry sites, landslide prone areas, piggeries/cattlefarms/poultry, kaingin areas, plantations, landfill site or dumpsite
o. Identify and locate the housing clusters, industrial areas, other major land development areas

Attachment 5.1

WATER QUALITY MONITORING
FIELD DATA FORM

Name of Waterbody: _____

Date of Sampling: _____ Sampling Team _____

Parameter	Sampling Site						
	1	2	3	4	5	6	7
GPS Coordinates							
Time of Sampling							
Air Temperature							
Cloud Cover %							
Weather condition							
Visual Color of Water							
Other Observation							
On-Site Analysis							
pH							
Temperature							
D.O							
Transparency*							
Conductivity*							

Sample for Laboratory Analysis:

Parameter for Analysis	**Sample Volume (ml)**	**Container Type**	**Sampling Method**	**Preservation Done**

Attachment 5.2

SS/COC Control #

SAMPLE SUBMITTAL/CHAIN OF CUSTODY FORM

Client/Facility/Source: WQMS

Tel: 920-22-73

Fax:

Department of Environment and Natural Resources
ENVIRONMENTAL MANAGEMENT BUREAU
Research and Development Division
DENR Compound, Visayas Avenue, Diliman, Quezon City
Tel. Nos. (0632)-4264338/4339; Fax. No. (0632) 426-4335/4340

Contact Address: EMB, DENR Cpd., Visayas Avenue, Diliman, Quezon City

Project Name: Bathing Water Quality Monitoring

Sampled by: Leza A. Acorda, et. al.

Sampling Source: Manila Bay (Bataan Coastal Waters)

Submitted by: Leza A. Acorda

Date mm/dd/yy:

Time: ____ a.m. ____ p.m.

Special Instructions/Comments:

FOR LABORATORY USE ONLY

Mode of Delivery	Condition Received	Category of Sample	Payment
☐ Walk - In EMB ☐ PENRO/CENRO ☐ Courier ☐ Others _____	☐ Frozen ☐ Y ☐ N Sealed ☐ Cold ☐ Y ☐ N Container Intact ☐ Ambient ☐ Y ☐ N # of sples match COC ☐ Preserved ☐ Others, _____	☐ Private ☐ Regional ☐ Project ☐ EMB ☐ Other	OP NO: Amount:

Received by: (Signature & Printed Name)

Date: mm/dd/yy

Time: ___AM ___PM

Total # of Samples Received: _____

Samples Relinquished To

Lab. Sample No.	Station No./Pt.	Sample identification	Sample Type	Date/ Time Sampled mm/dd/yy	am	pm	Analyses Requested	Field Preservation	Container #	Container Type	Quantity Received
		Metal	SW	**10/8/2007**	8:30		Total and Fecal Coliform	Ice		G (B)	
		Villa Carmen	SW	**10/8/2007**	9:00					G (B)	
		Brgy Wawa	SW	**10/8/2007**	9:30					G (B)	
		Villa Leonor	SW	**10/8/2007**	10:00					G (B)	

Lab Unit Concerned:

Date: mm/dd/yr

Time: _____a.m. _____ p.m.

Name/Initial of Lab Personnel:

Remarks:

Sample Type

A (A)-ambient air A (S)- Source emission
B- Brook Creek- Creek Falls - Falls F- fishpond L-lake RW-river water SW-sea water S-spring water
C - Crustacean Fish - Fish SG- sea grass Sed - Sediment SF - Shellfish
DW- deep well TW- treated water
IN- influent EF - effluent MW - mining waste OF- outfall WW - wastewater
QC-QC/PT sample LF- landfill SE- sewage Rain-rainwater Sludge- sludge oil- oil others _____

Container Type

Al-aluminum foil G-glass P-plastic G(B) glass borosilicate Al(S)-aluminum foil, solvent, rinsed G(E)-Glass Sterile
G(S) glass solvent rinsed G (A)or (PA)- glass or plastic, acid washed O- others, specify _____

Sample Source

☐ Air
■ Surface water
☐ Ground/ drinking water
☐ Biota/sediments
☐ Industries
☐ Other

Sample Disposal

☐ Laboratory Procedure
☐ Other procedure, specify _____
Total Quantity Disposed:
☐ _____ milliliters ☐ _____ grams

Disposed by: Date:
(Signature and Printed Name)

Other Comments:

MODIFIED GARBER CLASSIFICATION INDEX

CODE	IDENTIFICATION	APPLICATION
C	Clear water	Clear, no off color or particulate floating matter, no slicks or oil
D	Ocean Debris	Drifting objects from trees or large land borne plants
WH	Drifting freshwater plants	Water hyacinths, etc.
K*	Sewage debris	Garbage from raw sewage or dump sites
HL*	Human fecal matter	Intact human feces
CC*	Rubber goods	Any kind of rubber goods
R*	Refuse or garbage from beach or land use	Domestic trash such as cartoons, cans, boxes, bottles, and garbage from use of beach recreation areas
TR*	Floating trash and garbage from boats and ships	Similar to R above but judged to originate from boats or ships
S	Seaweed	Any kind of seaweed
B	Dead bird	Any dead marine bird
ML	Dead marine life	Fish and other marine animal
P	Plankton bloom or rafts	Plankton bloom discoloration of water
SP	Spores	Usually kelp spores that appear as a surface scum or film
O*	Oil	Mineral oil from ships or other sources. Ship bilge pumping, fuel spills, etc.
OS*	Mineral oil scum	Mineral oil slicks associated with natural oil seeps
G*	Particulate grease, sewage origin	Grease particles or balls near waste outlet
GS	Grease, scum, sewage origin	Slick appearing to originate at a sewage discharge point
T*	Tar	Mineral oil tar
N*	Noxious odors, fumes or gas- sewage	Sewage or treated sewage odors present in water or along beach
M*	Murky dirty	Water dirtied by causes other than plankton bloom. M1- 2m Secchi, M2- approx. 1.5m Secchi, M3- approx 1m Secchi
F	Outflow of water to ocean from land	Usually storm drain outflow which can affect ocean water condition
QUANTITY		
1	Low density	Visible floatables with distance between objects of same code more than 10 meters
2	Medium density	Two or more objects of same code visible within a quadratic area of 10 x 10 sq.m., but not classified as 3.
3	High density	Two or more objects of same code visible within a quadratic area of 1x1 sq. m.

* Indicates human-controllable waste product

Attachment 8.1.2

LITTER INDEX

STATION	NO OF DAYS	NO. OF CLEAR DAYS	CONTROLLABLE WASTES Iw	NATURAL OBJECTS In

ANNEX A
PROFILE OF THE WATER QUALITY PARAMETERS

1. Primary Parameters

The primary parameters include BOD, Chloride, Color (True), DO, Fecal Coliform, Nitrate as NO_3-N, pH, Phosphate, Temperature and Total Suspended Solids.

1.1 Biochemical Oxygen Demand (BOD)

(1) Basic Information

Biochemical Oxygen Demand or Biological Oxygen Demand (BOD) is a measure of how much oxygen is consumed by bacteria or microbes as they break down organic pollutant in water.

BOD is typically divided into two parts- carbonaceous oxygen demand and nitrogenous oxygen demand. Carbonaceous biochemical oxygen demand (CBOD) is the result of the breakdown of organic molecules such a cellulose and sugars into carbon dioxide and water. Nitrogenous biochemical oxygen demand is the result of the breakdown of proteins. Proteins contain sugars linked to nitrogen. After the nitrogen is "broken off" as sugar molecule, it is usually in the form of ammonia, which is readily converted to nitrate in the environment. The conversion of ammonia to nitrate requires more than four times the amount of oxygen as the conversion of an equal amount of sugar to carbon dioxide and water.

(2) Significance in Water Quality Monitoring

BOD measures the rate of oxygen used up by micro-organisms in a sample of water at a fixed temperature ($20^{O}C$) and over a given period of time in the dark. The BOD test is widely used to determine the pollution strength of domestic and industrial wastes. It is useful in determining the degree of pollution of streams and lakes at any time and hence can be used in determining the purification capacities of bodies of waters receiving organic wastes.

The test generally takes place over an elapsed period of five days, but other BOD tests are also used. The 5-day BOD (BOD_5) represents the amount of oxygen consumed by microorganisms to break down the organic matter present in the sample bottle during the incubation period.

The loss of DO in the sample, once corrections have been made for the degree of dilution, is called the BOD_5.
BOD is calculated by the following formula:

Undiluted: BOD = Initial DO – Final DO
Diluted: ((Initial DO – Final DO) –BOD of seed) x Dilution Factor

1.2 Chloride

(1) Basic Information

Chlorides are widely distributed in nature as salts of sodium (NaCl or table salt), potassium (KCl), and calcium ($CaCl_2$). It is a useful and reliable chemical indicator of river and groundwater fecal contamination because it is not reactive and is always present in sewage.

High chloride in a fresh water body could be an indication of salt water intrusion.

(2) Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	**Sodium Chloride**	**Potassium Chloride**	**Calcium Chloride**
Name: (Common)/ Other Name	Table salt, common salt, halite	Muriate of potash	Calcium dichloride
CAS No.	7647-14-5	7447-40-7	10043-52-4
Molecular Formula	NaCl	KCl	$CaCl_2$
Melting Point, ^{O}C	804	776	772 (anhydrous)
Molar mass, g/mol	58.442	74.551	
Boiling Point, ^{O}C	1413	-	>1600
Density, g/cm^3	2.16	1.987	2.15 (anhydrous) 0.835 (dehydrate) 1.71(hexahydrate)
Solubility in Water	35.7 g/100g at 0^{O}C	34.0 g/100 cm^3 (20^{O}C); 56.7 g/100 cm^3 (100^{O}C);	74.5 g/100 mL (20^{O}C)
Appearance	white or colorless crystals or powder	White crystalline solid	white or colorless solid
Chemical Properties:			
Sodium Chloride			
Potassium Chloride	Potassium chloride can react as a source of chloride ion. As with any other soluble ionic chloride, it will precipitate insoluble chloride salts		

	when added to a solution of an appropriate metal ion: $KCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + KNO_3(aq)$ Although potassium is more electropositive than sodium, KCl can be reduced to the metal by reaction with metallic sodium at 850^{o}C because the potassium is removed by distillation: $KCl(l) + Na(l) \circledcirc NaCl(l) + K(g)$ This method is the main method for producing metallic potassium. Electrolysis (used for sodium) fails because of the high solubility of potassium in molten KCl. As with other compounds containing potassium, KCl in powdered form gives a lilac flame test result.
Calcium Chloride	Calcium chloride can serve as a source of calcium ions in solution for instance for precipitation because many calcium compounds are insoluble: $3\ CaCl_2(aq) + 2\ K_3PO_4(aq) \rightarrow Ca_3(PO_4)_2(s) + 6\ KCl(aq)$ Molten $CaCl_2$ can be electrolysed to give calcium metal: $CaCl_2(l) \rightarrow Ca(s) + Cl_2(g)$

(3) Impact on Human Health

(a) Sodium Chloride

Inhalation may cause mild irritation to the respiratory tract. Ingestion of very large doses can cause vomiting, diarrhea, and prostration. Dehydration and congestion occur in most internal organs. Hypertonic salt solutions can produce violent inflammatory reactions in the gastrointestinal tract. It may irritate damaged skin on contact; absorption can occur with effects similar to those of ingestion. It also causes eye irritation, redness, and pain for salt concentrations greater than the normal saline present.

Sodium chloride toxicity has not been observed in humans except in the special case of sodium chloride metabolism such as congestive heart failure. Healthy individuals can tolerate intake of large quantities of chloride provided they drink sufficient amount of fresh water. Little is known about the effect of prolonged intake of large amounts of chloride in the diet.[1]

[1] http://www.who.int/Chloride in Drinking Water, Background document for development of WHO guidelines for drinking water quality

(b) Potassium Chloride

Potassium chloride is an essential constituent of the body for intracellular osmotic pressure and buffering, cell permeability, acid-base balance, muscle contraction and nerve function. In humans, acute oral toxicity is rare because large single doses induce nausea and vomiting, and because KCl is rapidly excreted in the absence of any pre-existing kidney damage.

(c) Calcium Chloride

Calcium chloride is easily dissociated into calcium and chloride ions in water. Calcium is essential for the formation of skeletons, neural transmission, muscle contraction, coagulation of the blood, and so on. Chloride is required for regulating intracellular osmotic pressure and buffering.

In humans, acute oral toxicity is rare because large single doses induce nausea and vomiting. Hypercalcemia may occur only when other factors that alter calcium homeostasis, such as renal inefficiency and primary hyperthyroidism exist.

Irritating effect of the substance was observed in human skin injuries caused by incidental contact with the substance or its high-concentration solutions.

Calcium and chloride are both essential nutrients for humans and a daily intake of more than 1000 mg each of the ions is recommended.

Genetic toxicity of calcium chloride was negative in the bacterial mutation tests and the mammalian chromosome aberration test. No reproductive toxicity study has been reported.

(4) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

KCl as inorganic salt is not subjected to further degradation processes in the environment. In water, potassium chloride is highly water soluble, and readily undergoes dissociation. In soil, transport/leaching of potassium and chloride is affected by the clay minerals (type and content), pH, and organic matter.

$CaCl_2$ released into the environment is distributed into the water compartment in the form of calcium and chloride ions. Calcium is known as an essential nutrient for higher plants and one of the basic inorganic elements of algae. Calcium plays crucial roles in

strengthening cell walls and plant tissues, reducing the toxicity of soluble organic acids, elongating roots, and so on. Chloride is also an essential micronutrient for plants and has important roles in the photosynthesis and osmoregulation.

1.3 Color (True)

True color is caused by dissolved compounds in water. It can be natural or caused by human activities. Dissolved and suspended solids (together) cause apparent color. For example, brown colored water could be the result of dissolved byproducts of plant biodegradation (true color) or suspended clay particles (apparent color) or both (also apparent color). Color is measured in Platinum-Cobalt units. Color can be measured using light with a wavelength of 455 nm.

1.4 Dissolved Oxygen (DO)

(1) Basic Information

DO is the concentration of oxygen dissolved in the water. It is measured either in concentration or "percent saturation." Concentration is the milligram of oxygen in a liter of water, expressed as mg/L. Percent saturation is the amount of oxygen in a liter of water relative to the total amount of oxygen that the water can hold at that temperature.

Much of the DO in water comes from air. Oxygen can also be mixed into the water by waves or lakes or fast-moving rivers. Algae and rooted aquatic plants also add oxygen through photosynthesis.

Dissolved oxygen is affected by many factors including:

- Volume and velocity of water flowing in the water body
- Climate or season
- Type and number of organisms in the water body
- Altitude
- Dissolved or suspended solids
- Amount of nutrients in water
- Organic wastes
- Riparian vegetation
- Groundwater inflow

(a) Volume and velocity of water flowing in the water body

Water in fast-moving streams is aerated by bubbles as it rolls over rocks and falls down waterfalls. These streams, if unpolluted, are usually saturated with oxygen. In slow, stagnant waters, oxygen enters

only the top layer of water. Deeper water is often low in DO because organic matter is decomposed by bacteria that live on or near the bottom of the reservoir.

Water-flow-retarding structures like dams slow down water and affect the DO concentration downstream. If water is released from the top of reservoir, it can be warmer because the dam has slowed the water, giving it more time to warm up and lose oxygen. If dams release water from the bottom of a reservoir, this water will be cooler, but may be low in DO due to decomposition of organic matter by bacteria.

(b) Climate or season

More oxygen can dissolve in cooler water. Thus DO concentrations are usually higher in the cooler months or rainy season than in summer or dry season.

During dry seasons, water levels decrease and the flow rate of a river slows down. As the water moves slower, it mixes less with the air, and the DO concentration decreases. During rainy seasons, oxygen concentrations tend to be higher because the rain interacts with oxygen in the air as it falls.

More sunlight and warmer temperatures also bring increased activity levels in plant and animal life; depending on what organisms are present, this may increase or decrease the DO concentration.

(c) Type and number of organisms in the water body

Plants release oxygen into the water during photosynthesis and remove oxygen from the water during respiration. Bacteria and fungi use oxygen as they breakdown dead organic matter in the stream. The organisms present (plant, bacteria, fungi) affect the DO concentration in a water body. If many plants are present, the water can be supersaturated with DO at daytime when photosynthesis takes place. Concentrations of oxygen can decrease significantly at night due to respiration. DO concentrations are usually highest in the late afternoon because photosynthesis has been occurring all day.

(d) Altitude

Oxygen is more easily dissolved in water at low altitudes than at high altitudes due to higher atmospheric pressure.

Table A.1 shows the barometric pressure for various altitudes and Table A.2 shows DO concentration as a function of temperature and barometric pressure.

Table A.1 Barometric Pressure at Various Altitudes

Altitude (ft)	Altitude (m)	Barometric Pressure (mmHg)
994	303	735
770	235	740
564	172	745
400	122	750
206	63	755
0	0	760

Table A.2 Dissolved Oxygen as a Function of Temperature and Barometric Pressure

Temp °C	Dissolved Oxygen Concentration, mg/L					
	Barometric Pressure, mm Hg					
	735	**740**	**745**	**750**	**755**	**760**
0	14.12	14.22	14.31	14.41	14.51	14.60
1	13.73	13.82	13.92	14.01	14.10	14.20
2	13.36	13.45	13.54	13.63	13.72	13.81
3	13.00	11.09	13.18	13.27	13.36	11.45
4	12.66	12.75	12.83	12.92	13.01	13.09
5	12.33	12.42	12.50	12.59	12.67	12.76
6	12.02	12.11	12.19	12.27	12.35	12.44
7	11.72	11.80	11.89	11.97	12.05	12.13
8	11.44	11.52	11.60	11.67	11.75	11.83
9	11.16	11.24	11.32	11.40	11.47	11.55
10	10.90	10.98	11.05	11.13	11.20	11.28
11	10.65	10.72	10.80	10.87	10.94	11.02
12	10.41	10.48	10.55	10.62	10.69	10.77
13	10.17	10.24	10.31	10.38	10.46	10.53
14	9.95	10.02	10.09	10.16	10.23	10.29
15	9.73	9.80	9.87	9.94	10.00	10.07
16	9.53	9.59	9.66	9.73	9.79	9.86
17	9.33	9.39	9.46	9.52	9.59	9.65
18	9.14	9.20	9.26	9.33	9.39	9.45
19	8.95	9.01	9.07	9.14	9.20	9.26
20	8.77	8.83	8.89	8.95	9.02	9.08
21	8.60	8.66	8.72	8.78	8.84	8.90
22	8.43	8.49	8.55	8.61	8.67	8.73
23	8.27	8.33	8.39	8.44	8.50	8.56
24	8.11	8.17	8.23	8.29	8.34	8.40
25	7.96	8.02	8.08	8.13	8.19	8.24
26	7.82	7.87	7.93	7.98	8.04	8.09
27	7.68	7.73	7.79	7.84	7.89	7.95
28	7.54	7.59	7.65	7.70	7.75	7.81
29	7.41	7.46	7.51	7.57	7.62	7.67
30	7.28	7.33	7.38	7.44	7.49	7.54
31	7.16	7.21	7.26	7.31	7.36	7.41
32	7.04	7.09	7.24	7.19	7.24	7.29
33	6.92	6.97	7.02	7.07	7.12	7.17

34	6.80	6.85	6.90	6.95	7.00	7.05
35	6.69	6.74	6.79	6.84	6.89	6.93
36	6.59	6.63	6.68	6.73	6.78	6.82
37	6.48	6.53	6.57	6.62	6.67	6.72
38	6.38	6.43	6.47	6.52	6.56	6.61
39	6.28	6.33	6.37	6.42	6.46	6.51
40	6.18	6.23	6.27	6.32	6.36	6.41

Source: Adopted from Table D-1. Metcalf and Eddy, Wastewater Engineering Treatment and Reuse. 4th Ed.

(e) Dissolved or suspended solids

Oxygen is more easily dissolved into water with low levels of dissolved or suspended solids. Waters with high amounts of salt, such as the ocean (which contains about 35 grams of salt for each 1000 grams of water) have low concentrations of DO. Freshwater lakes, streams, and tap water generally contain much less salt, so DO concentrations are higher. As the amount of salt in any body of water increases, the amount of dissolved oxygen decreases. An increase in salt concentration due to evaporation of water from an ecosystem tends to reduce the dissolved oxygen available to the ecosystem's inhabitants.

Table A.3 shows DO concentration in water as a function of salinity and temperature.

Table A.3 Dissolved Oxygen as a Function of Temperature and Salinity

Temp °C	Dissolved Oxygen Concentration, mg/L									
	Salinity, parts per thousand									
	0	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**
0	14.60	14.11	13.64	13.18	12.74	12.31	11.90	11.50	11.11	10.74
1	14.20	13.73	13.27	12.83	12.40	11.98	11.58	11.20	10.83	10.46
2	13.81	13.36	12.91	12.49	12.07	12.67	11.29	10.91	10.55	10.20
3	13.45	13.00	12.58	12.16	11.76	11.38	11.00	10.64	10.29	9.95
4	13.09	12.67	12.25	11.85	11.47	11.09	10.73	10.38	10.04	9.71
5	12.76	12.34	11.94	11.56	11.18	10.82	10.47	10.13	9.80	9.48
6	12.44	12.04	11.65	11.27	10.91	10.56	10.22	9.89	9.57	9.27
7	12.13	11.74	11.37	11.00	10.65	10.31	9.98	9.66	9.35	9.06
8	11.83	11.46	11.09	10.74	10.40	10.07	9.75	9.44	9.14	8.85
9	11.55	11.19	10.83	10.49	10.16	9.84	9.53	9.23	8.94	8.66
10	11.28	10.92	10.58	10.25	9.93	9.62	9.32	9.03	8.75	8.47
11	11.02	10.67	10.34	10.02	9.71	9.41	9.12	8.83	8.56	8.30
12	10.77	10.43	10.11	9.80	9.50	9.21	8.92	8.65	8.38	8.12
13	10.53	10.20	9.89	9.59	9.30	9.01	8.74	8.47	8.21	7.96
14	10.29	9.98	9.68	9.38	9.10	8.82	8.55	8.30	8.04	7.80
15	10.07	9.77	9.47	9.19	8.91	8.64	8.38	8.13	7.88	7.65
16	9.86	9.56	9.28	9.00	8.73	8.47	8.21	7.97	7.73	7.50
17	9.65	9.36	9.09	8.82	8.55	8.30	8.05	7.81	7.58	7.36
18	9.45	9.17	8.90	8.64	8.39	8.14	7.90	7.66	7.44	7.22
19	9.26	8.99	8.73	8.47	8.22	7.98	7.75	7.52	7.30	7.09
20	9.08	8.81	8.56	8.31	8.07	7.83	7.60	7.38	7.17	6.96

21	8.90	8.64	8.39	8.15	7.91	7.69	7.46	7.25	7.04	6.84
22	8.73	8.48	8.23	8.00	7.77	7.64	7.33	7.12	6.91	6.72
23	8.56	8.32	8.08	7.85	7.63	7.41	7.20	6.99	6.79	6.60
24	8.40	8.16	7.93	7.71	7.49	7.28	7.07	6.87	6.68	6.49
25	8.24	8.01	7.79	7.57	7.36	7.15	6.95	6.75	6.56	6.38
26	8.09	7.87	7.65	7.44	7.23	7.03	6.83	6.64	6.46	6.28
27	7.95	7.73	7.51	7.31	7.10	6.91	6.72	6.53	6.35	6.17
28	7.81	7.59	7.38	7.18	6.98	6.79	6.61	6.42	6.25	6.08
29	7.67	7.46	7.26	7.06	6.87	6.68	6.50	6.32	6.15	5.98
30	7.54	7.33	7.14	6.94	6.75	6.57	6.39	6.22	6.05	5.89
31	7.41	7.21	7.02	6.83	6.65	6.47	6.29	6.12	5.96	5.80
32	7.29	7.09	6.90	6.72	6.54	6.36	6.19	6.03	5.87	5.71
33	7.17	6.98	6.79	6.61	6.44	6.26	6.10	5.94	5.78	5.63
34	7.05	6.86	6.68	6.51	6.33	6.17	6.01	5.85	5.69	5.54
35	6.93	6.75	6.58	6.40	6.24	6.07	5.92	5.76	5.61	5.46
36	6.82	6.65	6.47	6.31	6.14	5.98	5.83	5.68	5.53	5.39
37	6.72	6.54	6.37	6.21	6.05	5.89	5.74	5.59	5.45	5.31
38	6.61	6.44	6.28	6.12	5.96	5.81	5.66	5.51	5.37	5.24
39	6.51	6.34	6.18	6.03	5.87	5.72	5.58	5.44	5.30	5.16
40	6.41	6.25	6.09	5.94	5.79	5.64	5.50	5.36	5.22	5.09

Source: Adopted from Table D-1. Metcalf and Eddy, Wastewater Engineering Treatment and Reuse. 4th Ed.

(f) Amount of nutrients in water

Nutrients are food for algae and water with high amounts of nutrients can produce algae in large quantities. When these algae die, bacteria decompose them, and use up oxygen. This process is called *eutrophication*. DO concentrations can drop too low, making it difficult for fish to breathe and thus lead to fishkill. However, nutrients can also lead to increased plant growth. This causes high DO concentrations during the day as photosynthesis occurs and low DO concentrations during the night when photosynthesis stops and plants and animals use the oxygen during respiration.

Nitrate and phosphate are nutrients. Nitrate is found in sewage discharge, fertilizer runoff, and leakage from septic systems. Phosphate is found in fertilizer and some detergents.

(g) Organic wastes

Organic wastes are the remains of any living or once-living organism. Organic wastes that can enter a body of water include leaves, grass clippings, dead plants or animals, animal droppings, and sewage. Organic waste is decomposed by bacteria; these bacteria remove dissolved oxygen from the water when they breathe. If more food (organic waste) is available for the bacteria, more bacteria will grow and use oxygen, and the DO concentration will drop.

Directly downstream from where sewage effluent is discharged to a river, DO content often decreases, because of the increase in growth rate of bacteria that consume the organic matter contained in the effluent. The degree and extent of the DO "sag" depends on the Biochemical Oxygen Demand (BOD) of the effluent (how much oxygen the effluent can consume).

(h) Riparian Vegetation

Shading tends to lower average summer temperature and reduce the daily duration of higher temperature. Removing trees reduces shade on the creek, allowing the sun to warm the water. This can affect DO concentrations in different ways. As mentioned above, in general, as water temperature increases, DO drops. Also, the bare soil exposed from removing the tree can erode, increasing the amount of dissolved and suspended solids in the water. This also leads to a decrease in DO concentrations. However, direct sunlight, along with increased nutrients can increase the growth rate of aquatic plants. These plants release oxygen to the water during the day, but then remove oxygen from the water at night. This can cause DO concentrations to become very high during the day, then very low during the night.

(i) Groundwater inflow

The amount of groundwater entering a river or stream can influence oxygen levels. Groundwater usually has low concentrations of DO, but it is also often colder than stream water. Therefore, groundwater may at first lower the DO concentration, but as groundwater cools the stream or river, the ability of the water to hold oxygen improves.

(2) Significance in Water Quality Monitoring

DO is a primary monitoring parameter in ambient water. It is an important measurement of aquatic health because aquatic organisms get all of their oxygen from water. Generally, a higher DO level indicates better water quality. Healthy freshwater bodies usually have DO levels of 8 mg/L or higher although a DO of at least 5 mg/L is sufficient for many aquatic species.

In contrast to lakes, where DO levels are most likely to vary vertically in the water column, the DO in rivers and streams changes more horizontally along the course of the waterway. This is especially true in smaller, shallower streams. In larger, deeper rivers, some vertical stratification of dissolved oxygen might occur. The DO levels in and below riffle areas, waterfalls, or dam spillways are typically higher than those in pools and slower-moving stretches. If one wants to measure the effect of a dam, it would be important to sample for DO behind the

dam, immediately below the spillway, and upstream of the dam. Since DO levels are critical to fish, a good place to sample is in the pools that fishes tend to favor or in their spawning areas.

Hot water discharges can raise the temperature of water and lower its oxygen content. Hence, the government has set a limit of $3^{O}C$ change in temperature for effluent water to be discharged to water bodies[2].

1.5 Fecal Coliform

Fecal coliform bacteriological test tells whether the water is free from disease-causing bacteria. Coliform bacteria grow in the digestive tracts of humans and other warm-blooded animals, and serve as indicators of fecal contamination and as a marker for other possibly pathogenic microorganisms. They are measured by counting the most probable number of bacteria colonies that grow from a 100 milliliter water sample (MPN/100ml). Sources of coliform bacteria include domestic and industrial wastewater discharges, septic tanks, domestic and farm animals, and wildlife.

Waters with fecal coliform counts greater than 150 MPN/100ml are considered unsafe for swimming.

1.6 pH

(1) Basic Information

pH is a measure of the hydrogen ion concentration in liquids. The "p" stands for 'potential for' and the "H" stands for 'Hydrogen'. Thus, pH is written with small letter p and capital letter H.

Water contains both hydrogen ions (H^+) and hydroxyl ions (OH^-). The pH test measures the H^+ ion concentration of liquids and substances.

Most substances have a pH in the range 0 to 14, although extremely acidic substances may have pH less than 0 and extremely basic substances may have pH greater than 14. Pure deionized water contains equal (H^+) and (OH^-), and is considered neutral (neither acidic nor basic). Pure deionized or neutral water has a pH of 7. Water with pH below 7 is acidic while water with pH above 7 is alkaline or basic.

pH is a logarithmic value, meaning that for every one-unit change, the actual hydrogen ion concentration change in the sample is ten-fold

[2] Based on the revised DAO 35 – General Effluent Standards. The degree change refers to the temperature difference of the effluent and abstracted water or the upstream and downstream water quality.

(power of 10). Water with a pH of 4 is ten times more acidic than water with pH of 5 and one hundred times more acidic than that with pH of 6.

To give a general picture of the range, consider the pH scale below showing the pH value of some common liquids.

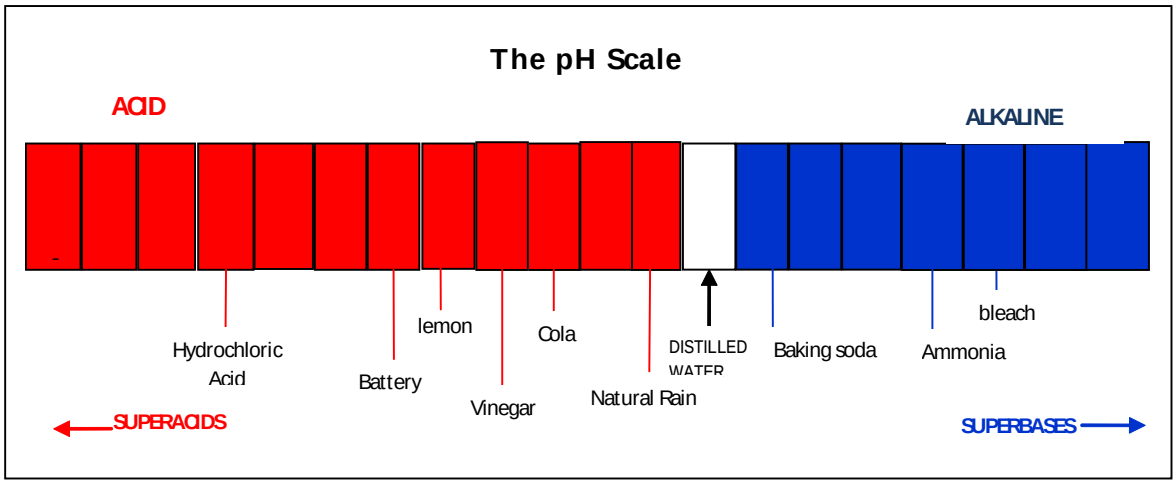


Fig. A.1 pH Scale Showing the Value for Some Common Substances

(2) Significance in Water Quality Monitoring

Changes in pH can greatly affect aquatic organisms. Organisms that have adapted to water of a specific pH may die if sudden changes in pH occur. pH changes between 0.2 and 0.3 are already stressful to some species. Chances of survival diminishes as pH falls below 5 or increases above 9. A pH of 6.5 to 8.2 is ideal for most organisms; the optimal range for most tropical fishes is 6.5 – 8.5.

At pH 6.0, the microorganisms which decompose organic matter begin to die. The plankton (microscopic plants and animals) which form the base of the food chain begins to decline drastically at this pH level. Between 6.0 and 5.5, the number of aquatic invertebrate species declines, most fish species lose their ability to reproduce and algal mats form along the shoreline. At stronger acid levels, toxic metals such as aluminum, mercury, lead and cadmium dissolve more readily and therefore are more easily absorbed by fish and other aquatic animals. Heavy metals can accumulate on the gills of fish or cause deformities in young fish, reducing their chances of survival.

Figure A.2 depicts the pH ranges that support aquatic life forms.

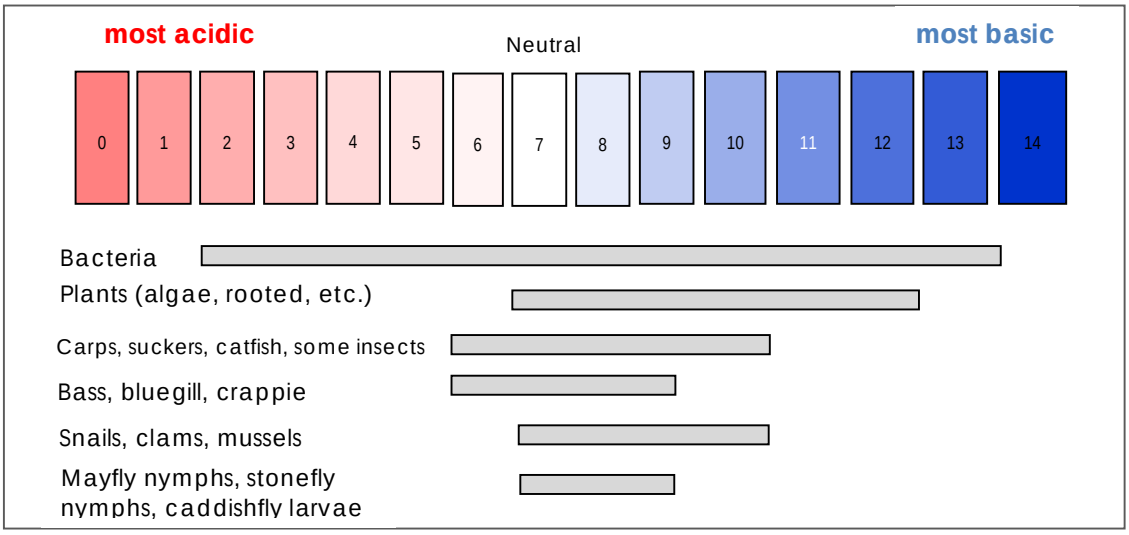


Fig. A.2 pH Ranges that Support Aquatic Life

1.6 Phosphate

(1) Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	**Phosphate**
Name: (Common)/ Other Name	
CAS No.	7723-14-0
Molecular Formula	(PO_4^{3-})
Melting Point, ^oC	44.2
Molar mass, g/mol	30.97
Boiling Point, ^oC	277
Density , g/m^3	1.823 (white); 2.69 (black), 2.34 (red)
Solubility in Water	4.13 g/100 g at 25^oC
Appearance	waxy white/ red/black/ colorless

(2) Sources

Phosphates are nutrients that come from both natural sources and human activities (fertilizers, detergents, wastewater, etc.). Sources of nitrates include fertilizers and domestic and industrial wastes. Sources of phosphate include polyphosphates in detergents, raw sewage, and run off from farms that use phosphate fertilizers.

(3) Fate and Transport

The transport of P in runoff can occur in dissolved and particulate forms. Particulate P encompasses all phase forms, which include P sorbed by soil particles and organic matter eroded during runoff and constitute the major proportion (75 to 90%) of P transported from cultivated land. Runoff from grass or forest land carries little sediment

and is therefore, generally dominated by the dissolved form. Dissolved P is immediately available for biological uptake while particulate P can provide a long-term source of P for aquatic biota. Both forms together constitute the bioavailable P.

(4) Impact on Human Health

Phosphorus nutrient pollution causes enormous algal bloom, a form of cyanobacteria, which can produce neurotoxins (affecting the nervous system) and hepatotoxins (affecting the liver). Ingestion of these algae-produced toxins while swimming can lead to death.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

The presence of excess phosphate ion affects aquatic ecology because it over fertilizes plants. Since there is commonly an excess of dissolved nutrients in lakes, phosphate ion usually functions as the limiting or controlling nutrient for algal growth. The larger the supply of phosphate ion, the more abundant is the growth of algae. When vast mass of excess algae eventually die and starts to decompose by oxidation, the water is depleted of DO and may result to asphyxiation of fishes. Dead algae contribute to foul-tasting, green and slimy water.

In areas with intensive confined animal operations, the land application of manure to marginal lands as a cheap source of nutrients and organic matter has increased both grass and crop yields. This in turn can increase stocking rates for grazed pasture, as well as sales of hay to neighboring farms. Thus, carefully managed P inputs to low fertility systems can have several direct and indirect benefits to the terrestrial environment.

The negative impacts of P on the terrestrial environment are limited due to its general lack of toxicity to major cash crops and only occur once P is transported from terrestrial to aquatic environments, where eutrophication can be accelerated.

1.7 Temperature

(1) Basic Information

Temperature is the measure of the intensity of heat and is an important water quality parameter because many biological, physical and chemical processes are affected by it. It is usually expressed in degree Celsius (^{O}C) or degree Fahrenheit (^{O}F). The formulas to convert ^{O}C to ^{O}F and vice versa are as follows:

$$^{O}F = {}^{O}C \times 1.80) + 32.0$$

$$^{O}C = \frac{(^{O}F - 32.0)}{1.80}$$

Liquid water is most dense at 4^{O}C hence this temperature is important for water. Below 4^{O}C water becomes less dense and rises to re-circulate with upper layers.

(2) Significance in Water Quality Monitoring

Temperature is very critical to both plants and animals. The amount of biological activity and the rate of chemical/metabolic reaction increase significantly with slight increase in water temperature. As water temperature rises, the rate of photosynthesis and plant growth increases.

Most aquatic organisms have adapted to survive within a range of water temperatures but few can tolerate extremely hot or cold temperature. Some organisms such as stonefly nymphs prefer cooler waters. Others like carp and dragonfly nymphs thrive better under warmer conditions. As the temperature of a water body increases, cool water species will be replaced by warm water organisms.

Ideal temperatures vary with different species but high temperatures in streams disrupt the naturally regulated timing of temperature related events such as migration and reproduction.

Temperature also affects aquatic life's sensitivity to toxic wastes, parasites and disease. Thermal pollution may cause fish to become vulnerable to disease, either because of stress due to rising temperatures or due to resulting decrease in dissolved oxygen.

Fig. A.3 shows the differences in temperature tolerance level of selected organisms in water.

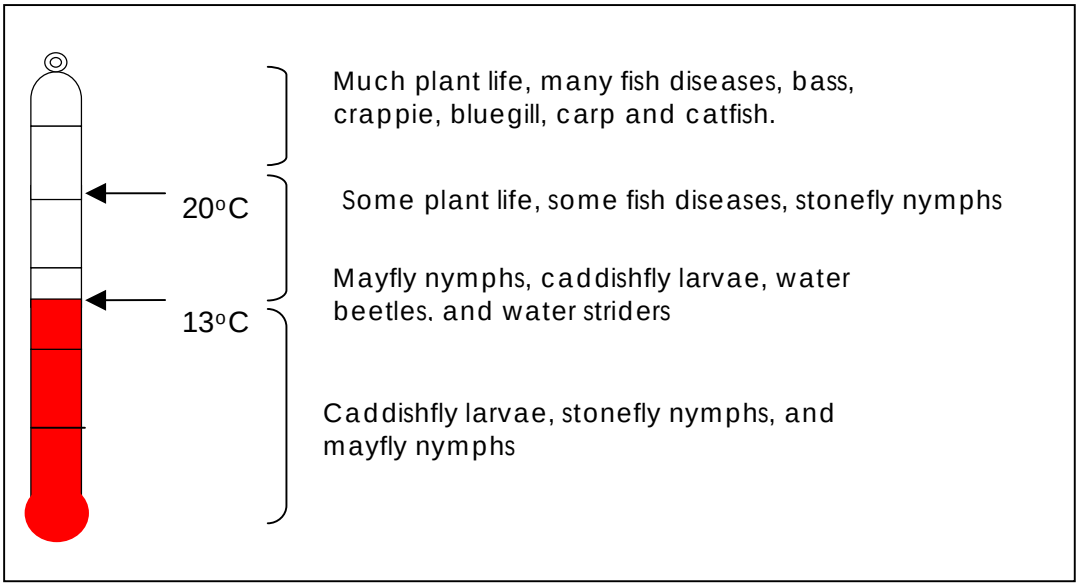


Fig. A.3 Temperature Tolerance Level of Selected Aquatic Organisms

1.8 Total Suspended Solids

(1) Basic Information

TSS are solids or substances suspended in water including clay, silt, decaying plant, algae, plankton, sand, microbes, animal matter, industrial wastes and sewage that cause water turbidity. These are the solids that can be trapped by a filter.

TSS is affected by the following factors:

- High flow rate or wave action
- Soil erosion
- Runoff
- Wastewater and septic system effluent
- Decaying plant and animals
- Bottom-feeders

(a) High flow rate

The flow rate of the water body is a primary factor in TSS concentration. Fast moving water can carry more particles and larger-sized sediment. Heavy rains can pick up sand, silt, clay and organic particles from the land and carry it to surface water. Wave and wind can increase TSS concentration in coastal area as strong winds cause strong waves that carry sand, silt and other debris from the shore to

the coast. In shallow lakes, wind can cause re-suspension of bottom sediment and increase TSS levels.

(b) Soil erosion

Soil erosion is caused by disturbance of land surface. Soil erosion can be caused by building or road construction, forest fires, logging, and mining. The eroded soil particles can be carried by storm water to surface water and increase the TSS of the water body.

(c) Run-off

When it rains, soil particles and debris from streets and industrial, commercial, residential and agricultural areas can be washed into streams. In urban areas where large areas are paved, infiltration of water to the ground is decreased and sediment and other solid wastes are carried through storm drains directly into creeks and rivers. In agricultural areas, rainwater carries soil from denuded or ploughed areas into creeks, rivers, lakes and eventually to the receiving coastal waters, increasing the TSS concentration.

(d) Wastewater and septic system effluent

Effluent from WTPs can add suspended solids to a water body. While most of the solids are removed by the WTP before discharge, treatment can not totally eliminate TSS.

(e) Decaying plants and animals

As plants and animals decay, suspended organic particles are released and increase TSS level.

(f) Bottom-feeders

Bottom-feeders can stir up sediments as they remove vegetation. These sediments can contribute TSS.

(2) Significance in Water Quality Monitoring

High concentration of suspended solids in water decreases the passage of light through the water and can block light from reaching submerged vegetation. Consequently, the rate of photosynthesis will slow down. When the rate of photosynthesis is reduced, plants release less DO into the water. If light is completely blocked, the plants will die. As the plants decompose, bacteria will use up even more oxygen from the water and further lower down the DO. Low DO can lead to fish kills.

TSS decrease water clarity, the fishes lose their ability to see and catch food, resulting in retardation of growth.

TSS increases water temperatures because suspended particles absorb more heat. High temperature reduces the concentration of DO because warm water holds less DO than cold water.

Furthermore, suspended sediment can clog fish gills, reduce their growth rates, decrease resistance to disease and prevent egg and larval development. When suspended solids settle to the bottom of a water body, they can choke the eggs of fish and aquatic insects and their larvae. Settling sediments can fill in spaces between rocks which could have been used by aquatic organisms for homes.

A.2. Secondary Parameters

2.1 Ammonia-Nitrogen (NH_3-N)

(1) Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	Azane NH_3; Hydrogen nitride
Name: (Common)/ Other Name	Spirit of hartshorn, Nitrosil Vaporole
CAS No.	7664-41-7
Molecular Formula	NH_3
Melting Point, ^oC	- 77.73
Molar mass, g/mol	58.442
Boiling Point, ^oC	-33.34
Density, g/m^3	0.6942
Solubility in Water	89.9 g/100 ml at 0 ^oC
Appearance	Colorless gas with strong pungent odor
Compounds	Urea, ammonium nitrate, ammonium phosphates, nitric acid, and ammonium sulfate, diammonium phosphate, monoammonium phosphate, calcium nitrate, calcium cyanamide, potassium nitrate, sodium nitrate

(2) Sources

Wastewater from the manufacture of plastics, synthetic fibers and resins, explosives, and numerous other chemical compounds are the major point sources.

Ammonia is used for fertilizer, including anhydrous ammonia for direct application, urea, ammonium nitrates, ammonium phosphates, and

other nitrogen compounds hence agricultural run-off is the major non-point source.

Ammonia results from the breakdown of fish feed and wastes.

(3) Fate and Transport

In water, ammonia exists in two forms: ionized ($NH4^+$) and un-ionized (NH3). These two forms constitute total ammonia nitrogen.

Anhydrous ammonia, or gaseous NH_3, is a very important direct-application N-fertilizer. Gaseous NH_3, when in contact with moist soil, dissolves in and reacts with soil water to form NH_4^+ and OH^- ions. The pH is increased dramatically immediately around the application zone of anhydrous NH_3. Therefore, depending upon the buffering capacity of the soil and the resulting soil pH, equilibrium is approached between soil solution NH_4^+ and NH_3 in the soil solution and gaseous NH_3, as was discussed above. The gaseous NH_3 can be lost by volatilization into the atmosphere. In addition, if anhydrous NH_3 is placed in dry soil or at too shallow a depth, the NH_3 is also subject to volatilization. However, the N that is in NH_4^+ form is readily sorbed to the CEC of the soil.

All of the compounds of ammonia are highly water soluble. For those with NH_4 as part in their chemical formula, the NH_4^+ will sorb to the CEC of the soil. Therefore, the primary transport mechanism for NH_4^+ ions is in association with eroding sediments since they are sorbed to the CEC of the soil.

Urea and calcium cyanamide are organic forms of N that, when applied to soil, are acted upon by enzymes to mineralize the N in them to NH_4^+ ions. Once in NH_4^+ form, the N in these two fertilizers is also sorbed to the CEC of the soil and is subject to the soil-erosion transport process described above. Also, the N in other organic materials such as manures and crop residues is also mineralized to NH_4^+, again being subject to transport with eroding sediments.

For compounds which have NO_3^- as part of their chemical formula, the NO_3^- does not sorb to the CEC of the soil. Therefore, the primary transport mechanism for NO_3^- ions is with percolating water by leaching or surface runoff (including return flow). Nitrate that is leached below the crop root zone often ends up as a pollutant in ground-water supplies. Nitrate can also be dissolved in surface runoff water or in return-flow water that returns to the surface to become part of the runoff.

(4) Impact on Human Health

The primary concern about the impact of N on the environment is leaching of nitrate (NO_3^-) into ground water. This concern largely results from the potential for health effects that may result from humans and ruminant animals drinking contaminated ground water.

When NO_3^- accumulates in ground water and is ingested in high enough amounts, potential adverse health effects may occur. These health effects are reported to include methemoglobinemia, possibly cancer, and possibly other adverse effects.
Methemoglobinemia (blue-baby syndrome) results when ingested NO_3^- is converted to the NO_2^- ion in the oral cavity and stomach and then absorbed from the gastrointestinal tract into the blood. Nitrite in the blood becomes involved in the oxidation of hemoglobin (Hb) to methemoglobin (metHb). The ferrous iron (Fe^{+2}) in the heme group is oxidized to ferric iron (Fe^{+3}) which NO_2^- firmly bonds, thus inhibiting transport of oxygen by the blood. Infants younger than three months are highly susceptible to gastric bacterial NO_3^- reduction because they have very little gastric acid production and low activity of the enzyme that reduces metHb back to Hb.

Nitrite can give rise to the formation of N-nitroso compounds by reaction with "nitrosatable compounds," including secondary and tertiary amines and amides, N-substituted ureas, guanidines, and urethanes. Sufficient toxicological data are available to indicate that humans are likely susceptible to the carcinogenicity of these compounds.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Ammonia is toxic to fresh water organisms at concentrations ranging from 0.53 to 22.8 mg/L. Toxic levels are both pH and temperature dependent. Toxicity increases as pH decreases and as temperature increases. Acute un-ionized ammonia toxicity occurs at concentrations of 0.6mg/L and chronic exposure to as little as 0.06 mg/L of the total ammonia concentration in the unionized form is toxic to warm water species like catfish and tilapia.

Plants are more tolerant of ammonia than animals and invertebrates are more tolerant than fish. Hatching and growth rate of fishes may be affected by ammonia. In the structural development, changes in tissues of gills, liver and kidneys may also occur. Toxic concentrations of ammonia in humans may cause loss of equilibrium, convulsions, coma and death.

2.2 Barium (Ba)

(1) Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	**Barium**
CAS No.	7440-39-3
Molecular Formula	Ba
Melting Point, ^{O}C	727
Molar mass, g/mol	58.442
Boiling Point, ^{O}C	1897
Density, g/m^3	3.51
Solubility in Water	0.00115 g/L (18°C)
Appearance	Silvery white
Compounds	barium chloride, barium nitrate, and barium hydroxide, barium acetate, barium carbonate, barium chloride, barium hydroxide, barium nitrate, and barium sulfide

(2) Sources

Barium is a lustrous, machinable metal which exists in nature only in ores containing mixtures of elements. It is used in making a wide variety of electronic components, in metal alloys, bleaches, dyes, fireworks, ceramics, and glass. In particular, it is used in well drilling operations where it is directly released into the ground.

Barium waste may be released to air, land, and water during industrial operations. Barium is released into the air during the mining and processing of ore and during manufacturing operations. Some industries dump wastes containing barium compounds onto land or into the ocean and other bodies of water.

(3) Fate and Transport

Barium is primarily found in and extracted from the mineral barite which is crystalized barium sulfate. It is commercially produced through the electrolysis of molten barium chloride ($BaCl_2$). Barium sulfate and barium carbonate are the forms of barium most commonly found in the soil and water. If barium sulfate and barium carbonate are released onto land, they will combine with particles of soil.

Barium compounds that do not dissolve well in water, e.g., barium sulfate and barium carbonate, can last a long time in the environment. Barium compounds that dissolve easily in water usually do not last a long time in the environment. Barium that is dissolved in water quickly

combines with sulfate or carbonate ions and becomes the longer lasting forms (barium sulfate and barium carbonate).

(4) Impacts on Human Health

Barium has been found to potentially cause gastrointestinal disturbances and muscular weakness when people are exposed to it at levels above 2mg/L for relatively short periods of time. Barium has the potential to cause high blood pressure from lifetime exposure at levels above 2mg/L.

All compounds of barium that are water or acid soluble are extremely poisonous. At low doses, barium acts as a muscle stimulant, while higher doses affect the nervous system, causing cardiac irregularities, tremors, weakness, anxiety, dyspnea and paralysis. This may be due to its ability to block potassium ion channels which are critical to the proper function of the nervous system.

Barium sulfate can be used in medicine only because it does not dissolve, and is eliminated completely from the digestive tract. Unlike other heavy metals, barium does not bioaccumulate. However, inhaled barium dust can accumulate in the lungs, a benign condition called baritosis.

A barium dose of 550 to 600 mg is considered fatal to human beings.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Barium has been reported to inhibit growth and cellular processes in microorganisms, and to affect the development of germinating spores. No information was obtained on the adverse effects of barium on terrestrial plants or wildlife. No toxic effects have been reported in aquatic plants due to barium at the usual concentrations found in water. LC_{50} values for fish in fresh water range from 46 to 78 mg/L.

2.3 Boron

(1) Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	**Boron**
CAS No.	7440-42-8
Molecular Formula	B
Melting Point, ^{O}C	2076
Molar mass, g/mol	10.811
Boiling Point, ^{O}C	3927
Density, g/m^3	2.34

Solubility in Water	-
Appearance	black/brown metalloid
Ores	Borax, ulexite
Compounds	Sodium tetraborate pentahydrate, Orthoboric acid, sodium tetrborate decahydate (borax), Boron nitride, borazole

(2) Sources

Boron exists as a solid at room temperature, either as black monoclinic crystals or as a yellow or brown amorphous powder when impure, but is never found in the elemental form in nature. It exists as a mixture of the 10B (19.78%) and 11B (80.22%) isotopes. It is a relatively inert metalloid except when in contact with strong oxidizing agents.

In natural waters, boron exists primarily as undissociated boric acid with some borate ions. The boron–oxygen compounds are sufficiently soluble in water. Seawater has an average boron concentration of 4.5 mg/kg.

Primary sources of Boron in the environment include tailings from boron mining and refining, wastewater from boric acid plants and from industries that utilize boron compounds, e.g., manufacture of fiberglass and sodium perborate bleach; manufacture of adhesives, detergents and anti-corrosion systems using borax; textiles industry using boric acid; etc.

Boric acid and borates are used in glass manufacture (fibreglass, borosilicate glass, enamel, frit, and glaze), soaps and detergents, flame retardants, and neutron absorbers for nuclear installations. Boric acid, borates, and perborates have been used in mild antiseptics, cosmetics, pharmaceuticals (as pH buffers), boron neutron capture therapy (for cancer treatment), pesticides, and agricultural fertilizers.

(3) Fate and Transport

Boron is released to the environment from natural sources such as oceans, volcanoes, and geothermal steam. Boron is also released from industries that use it. No information is available on how long boron remains in air, water, or soil. Boron does not appear to accumulate in fish or other organisms in water. Boron accumulates in plants and is found in foods, mainly fruits and vegetables.

Waterborne boron may be adsorbed by soils and sediments. Adsorption–desorption reactions are the significant mechanism influencing the fate of boron in water. The extent of boron adsorption

depends on the pH of the water and the concentration of boron in solution. The greatest adsorption is generally observed at pH between 7.5 and 9.0.

(4) Impacts to Human Health

Studies have shown that boric acid and borax are absorbed from the gastrointestinal tract and from the respiratory tract, as indicated by increased levels of boron in the blood, tissues, or urine or by systemic toxic effects of exposed individuals or laboratory animals.

There is little information on the health effects of long-term exposure to boron. Most of the studies are on short-term exposures. Breathing moderate levels of boron can result in irritation of the nose, throat, and eyes. Reproductive effects, such as low sperm count, were seen in men exposed to boron over the long-term. Animal studies have shown effects on the lungs from breathing high levels of boron.

Ingesting large amounts of boron over short periods of time can harm the stomach, intestines, liver, kidney, and brain.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Animal studies of ingestion of boron found effects on the testes in male animals. Birth defects were also seen in the offspring of female animals exposed during pregnancy. Animal studies have found skin irritation when boron was applied directly to the skin.

2.4 Fluoride (F)

(1) Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	**Sodium Fluoride**	**Potassium Fluoride**	**Calcium Fluoride**
Name: (Common)/ Other Name			
CAS No.	7681-49-4	7789-23-3	7789-75-5
Molecular Formula	NaF	KF	CaF_2
Melting Point, ^{O}C	993	846	1402
Molar mass, g/mol	41.99	58.10	
Boiling Point, ^{O}C	1700	1505	2497
Density, g/m^3	2.558	2.48	3.18×10^3 kg/m^3 (solid)
Solubility in Water	4.13 g/100 g at 25 ^{O}C		virtually insoluble
Appearance	White solid	colorless crystals	White crystalline solid

(2) Sources

Fluorides are organic and inorganic compounds containing the element fluorine. As a halogen, fluorine forms a monovalent ion (−1 charge). Fluoride forms a binary compound with another element or radical. Examples of fluoride compounds include hydrofluoric acid (HF), sodium fluoride (NaF), potassium fluoride (KF) and calcium fluoride (CaF_2). Fluoride can enter groundwater by natural processes. Weathering can leach out fluoride from bedrock with high fluoride content in the soil.

Sources include hydrofluoric acid which is used in the etching of glass and other industrial applications, including integrated circuit manufacturing, drug manufacture, in synthetic organic chemistry and fluoride salts used to inhibit the activity of serine/threonine phosphatases.

(3) Fate and Transport

Fluoride compounds are naturally found in low concentration in drinking water and some foods, such as tea, seaweed and fish bones (as in fish soup). Water with underground sources is more likely to have higher levels of fluoride, while the total concentration in seawater has an average concentration of 1.3 ppm. Fresh water supplies generally contain between 0.01-0.3 ppm, while the ocean contains between 1.2 and 1.5 ppm.

(4) Impact on Human Health

Fluoride is widely known to combat and even reverse the early stages of tooth decay however, though fluoride benefits adults, it is especially critical to the health of developing teeth in children.

As with most minerals and vitamins, overexposure can be harmful. Too much fluoride before 8 years of age can cause enamel fluorosis, a discoloration or mottling of the permanent teeth. This condition is unsightly but harmless and often can be treated with cosmetic procedures. Fluorosis is caused not only by drinking fluoride in groundwater but also by breathing airborne fluoride released from the burning of fluoride-laden coal. Fluorosis is said to be prevalent in some parts of central and western China.

Very rarely, fluoride toxicity can occur when large amounts of fluoride are ingested during a short period of time. Children under age 6 are susceptible although outcomes are generally not serious. Symptoms may include nausea, diarrhea, vomiting, abdominal pain, increased salivation, or increased thirst. Symptoms begin 30 minutes after ingestion and can last up to 24 hours.

2.5 Iron (Fe)

(1) Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	
Name: (Common)/ Other Name	Iron
CAS No.	7439-89-6
Molecular Formula	Fe
Melting Point, ^{O}C	1538
Molar mass, g/mol	55.845
Boiling Point, ^{O}C	2861
Density, g/m^3	7.86
Solubility in Water	4.13 g/100 g at 25 ^{O}C
Appearance	lustrous metallic with a grayish tinge

(2) Sources

Iron is one of the earth's most plentiful resources and makes up at least five percent of the earth's crust. Rainfall seeping through the soil dissolves iron in the earth's surface and carries it into almost every kind of natural water supply, including well water. Although iron is naturally present in water, it is seldom found at concentrations greater than 10 mg/L.

Sources of pollutants include iron ore mine tailings, wastewater from the manufacture of steel and other alloys of iron, and wastewater from other applications using iron compounds, e.g., dyeing of cloth, blueprints, water purification, ceramic, fertilizer, production of ammonia, fertilizer, pesticides, and wood preservation.

(3) Fate and Transport

Iron is transported to water bodies during the mining of iron ore, during production of iron from iron ore, and from wastewater produced by industries that uses iron and its alloys. Water-soluble iron cyanide compounds are widely used as anticaking agents in road salt, which creates potential contamination of surface and groundwater with these compounds when the salt dissolves and is washed off roads in runoff.

Rainfall seeping through the soil dissolves iron in the earth's surface and carries it into almost every kind of natural water supply, including well water. Although iron is present in water, it is seldom found at concentrations greater than 10 mg/L.

(4) Impact on Human Health

Excessive iron can be toxic, because free ferrous iron reacts with peroxides to produce free radicals, which are highly reactive and can damage DNA, proteins, lipids, and other cellular components. Thus, iron toxicity occurs when there is free iron in the cell, which generally occurs when iron levels exceed the capacity of transferrin to bind the iron.

Large amounts of ingested iron can cause excessive levels of iron in the blood and can cause damage to the cells of the gastrointestinal tract that prevents them from regulating iron absorption. High concentrations of iron in blood damage cells in the heart, liver and elsewhere, which can cause serious problems, including long-term organ damage and even death.

Humans experience iron toxicity above 20 milligrams of iron for every kilogram of mass, and 60 milligrams per kilogram is a lethal dose. Over-consumption of iron, often the result of children eating large quantities of ferrous sulfate tablets intended for adult consumption, is one of the most common toxicological causes of death in children under six.

Iron gives the water unpalatable taste and undesirable appearance. Iron levels exceeding 0.3 mg/L limit could already impart red, brown, or yellow staining of laundry, glassware, dishes and household fixtures such as bathtubs and sinks. The water may also have a metallic taste and an offensive odor. Iron restricts and clogs water system piping and fixtures.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Iron has a high potential for biological toxicity. Many bacteria require iron, so restricting its availability to bacteria (generally by sequestering it inside cells) can help to prevent or limit infections. This is probably the reason for the relatively low amounts of iron in mammalian milk. A major component of this regulation is the protein transferrin, which binds iron absorbed from the duodenum and carries it in the blood to cells.

2.6 Sulfate ($SO4^{-2}$)

(1) Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	**Sulfate**
Name: (Common)/ Other Name	Sulphate
CAS No.	14808-79-8
Molecular Formula	SO_4^{-2}
Molar mass, g/mol	96.06
Appearance	salt

(2) Sources

The natural mineral form mirabilite is the primary source of decahydrate (Glauber's salt) produced worldwide. Anhydrous sodium sulfate occurs in arid environments as the mineral thenardite, which is less common than mirabilite. Thernardite slowly turns to mirabilite in damp air. Significant amount of sodium sulfate are also produced as a by-product from the production of other materials, like ascorbic acid, boric acid, cellulose, rayon, and silica pigments. Other sources include emissions from coal-fired power plants, smelters, industrial emissions, and even volcanoes. In paper and paper pulp industry, a small amount is recycled.

(3) Fate and Transport

Sulfur emissions in the form of reduced sulfur species and SO_2 fall back to land and seas in the form of SO_2(g) (dry deposition), sulfate aerosols (H_2SO_4, $(NH_4)_2SO_4$, $MgSO_4$, $CaSO_4$ in dry deposition), and sulfate ions (H_2SO_4 and $CaSO_4$ in wet deposition). Sulfate aerosols and cloud condensation nuclei play an important role as a negative feedback effect to global warming by increasing the earth's albedo on a global scale. SO2(g) results in H2SO4 (sulfuric acid) and acid deposition.

(4) Impact on Human Health

Sulfate is a substance that occurs naturally in drinking water. Health concerns regarding sulfate in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulfate. Of particular concern are groups within the general population that may be at greater risk from the laxative effects of sulfate when they experience an abrupt change from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Sulfates occur as microscopic particles (aerosols) resulting from fossil fuel and biomass combustion. They increase the acidity of the atmosphere and form acid rain. Acid sulfate soil runoff has become a significant environmental, economic and social concern to many coastal communities. Acid sulfate runoff is seen as among the causes of fish kills and decline in fishery and aquaculture production. Sulfate runoff compromises valuable tourist resources like good fishing grounds, swimming areas and other water sports areas. Acid discharges also damage town services and structures like pipes, foundations, drains, bridges and flood controls.

Sulfates are implicated in global dimming, which may have acted to offset some of the effects of global warming.

3. Secondary Parameters – Toxic Metals

Among the heavy metals, Arsenic (As), Cadmium (Cd), Hexavalent Chromiun (Cr^{+6}), Copper (Cu), Lead (Pb), Mercury (Hg), and Nickel (Ni) are of great concern because they are found to be the most environmentally hazardous owing to their extensive use, toxicity and widespread distribution. Metals are totally non-degradable or practically speaking, indestructible, and so they accumulate in the environment.

3.1 Arsenic

(1) Basic Characteristics (Physical and Chemical Properties)

Name (Symbol)	**Arsenic (As)**
Chemical Series	Metalloid
CAS No.	7440-38-2
Molecular Formula	-
Melting Point. ^{O}C	817.2
Molar mass, g/mol	74.92
Boiling Point, ^{O}C	614
Density , g/m^3	5.22
Solubility in Water	-
Appearance	Steel gray brittle metalloid

(2) Sources

Inoranic arsenic naturally occurs in the environment combined with other elements like oxygen, chlorine, and sulfur. Arsenic combined with carbon and hydrogen is called organic arsenic. The inorganic form is more harmful than the organic form. Some metalloidal forms of arsenic

with different crystal structures, including the minerals arsenic sensu strictu, arsenolamprite, and pararsenolamprite exist in nature but it is more commonly found as arsenide and arsenate compounds. Arsenic and its compounds are used as pesticides, herbicides, insecticides and various alloys. As in the environment stem from the continuing use of its compounds as pesticides, from unintended release during the mining of gold and lead, and from the combustion of coal. The leachate from abandoned gold mines of previous decades and centuries can still be a significant source of As pollution in water systems.

(3) Fate and Transport

Arsenic in groundwater is of natural origin and is released from the sediment into the groundwater due to the anoxic conditions of the subsurface. Although As does not evaporate, it can get into air as dust. This can happen when smelters heat ores containing arsenic, when people burn any material containing arsenic, or when wind blows soil that contains arsenic into the air. Once in the air, As particles will travel with the wind and settle back to the ground. Most As compounds can also dissolve in water and thus can get into lakes, rivers or underground water by dissolving in rain or floodwater or through the discharge of industrial waste. Some of the arsenic will stick to the sediment at the bottom of the lake or river and some will be carried along by the water.

Arsenic is not broken down or destroyed in the environment. It can change form by natural chemical reactions, and also by the action of bacteria in the soil or water. Some fish and shellfish accumulate As in their tissue, most of which are in the form that is not toxic.

(4) Impact on Human Health

Arsenic and arsenic compounds are especially potent poisons and are classified as “toxic” and dangerous for the environment by the European Union under directive 67/54/EEC. The EU lists arsenic trioxide, arsenic pentoxide and arsenate salts as category 1 carcinogens. The IARC recognizes arsenic and arsenic compounds as group 1 carcinogens.

Arsenic causes arsenicosis, a condition leading to death from multisystem organ failure. Lung cancer could be caused by inhalation or probably by ingestion of arsenic.

There is some evidence that small amounts of arsenic in normal diet (10-50ppb) may be beneficial to human health.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Tiny amounts of As act as growth stimulants and are used to fatten pigs and poultry. Provided the use of the stimulant is stopped at least a few days before slaughter, As levels in the resulting meat may not cause health problems.

Plants can take up arsenic from fly ash, sludge and by manure dumped on the land, although plants grown on contaminated sources seldom accumulate dangerous levels of As. This could be because: 1) before the plant can assimilate dangerous levels of arsenic it may have already died; and 2) phosphorus which is more readily available competes with arsenic to gain entry into plants and can hinder the latter's entrance into the plant. Animals are generally less sensitive to arsenic.

Arsenic is one of the most toxic elements to fish. Acute exposures can result in immediate death. Chronic exposures can result in the accumulation of the metalloid to toxic levels. In fish, bizarre morphological alterations, as well as early neoplastic alterations are produced in the liver. The signs of inorganic trivalent arsenite poisoning in birds (mallard, quail, pheasant) include ataxia, goose-stepping ataxia, asthenia, slowness, jerkiness, falling, hyporeactivity, fluffed feathers, ptosis, huddled position, unkempt appearance, loss of righting reflex, immobility, and tetanic seizures. Signs appeared as soon as 1 hour and mortalities usually after exposure; remission took up to 1 month

3.2 Cadmium (Cd)

(1) Basic Characteristics (Physical and Chemical Properties)

Name (Symbol)	Cadmium (Cd)
Chemical Series	Metal
CAS No.	7440-43-9
Melting Point, ^{O}C	817.2
Molar mass	74.92
Boiling Point, ^{O}C	614
Density, g/m^3	5.22
Appearance	Steel gray brittle metalloid

(2) Sources

Cadmium is a natural element in the earth's crust. It is usually found as a mineral combined with other elements such as oxygen (cadmium oxide), chlorine (cadmium chloride), or sulfur (cadmium sulfate, cadmium sulfide).

Cadmium is also used in industry. The cadmium used in industry is a byproduct of zinc, lead, and copper refining. Industrial uses of cadmium include production of metal plating, rechargeable batteries, paint pigments, and plastics. Cd is rather insoluble in water unless sulfide ions are also present to precipitate the metal as cadmium sulfide (CdS). Humans usually receive only a small proportion of cadmium directly from drinking water or from air.

Cadmium can be found in dust. The body does not readily release cadmium once inhaled or ingested. Exposure to low doses of cadmium over a long time can build up to a toxic level.

(3) Fate and Transport

Cadmium can enter the environment in several ways. It can enter the air from the burning of coal and household waste, and metal mining and refining processes. It can enter water from disposal of waste water from households or industries. Fertilizers often have some cadmium in them and fertilizer use causes cadmium to enter the soil. Spills and leaks from hazardous waste sites can also cause cadmium to enter soil or water. Cadmium attached to small particles may get into the air and travel a long way before coming down to earth as dust or in rain or snow. Cadmium does not break down in the environment but can change into different forms. Most cadmium stays where it enters the environment for a long time. Some of the cadmium that enters water will bind to soil but some will remain in the water. Cadmium in soil can enter water or be taken up by plants. Fish, plants, and animals take up cadmium from the environment.

(4) Impact on Human Health

People can be exposed to cadmium when they eat plants grown in contaminated soil, or when they eat fish from contaminated water. Cadmium occurs naturally at low levels in many foods. The normal intake of cadmium (1-3 micrograms/day) does not appear to cause health problems. People can be exposed to increased amounts of cadmium by drinking contaminated water.

Cadmium is acutely toxic with lethal dose of only about one gram. Humans are protected against chronic exposure by the sulfur-rich protein m*etallothionein* that regulates cadmium metabolism. However, if the amount of cadmium absorbed by the body exceeds the capacity of metallothionein to complex it, the metal is stored in the liver and kidneys. Chronic exposure to cadmium eventually leads to increased chance of acquiring kidney disease. Although cadmium is not bio-

magnified, it is a cumulative poison since if not eliminated quickly by metallothionein, its lifetime in the body is several decades.

Cadmium is also responsible for the disease called *itai-itai* ("ouch-ouch") which is manifested by severe pain in the joints. In this disease, Cd^{+2} ions replace some of the calcium ions (Ca^{+2}) in the bones. The bones slowly become porous and subsequently fracture and collapse.

Contamination of drinking water typically results from improper disposal of industrial chemicals.

Cadmium is found in smoke from burning fossil fuels, municipal wastes, and cigarettes. People who smoke cigarettes have higher cadmium levels in their bodies than nonsmokers. Industrial facilities that process metal can create high levels of cadmium in the air and significantly increase the exposure of people living or working near them.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Studies showed that marine organisms generally contain higher cadmium residues than their freshwater and terrestrial counterparts. Cadmium tends to concentrate in the viscera of vertebrates, especially the liver and kidneys. Cadmium concentrations are generally higher in older organisms.

Higher cadmium residues are generally associated with industrial and urban sources, although this does not apply to sea birds and sea mammals.

Cadmium residues in plants are normally less than 1 mg/kg. However, plants growing in soil amended with cadmium (e.g., from sewage sludge) may contain significantly higher levels.

3.3 Hexavalent Chromium (Cr^{+6})

(1) Basic Characteristics (Physical and Chemical Properties)

Name (Symbol)	Hexavalent Chromium (Cr^{+6})
CAS No.	18540-29-9
Molecular Formula	Cr^{+6}
Appearance	odorless, steel-gray, hard metal that is lustrous
Related compounds	Ammonium Dichromate; Barium Chromate; tert-Butyl Chomate; Calcium Chromate; Chromium Trioxide;; Lead Chromate;

	Potassium Chromate; Potassium Dichromate; Silver Chromate; Sodium Chromate; Sodium Dichromate; Strontium Chromate; Zinc Chromate; Zinc Dichromate

(2) Sources

Chromium (Cr) is a micronutrient which is abundant in the environment, occurring naturally in the air, water, rocks and soil. It occurs in several forms, depending on pH, the most common being hexavent chromium or Cr^{+6}. Natural sources of water contain very low concentrations of chromium.

Chromium is used in stainless steel, electroplating of chrome, dyes, leather tanning and wood preservatives, and are the main sources of chromium in wastewater, water bodies and soils.

(3) Fate and Transport

Chromium enters the air, water, and soil mostly in the chromium (III) and chromium (VI) forms.

In air, chromium compounds are present mostly as fine dust particles which eventually settle over land and water.

Chromium can strongly attach to soil and only a small amount can dissolve in water and move deeper in the soil to underground water.

(4) Impact on Human Health

Breathing high levels of hexavalent chromium causes irritation to the nose, such as runny nose, nosebleeds, and ulcers and holes in the nasal septum.

Ingesting large amounts of Cr^{+6} can cause stomach upsets and ulcers, convulsions, kidney and liver damage, and even death.

Skin contact with certain Cr^{+6} compounds can cause skin ulcers. Some people are extremely sensitive to Cr^{+6} or Cr^{+3}. Allergic reactions consisting of severe redness and swelling of the skin have been noted.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Plants and animals do not bioaccumulate chromium; therefore, the potential impact of high chromium levels in the environment is acute

toxicity to plants and animals. In animals, as in humans this toxicity is manifested as skin lesions or rashes and kidney and liver damage.

Fish do not accumulate much chromium in their bodies from water.

3.4 Copper (Cu)

(1) Basic Characteristics (Physical and Chemical Properties)

Name (Symbol)	**Copper (Cu)**
Chemical Series	Transition metal
CAS No.	7440-50-8
Melting Point, ^{O}C	1084.62
Atomic Weight, $g \cdot mol^{-1}$	63.546(3)
Boiling Point, ^{O}C	2567
Density , g/m^3	8.96
Appearance	metallic pinkish red

(2) Sources

The primary source of copper in drinking water is corrosion of copper pipes, which are widely used for interior plumbing of residences and other buildings. In some cases, copper is a component of additives to drinking water used by systems to control the growth of algae.

All water is corrosive toward copper to some degree, depending on the pH of the water. Water with low pH has higher level of copper corrosion by-products.

Although copper rarely occurs in source water, it is widely distributed in nature in the elemental state, in sulfides, arsenites, chlorides, and carbonates. The concentration of copper in the continental crust tends to be highest in the ferromagnesium minerals, such as the basalts pyropene and biotite, where it averages 140 ppm. Sandstones contain 10-40 ppm, shales 30-150 ppm, and marine black shales 20-300 ppm. Coal is relatively low in copper. In the sedimentary cycle copper is concentrated in the clay mineral fractions with a slight enrichment in those clays rich in organic carbon.

Smelting operations and municipal incineration may also produce copper. Water and pasture have been found to be contaminated with copper in the vicinity of copper mines or smelting works. The principal source of elevated copper levels in air is copper dust generated by copper processing operations.

(3) Fate and Transport

Copper is a contaminant of concern for which storm water runoff is a potentially significant transport pathway. Copper may be released to the landscape from several sources, including automobile brake pad wear debris.

Copper exists in four oxidation states: Cu0, Cu^{+1}, Cu^{+2}, and Cu^{+3}. The cupric ion (Cu^{+2}) is the one generally encountered in water and it is the most readily available and toxic inorganic species of copper.

The amounts of the various copper compounds and complexes present in solution in freshwater depends on water pH, temperature, hardness, alkalinity, and concentrations of bicarbonate, sulfide, and organic ligands, size and density of suspended materials, and rates of coagulation and sedimentation of particulates. The majority of copper released to surface waters settles out or adsorbs to sediments

The concentration of copper found in interstitial water is usually much lower than that in surface water. While some copper complexes can undergo metabolism by aquatic biota, biotransformation of copper is low. Bioavailability of copper in sediments is controlled by the degree of complexation with acid volatile sulfide and adsorption to organic matter.

(4) Impact on Human Health

Copper is an essential nutrient, but at high doses can cause stomach and intestinal pain, damages the liver and kidney, or cause anemia.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Copper is taken up by aquatic organisms primarily through dietary exposure and is an essential micronutrient for animals as a component of a number of essential enzymes. Most organisms retain only a small proportion of the copper ingested with their diet. Once ingested, copper travels through the gastrointestinal tract, where some of it is absorbed into the blood and becomes associated with plasma albumin and amino acids. Albumin bound copper is eventually transported to the liver; however, minor fractions are transported into the bone marrow, the erythrocytes, or other tissues.

Copper can internally interact with essential trace elements such as iron, zinc, molybdenum, manganese, nickel, and selenium and also with nonessential elements including silver, cadmium, mercury, and lead; interactions may be either beneficial or harmful to the organism.

About 80 percent of the absorbed copper is bound to metallothionein in the liver and the remainder is incorporated into enzyme compounds. Copper is stored mainly in liver, brain, heart, kidney, and muscle; almost all of the copper retained in the body plays a particular physiological role. In mammals, copper is excreted mainly via the bile in association with glutathione or unidentified high molecular weight molecules.

Copper bioconcentrates in aquatic organisms but does not bioaccumulate in mammals or biomagnify in aquatic food chains. Concentration of copper in benthic organisms from contaminated areas can be one to two orders of magnitude higher than normal.

3.5 Lead (Pb)

(1) Basic Characteristics (Physical and Chemical Properties)

Name (Symbol)	**Lead (Pb)**
Chemical Series	Post transition metal or poor metal
CAS No.	7439-92-1
Melting Point, ^{O}C	327.46
Atomic Weight, g/mol	207.2(1)
Boiling Point, ^{O}C	1749
Density , g/m^3	11.34
Appearance	bluish gray, cubic face-centered

(2) Sources

Lead (Pb) is a neurotoxin and a good example of multimedia pollutant. The main sources of lead pollution in the environment include petrol, lead-containing paints, solders and varnishes used on interiors of food cans, lead pipes for water supply, pesticides. Lead shots in guns for game shooting, mining and smelting processes.

(3) Fate and Transport

Most lead entering natural waters is precipitated to the sediment in the form of carbonate and hydroxide (anionic) complexes. It can be mobilized and released from sediment when the pH decreases suddenly or ionic composition changes. Sorption is higher in sediments containing clay, and lower in sediments containing a higher percentage of sand or sand and loam Chemical and microbial process can transform the Pb^{2+} in sediments to tetraalkyl lead compounds, including tetramethyl lead. However, most organolead compounds result from anthropogenic inputs. TAL and TML are widely used as antiknock fuel additives. Generally, tetraalkyl lead concentration in

sediments is low, less than 10 percent of total lead. Although methylated lead is rapidly taken out from the water, e.g., by rainbow trout, there is no evidence of bioaccumulation in the aquatic environment.

The bioavailability of lead in sediment is controlled largely by the concentration of acid volatile sulfides (AVS) and organic matter.

(4) Impact on Human Health

Lead does not generally become an environmental problem until it dissolves to yield the ionic form, which is poisonous. Effects of lead to humans include anemia, kidney dysfunction and permanent brain damage.

Lead in water is more fully absorbed by the body than lead in food. Some lead used as solder in the joints of domestic copper water pipes can dissolve in drinking water, particularly if the water is quite acidic or if it is soft, hence, drinking water could be a source of collective lead intake in humans.

Most lead in humans is initially present in the blood, but some amount eventually reaches a plateau and the excess next enters the soft tissues, including the organs, particularly the brain. The toxicity of lead is proportional to the amount present in the soft tissues, not to the blood or bone. Lead remains in the human bodies for several years and thus can accumulate in the body.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Aquatic organisms accumulate lead from water as well as from dietary exposure. Organolead is rapidly bioaccumulated and concentrate in the fatty tissues of aquatic organisms. Lead does not biomagnify to a great extent in food chains, but accumulation by plants and animals has been extensively documented. Tissues of older organisms usually contain higher lead concentrations with the majority of accumulation occurring in the bony tissue of vertebrates.

3.6 Mercury (Hg)

(1) Basic Characteristics (Physical and Chemical Properties)

Name (Symbol)	**Mercury (Hg)**
Chemical Series	Transition metal
CAS No.	7439-97-6
Atomic Weight, g/mol	200.59

Melting Point, ^{O}C	-38.83
Boiling Point, ^{O}C	356.73
Density , g/m^3	13.534 (liquid)
Appearance	silvery

(2) Sources

Mercury may be present in the environment in a number of forms and can exist in three oxidation states: elemental mercury (Hg^{O}), mercurous di-ion ($Hg2^{2+}$), and mercuric ion (Hg^{2+}). Of all the inorganic forms, Hg^{2+} is the most toxic. Mercury compounds in an aqueous solution are chemically complex. Depending on pH, alkalinity, redox, and other variables, a wide variety of chemical species are liable to be formed, having different electrical charges and solubilities. Nonvolatile inorganic forms of mercury compounds sorb readily to sediments, particularly those sediments containing high organic carbon and reduced sulfur levels thereby reducing the bioavailability.

Mobilization of sorbed mercury can be caused by bioreduction to elemental mercury and bioconversion to more volatile and soluble forms, such as methylmercury. Methylmercury is the most hazardous mercury species due to its high stability, its lipid solubility, and its possession of ionic properties that lead to a high ability to penetrate membranes in living organisms.

(3) Fate and Transport

All mercury discharged into rivers, bays, or estuaries as elemental (metallic) mercury, inorganic divalent mercury, phenylmercury, or alkoxyalkyl mercury can be converted into methylmercury compounds by natural biological (bacterial microorganisms) or chemical processes). Under naturally occurring conditions of pH and temperature, methylated mercury forms in the aquatic environment predominantly through biological processes. The mercury methylation process depends on mercury loadings, microbial activity, nutrient content, pH and redox condition, suspended sediment load, sedimentation rates, and other variables; anaerobic conditions favormethylmercury formation more than aerobic conditions. Bacterial microbes are also responsible for methylmercury decomposition (demethylation). They are widespread in the environment and have been isolated from water, sediments, soils, and from the gastrointestinal tract of mammals, including humans.

Mercury from air caused by emissions from industries and mercury-containing fuels, and runoff containing mercury-sodden soil from mine tailings and ore are the main sources of mercury in water bodies and

fish. Mercury is very slowly removed from soil, and long after anthropogenic emissions are reduced, soil and water concentrations can be expected to remain elevated.

(4) Impact on Human Health

Mercury is the most volatile of all metals and its vapor is highly toxic. When inhaled, it diffuses from the lungs into the bloodstream and then crosses the blood/brain barrier to enter the brain. This results in serious damage to the central nervous system, which is manifested by difficulties in coordination, eyesight, and tactile lenses. Hg vapor and Hg salts also attack the kidney and the liver where it can cause extensive damage.

Methylation of Hg through the action of enzymes secreted by microorganisms found in bottom sediments of rivers, lakes and coastal waters produces the most toxic form of Hg, Methyl Mercury being the most potent. Most of the Hg present in humans is in this form, and almost all of it originates from the fish in our food supply.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Fish bioconcentrate methylmercury directly from water by uptake across the gills. Methylmercury accumulation from either source may be substantial, but the relative contribution of each pathway may vary with fish species. In addition, invertebrates generally have a lower percentage of methylmercury in their tissues than fish or marine mammals.

In birds, there is a tendency for mercury concentrations to be highest in species feeding on fish (or on other seabirds). However, when one compares mercury levels among predominantly fish eating species, levels apparently do not show clear patterns or any evident association with diet composition. There is an inverse relationship between total mercury and percent methylmercury in tissues of various avian species. Among furbearers, mercury burdens are higher in fish eating species than in herbivores.

The amount of methylmercury in animal tissues increases proportionately with the age of the organism, with the exception of marine mammals. Because marine mammals feed primarily on fish, they have the greatest potential for the highest tissue concentrations of methylmercury compared to other marine organisms. Contrary to other species or groups of animals, the tissue concentrations of methylmercury are higher in juvenile marine mammals than in adults

because the adults can mineralize methylmercury into inorganic mercury.
Mercury bio-magnifies; its concentration increases progressively along an ecological food chain. It is bio-concentrated by many aquatic organisms. Oysters and mussels can contain levels of Hg and Cd that are 100,000 times greater than the contents in the water body where they live.

3.7 Nickel (Ni)

(1) Basic Characteristics (Physical and Chemical Properties)

Name (Symbol)	**Nickel (Ni)**
Chemical Series	Transition metal
CAS No.	7440-02-0
Phase	Solid
Melting Point, ^{O}C	1455
Mol. Mass/At. Wt., g/mol	58.6934(2)
Boiling Point, ^{O}C	2913
Density, g/m^3	8.908
Appearance	lustrous, metallic and silvery with a gold tinge

(2) Sources

Nickelis a dietary requirement for many organisms but may be toxic in larger doses. The human body contains approximately 10 mg Ni.

Diffuse nickel emissions may stem from power plants, waste incinerators and metal industries. Nickel is directly emitted from various industries through discharge on surface waters. It is applied in alloys for treatment of heavy metal polluted surface water, in nickel-cadmium batteries, as a catalyzer and as a pigment.

Phosphate fertilizers contain traces of nickel. Nickel is often present in agricultural soils situated near fossil fuel industries. Organic matter adsorbs nickel, causing coal and oil to contain traces of the element. Nickel compounds may also be found in sludge, and in slags and fly ashes from waste incinerators.

(3) Fate and Transport

Stacks of large furnaces used to make alloys, power plants and garbage incinerators release nickel in the form of dust particles. These particles settle to the ground or mix with rain. It usually takes many days for nickel to be removed from the air. If the nickel is attached to very small particles, removal can take longer than a month. Most nickel end up in

the soil or sediment and attach to particles containing iron or manganese. Nickel is more mobile in acidic soil and may seep into groundwater.

(4) Impact on Human Health

Inhalation of Ni poses a greater risk than nickel in water. Inhalation may cause lung cancer, or nasal tumors. Many people develop dermatitis upon skin contact with nickel or nickel solutions. Nickel allergies are more common among women. Nickel compounds may be toxic in high concentrations, but these are often water insoluble, limiting potential harm. Upon intake of higher doses of nickel one usually vomits, resulting in rapid removal from the body.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Metallic Ni and some other nickel compounds are carcinogenic to mammals. Nickel restrains the growth of algae at concentrations between 0.5 and 10 ppm. Fishes are less susceptible but this differs between species. Nickel may end up in water from both point and non-point sources.

Most plants have high Ni tolerance but grain species are generally more susceptible. Grains may die if sprinkled with water of 40 mg/L Ni concentration.

4. Secondary Parameters - Organics

4.1 Animal-Vegetable Fat and Oil

Vegetable oils and animal fats and their constituents have the potential to cause devastating physical effects, by coating animals and plants depleting them of oxygen resulting in suffocation, form toxic products, destroy future and existing food supplies, animals and habitats, produce rancid odors and pollute shorelines, clog water treatment plans and catch fire when ignition sources are present. They also form products that stay in the environment for years.

AVFO spills can kill or injure fish, birds, mammals, and other species and produce other undesirable effects. Waterfowl and other birds, mammals, and fish that get coated with animal fats or vegetable oils could die of hypothermia, dehydration and diarrhea, or starvation. They can also sink and drown or fall victim to predators. Fish and other aquatic organisms may suffocate because of the depletion of oxygen caused by spilled animal fats and vegetable oils in water. Whether these oils are "toxic" to wildlife or kill wildlife indirectly through other

processes is not the issue. Spills of animal fats and vegetable oils have the same or similar devastating impacts on the aquatic environment as petroleum oils.

4.2 BTEX

4.2.1 Benzene

(1) Basic Characteristics (Physical and Chemical Properties**)**

Name (IUPAC)	Benzene
Name: (Common)/ Other Name	Benzol, Benzinecyclohexa-1,3,5-triene
CAS Reg. No.	71-43-2
Molecular Formula	C6H6
Melting Point, ^{O}C	5.5
Molar mass, g/mol	78.1118
Boiling Point, ^{O}C	80.1
Density, g/m^3	0.8786 (liquid)
Solubility in water g/100ml	1.79 g/L (25 ^{O}C)
Appearance	Colorless liquid with sweet odor
Related Compounds	Phenol, toluene, aniline, biphenyl, naphthalene, anthracene, pyridine, pyrimidine, pyrazine

(2) Sources

Benzene is produced in trace amounts during incomplete combustion of carbon-rich materials, eruption of volcanoes, forest fires, and smoking of cigarettes. It is also a byproduct of production of coke (or "coke-oven light oil") in the steel industry. In recent years, benzene is produced mostly from the petrochemical industry. Benzene is also released through motor vehicle exhaust, and evaporation from gasoline service stations.

Industrial processes are the main sources of benzene in the environment. Benzene is used in the production of styrene, which is used to make polymers and plastics; phenol which is used in the production of resins and adhesives; and cyclohexane which is used in the manufacture of nylon. Small amount of benzene is used in the production of rubber, detergent, lubricant, explosives, pesticides, drugs, detergents and napalm.

Benzene has been used as a basic research tool in a variety of experiments, and in watch-making for the cleaning of hairsprings.

(3) Fate and Transport

Water and soil contamination are important pathways of concern for transmission of benzene. Benzene can pass into air from water and soil surfaces. In the air, benzene reacts with other chemicals and breaks down within a few days. From the air, it can be deposited on the ground by rain or snow.

Benzene in water and soil breaks down more slowly. It is slightly soluble in water and can pass through the soil into underground water.

(4) Impact on Human Health

Breathing low level of benzene causes drowsiness, dizziness, rapid heart rate, tremor, confusion, headache and unconsciousness and breathing high level can lead to death. Ingestion of food containing high level of benzene can cause vomiting, dizziness, stomach irritation, drowsiness, convulsions, and even death.

Long-term exposure can damage the bone marrow and can decrease red blood cells that may lead to anemia. It can also cause excessive bleeding and lowering of the immune system.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Pregnant animals that have breathed benzene tend to have low birth weights, delayed bone formation, and bone marrow damage. Benzene in the environment does not build up in plants or animals.

4.2.2 Toluene

(1) Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	Toluene
Name: (Common)/ Other Name	Methyl benzene, phenyl methane, toluol,
CAS Reg. No.	108-88-3
Molecular Formula	C_7H_8 ($C_6H_5CH_3$)
Melting Point, ^oC	−93
Molar mass, g/mol	78.1118
Boiling Point, ^oC	110.6
Density, g/m^3	0.8669 (liquid)
Solubility in water, g/100ml	0.053 (20-25 °C)
Appearance	Clear colorless liquid
Related Compounds	Benzene, xylene, naphthalene, methyl xyclohexane

(2) Sources

Toluene occurs naturally in crude oil at low levels. It is usually produced during the production of gasoline and other fuels from crude oil, when making coke from coal, and as a by-product in the manufacture of styrene which is used for making polystyrene, a commonly used plastic material.

Toluene is a common solvent. It is used in making paint, paint thinner, printing ink, many chemical reactants, glue or adhesive, rubber, lacquers, leathers, nail polish and disinfectants. It is a raw material in the production of TNT and toluene diisocyanate which is used in the manufacture of polyurethane foam. When oxidized, toluene yields benzaldehyde and benzoic acid, two important intermediates in chemistry. Toluene can be used to break open red blood cells in order to extract hemoglobin in biochemistry experiments. Toluene is an octane booster in gasoline fuels.

(3) Fate and Transport

Toluene enters the environment when materials that contain it are used. These include paints, paint thinners, adhesives, fingernail polish, and gasoline. The toluene evaporates and mixes with the air. It enters surface water and groundwater through spills of solvents and petroleum products and from leaks from gasoline storage tanks, gasoline stations and other facilities.

When toluene-containing products are placed in landfills or waste disposal facilities, the toluene can enter the soil and the water body near the waste disposal site. Toluene does not usually stay in the environment; it is readily broken down to other chemicals by microorganisms in soil and evaporates from surface water and surface soils. However, toluene dissolved water does not break down quickly while the water is under the ground because there are few microorganisms in underground water. Once the water is brought to the surface, the toluene will evaporate into the air.

The toluene in the air will combine with oxygen and form benzaldehyde and cresol. These compounds are harmful to humans. Thus, in rooms where toluene-containing products are used, windows and doors should be opened to allow the toluene gas to escape.

(4) Impact on Human Health

When inhaled, toluene fumes intoxicate and in larger doses induce nausea. Toluene may enter the human system through inhalation of

the vapor. If the soil is contaminated by toluene and a person gets in contact with soil, ingestion of contaminated groundwater or soil vapour off-gassing can occur.

A serious health concern is that toluene may have an effect on the brain. Toluene can cause headaches, confusion, and memory loss depending on the amount of intake and length of exposure. Symptoms usually disappear when exposure is halted.

Repeated breathing in of toluene from glue or paint thinners, may lead to permanent brain damage. It may also cause speech, vision, or hearing problems or loss of muscle control, memory loss, poor balance, and decreased mental ability. Some of these changes may be permanent. Exposure can even cause death by interfering with the way a person breathes and the way his heart beats.

Toluene may change the way the kidneys works. Combination of the effect of drinking alcohol and exposure to toluene can affect the liver more than either compound alone. This phenomenon is called synergism. Combinations of toluene and some common medicines like aspirin and acetaminophen may increase the effects of toluene on a person's hearing ability.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

In animals, the main effect of toluene is on the nervous system. Animals exposed to moderate or high levels of toluene may also show slightly adverse effects in their liver, kidneys, and lungs.

Several studies have shown that unborn animals were harmed when high levels of toluene were breathed in by their mothers. When the mothers were fed high levels of toluene, the unborn animals did not show any structural birth defects, although some effects on behavior were noted.

Toluene can be taken up by fish, shellfish, plants and animals living in water containing toluene, but it does not concentrate or build up to high levels because most animal species can make the toluene into other compounds that are excreted.

Both the IARC and the US EPA have not classified toluene as a human carcinogen.

4.2.3 Ethylbenzene

Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	Ethylbenzene, Ethylbenzol
Name: (Common)/ Other Name	EB, phenylethane
CAS Reg. No.	100-41-4
Molecular Formula	C8H10
Melting Point, ^{o}C	-95
Molar mass, g/mol	106.167
Boiling Point, ^{o}C	136
Density, g/cm^3	0.867, liquid
Solubility in water, g/100 ml	0.015 (20 ^{o}C)
Appearance	Colorless liquid
Related Compounds	styrene, toluene, benzene, polystyrene

(2) Sources

Ethyl benzene is an organic chemical compound which is an aromatic hydrocarbon. Its major use is in the petrochemical industry as an intermediate compound for the production of styrene, which in turn is used for making polystyrene, a commonly used plastic material. Although often present in small amounts in crude oil, ethylbenzene is produced in bulk quantities by combining the petrochemicals benzene and ethylene in an acidically-catalyzed chemical reaction. Catalytic dehydrogenation of the ethylbenzene produces hydrogen gas and styrene, which is vinylbenzene. Ethylbenzene is also an ingredient in some paints.

(3) Fate and Transport

The majority of ethylbenzene releases to the environment occurs to the atmosphere. Its release can occur during manufacturing, processing, and handling, e.g., during the catalytic reformate production, fuels and solvents and tail pipe emissions of gasoline-powered vehicles.

Ethylbenzene moves easily into the air from water and soil. It takes about 3 days for ethylbenzene to be broken down in air into other chemicals. In surface water, ethylbenzene breaks down by reacting with other chemicals found naturally in water. Ethylbenzene can move through soil into groundwater. In soil, it is broken down by bacteria.

(4) Impact on Human Health

People living in a city or near many factories or heavily traveled highways are prone to exposure to ethylbenzene in the air. Ethylbenzene may also be released into the air during the burning of oil, gas, and coal and from industries using ethylbenzene.

Ethylbenzene is not often found in drinking water. Higher levels may be found in residential drinking water wells near landfills, waste sites, or leaking underground fuel storage tanks.

4.2.4 Xylene

(1) Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	Xylene
Name: (Common)/ Other Name	Xylol, dimethyl benzene
CAS Reg. No.	1330-20-7
Molecular Formula	C_8H_{10} ($C_6H_4C_2H_6$)
Melting Point, ^oC	-47.4°C
Molar mass, g/mol	106.16 g/mol
Boiling Point, ^oC	138.5^oC
Density, g/cm^3	0.864 g/mL, liquid
Solubility in water, g/100 ml	practically insoluble
Appearance	clear, colorless liquid
Related Compounds	xylenols - types of phenols

(2) Sources

Xylene is a colorless, flammable liquid with a sweet odor. It is a synthetic chemical produced from petroleum and occurs naturally in petroleum and coal tar. It is also formed during forest fires.

Xylene is used as a solvent (a liquid that can dissolve other substances) in the printing, rubber, and leather industries. Its applications include cleaning agent and thinner for paint and varnishes. It is found in small amounts in airplane fuel and gasoline. Xylene is used as a material in the chemical, plastics, and synthetic fiber industries and as an ingredient in the coating of fabrics and papers. Isomers of xylene are used in the manufacture of certain polymers, such as plastics. It is also used as a color marker to monitor the process of agarose gel electrophoresis and polyacrylamide gel electrophoresis; in 1% agarose gels, it typically migrates at about the same rate as a 4000 base pair DNA fragment. Xylene can enter the environment when it is made, packaged, shipped, or used. Most xylene that is accidently released

evaporates into the air, although some is released into rivers or lakes. Xylene can also enter soil, water, or air in large amounts after an accidental spill or as a result of an environmental leak during storage or burial at a waste site.

(3) Fate and Transport

Xylene is a liquid, and it can leak into soil, surface water (creeks, streams, rivers), or groundwater, where it may remain for months or more before it breaks down into other chemicals. However, because it evaporates easily, most xylene (if not trapped deep underground) goes into the air, where it stays for several days. In the air, the xylene is broken down by sunlight into other less harmful chemicals.

Most xylene in surface water evaporates into the air in less than a day. The rest of it is slowly broken down into other chemicals by small living organisms in the water. Only very small amounts are taken up by plants, fish, and birds. It is not known exactly how long xylene stays in water, but it stays longer in underground water than in lakes and rivers, probably because it can evaporate from the latter.

Xylene evaporates from soil surfaces. Xylene below the soil surface stays there for several days and may travel down through the soil and enter underground water (groundwater). Small living organisms in soil and groundwater may transform it into other less harmful compounds, although this happens slowly. It is not clear how long xylene remains trapped deep underground in soil or groundwater, but it may be months or years. Xylene stays longer in wet soil than in dry soil. If a large amount of xylene enters soil from an accidental spill, a hazardous waste site, or a landfill, it may travel through the soil and contaminate drinking water wells. Only a small amount of xylene is absorbed by animals that live in water contaminated with xylene.

(4) Impact on Human Health

Short-term exposure can irritate the skin, eyes, nose, and throat; cause breathing difficulty; impair the lungs, memory and response to visual stimulus; and cause stomach discomfort. Exposure to high concentrations may affect the nervous system and impair sense of balance and muscle coordination. It may also cause headache, dizziness and confusion. Short exposure to very high levels of xylene could cause death.

Exposure of pregnant women to high levels of xylene may harm the fetus. Longer exposure to high concentrations increases the risk to health. Lower concentrations of xylene are not so harmful.

It is not confirmed if xylene causes cancer in humans. There is insufficient information to determine whether or not xylene is carcinogenic and both the IARC and EPA have not classified xylene as a human carcinogen.

(5) Impact on Environment

Xylene is rarely found in high concentrations in topsoil or surface water (river, creeks) unless there has been a recent spill or continuing source of contamination. Any xylene that does not evaporate quickly from soil or water is broken down by small organisms. Only very small amounts are taken up by plants, fish, and birds.

Short-term exposure to very high concentrations of xylene causes death in animals, as well as muscular spasms, incoordination, hearing loss, changes in behavior, changes in organ weights, and changes in enzyme activity.

4.3 Cyanide

(1) Basic Characteristics (Physical and Chemical Properties)

Name (IUPAC)	Free Cyanide
Name: (Common)/ Other Name	Cyanide ion, simple cyanide,
CAS Reg. No.	57-12-5
Molecular Formula	CN^-, $C\equiv N$:
Related Compounds	Hydrogen Cyanide, hydoxianic acid

(2) Sources

Free cyanide is the primary toxic agent in the aquatic environment. Free cyanide refers to the sum of molecular HCN and the cyanide anion (CN-), regardless of origin.

In aqueous solution with pH 9.2 and lower, the majority (>90%) of the free cyanide is in the form of molecular HCN [517,754].

Cyanides are used widely and extensively in the manufacture of synthetic fabrics and plastics, in electroplating baths and metal mining operations, as pesticidal agents and intermediates in agricultural chemical production, and in predator control devices.

(3) Fate and Transport

Cyanide enters air, water, and soil from both natural processes and industrial activities. Cyanide enters air, water, and soil from both natural processes and industrial activities.

In air, cyanide is mainly found as gaseous hydrogen cyanide; a small amount is present as fine dust particles.

The half-life (the time needed for half of the material to be removed) of hydrogen cyanide in the atmosphere is about 1– 3 years.

- Most cyanide in surface water will form hydrogen cyanide and evaporate.
- Cyanide in water does not build up in the bodies of fish.
- Cyanides are fairly mobile in soil. Once in soil, cyanide can be removed through several processes. Some cyanide compounds in soil can form hydrogen cyanide and evaporate, whereas some cyanide compounds will be transformed into other chemical forms by microorganisms in soil. At the high concentrations, cyanide becomes toxic to soil microorganisms. Because these microorganisms can no longer change cyanide to other chemical forms, cyanide is able to passes through soil into underground water.

(4) Impact on Human Health

People are not likely to be exposed to large enough amounts of cyanide in the environment to cause adverse health effects. The severity of the harmful effects following cyanide exposure depends in part on the form of cyanide, such as hydrogen cyanide gas or cyanide salts. Exposure to high levels of cyanide for a short time harms the brain and heart and can even cause coma and death. Workers who inhaled low levels of hydrogen cyanide over a period of years had breathing difficulties, chest pain, vomiting, blood changes, headaches, and enlargement of the thyroid gland.

Symptoms of cyanide poisoning include rapid, deep breathing and shortness of breath, followed by convulsions (seizures) and loss of consciousness. These symptoms can occur rapidly, depending on the amount eaten. The health effects of large amounts of cyanide are similar, whether you eat, drink, or breathe it; cyanide uptake into the body through the skin is slower than these other means of exposure. Skin contact with hydrogen cyanide or cyanide salts can irritate and produce sores.

There are no reports that cyanide can cause cancer in people or animals. EPA has not classified cyanide as a human carcinogen.

(5) Impact to Aquatic/Terrestrial Life and Agricultural Productivity

Aquatic Organisms: Fish and aquatic invertebrates are sensitive to cyanide exposure. Cyanide concentrations of 5.0 to 7.2 micrograms per liter of water already affect swimming ability and inhibit reproduction of many fish species, and affect respiration, osmotic regulation and growth. Concentrations of 20 to 76 micrograms per liter free cyanide can cause the death of many species. Concentrations of more than 200 micrograms per liter are highly toxic to most fishes.

Aquatic plants are unaffected by cyanide at concentrations that are lethal to most fish and invertebrate species but cyanide has the potential to alter plant community structure, with cyanide exposures leaving a plant community dominated by less sensitive species.

The sensitivity of aquatic organisms to cyanide is highly species specific, and is also affected by water pH, temperature and oxygen content, as well as the life stage and condition of the organism.

Birds: Reported oral LD50 for birds range from 0.8 milligrams per kilogram of body weight (American racing pigeon) to 11.1 milligrams per kilogram of body weight (domestic chickens). Symptoms including panting, eye blinking, salivation and lethargy appear within one-half to five minutes after ingestion in more sensitive species, and up to ten minutes after ingestion by more resistant species. Exposures to high doses resulted in deep, labored breathing followed by gasping and shallow intermittent breathing in all species. Mortality typically occurred in 15 to 30 minutes; however birds that survived for one hour frequently recovered, possibly due to the rapid metabolism of cyanide to thiocyanate and its subsequent excretion.

Mammals: Exposure of mammals to cyanide toxicity is relatively common because of prevalence of cyanogenic forage plants like corn, sorghum and sudan grasses. Concentrations of cyanide in these plants are typically highest during blooms. Dry growing conditions enhance the accumulation of cyanogenic glycosides in certain plants as well as increase the use of these plants as forage.

Cyanide seems not to have any direct effect on recreational uses of water other than its effect on aquatic life.

GLOSSARY OF TERMS

Acid

A solution that is a proton (H^+) donor and has a pH less than 7 on a scale of 0-14. The lower the pH the greater the acidity of the solution.

Acidity

A measure of how acid a solution may be. A solution with a pH of less than 7.0 is considered acidic. Solutions with a pH of less than 4.5 contain mineral acidity (due to strong inorganic acids), while a solution having a pH greater than 8.3 contains no acidity.

Acid rain

Precipitation having a pH lower than the natural range of ~5.2 - 5.6; caused by sulfur and nitrogen acids derived from anthropogenic emissions.

Algae

Simple single-celled, colonial, or multi-celled, aquatic plants. Aquatic algae are (mostly) microscopic plants that contain chlorophyll and grow by photosynthesis, and lack roots and stems ((non-vascular), and leaves. They absorb nutrients (carbon dioxide, nitrate, ammonium, phosphate and micronutrients) from the water or sediments, add oxygen to the water, and are usually the major source of organic matter at the base of the food web in lakes. Freely suspended forms are called *phytoplankton;* forms attached to rocks, stems, twigs, and bottom sediments are called periphyton.

Alkalinity

Acid neutralizing or buffering capacity of water; a measure of the ability of water to resist changes in pH caused by the addition of acids or bases and therefore, the main indicator of susceptibility to acid rain; in natural waters it is due primarily to the presence of bicarbonates, carbonates and to a much lesser extent occasionally borates, silicates and phosphates. It is expressed in units of milligrams per liter (mg/l) of $CaCO_3$ (calcium carbonate) or as microequivalents per liter (ueq/l) where 20 ueq/l = 1 mg/l of $CaCO_3$. A solution having a pH below about 5 contains no alkalinity.

Anaerobic

A descriptive term for a process such as fermentation that can proceed only in the absence of oxygen, or a living thing that can survive only in the absence of oxygen. Technically this means "*without air*" but in limnology it is used synonymously with *"anoxic"* that means completely lacking in oxygen.

Anthropogenic

Caused by humans or human activity.

Atmospheric (Barometric) Pressure

Measure of the pressure of the earth's atmosphere per unit area. It is 760 mm Hg at sea level and decreases with increasing elevation.

Aufwuchs

The community of algae and other microorganisms that attach to surfaces such as rocks, twigs, and aquatic plants; essentially the same as "*periphyton*" that means "*attached algae*."

Base

A substance which accepts protons (H^+) and has a pH greater than 7 on a scale of 0-14; also referred to as an alkaline substance.

Basin

Geographic land area draining into a lake or river; also referred to as *drainage basin* or watershed.

Benthic

Refers to being on the bottom of a water body.

Bioaccumulation

The accumulation of substances in life forms or biological system through uptake from the environment or food chain.

The increase in concentration of a chemical in organisms that reside in environments contaminated with low concentrations of various organic compounds. Also used to describe the progressive increase in the amount of a chemical in an organism resulting from rates of absorption of a substance in excess of its metabolism and excretion. Certain chemicals, such as PCBs, mercury, and some pesticides, can be concentrated from very low levels in the water to toxic levels in animals through this process.

Biochemical Oxygen Demand (BOD)

Sometimes referred to as *Biological Oxygen Demand (BOD)*. A measure of the amount of oxygen removed (respired) from aquatic environments by aerobic microorganisms either in the water column or in the sediments. The parameter BOD uses the maximum rate of O_2 consumption over a 5 day period in the dark at 20^0 to estimate the total amount of "biodegradable" organic matter in the system. Typically too insensitive to be useful for pristine lakes and so is used primarily for wastewater "streams" or systems impacted by organic pollution.

Biomass

The weight of a living organism or assemblage of organisms.

Chlorophyll

Green pigment in plants that transforms light energy into chemical energy in photosynthesis.

Clarity

Transparency; routinely estimated by the depth at which you can no longer see a secchi disk. The Secchi disk is a 20 cm (8 inch) diameter weighted metal plate with alternating quadrants painted black and white that is used to estimate water clarity (light penetration). The disc is lowered into water until it disappears from view. It is then raised until just visible. An average of the two depths, taken from the shaded side of the boat, is recorded as the Secchi depth.

Combustion

More commonly known as burning, a complex sequence of exothermic chemical reactions between a fuel and an oxidant accompanied by the production of heat or both heat and light in the form of either a glow or flames.

Composite Sample

A series of individual grab samples taken at different times from the same sampling point and mixed together

Conductivity (electrical conductivity and specific conductance)

Measures water's ability to conduct an electric current and is directly related to the total dissolved salts (ions) in the water. Called EC for electrical conductivity and is reported in micromhos per centimeter (umhos/cm) which has been recently renamed as uS/cm (microSiemans per centimeter). EC is temperature sensitive and increases with increasing temperature. Most modern probes automatically correct for temperature and standardize all readings to 25°C and then refer to the data as *specific* EC.

Contamination

A general term referring to the introduction of materials not normally found in water that make the water less desirable or unfit for its intended or beneficial uses.

Decomposition

The reduction of the body of a formerly living organism into simpler forms of matter. The breakdown of organic matter by bacteria and fungi.

Density

The mass of a substance or organism per unit volume (kg/cubic meter; grams/liter).

Density Stratification

Creation of layers in a water body due to density differences; controlled by temperature, dissolved solids concentration and particle concentration.

Diatom

Group of algae characterized by glass (silica) cell wall, beautifully ornamented; often the brown stuff attached to rock surfaces.

Dissolved Oxygen (DO)

The concentration of free (not chemically combined) molecular oxygen (a gas) dissolved in water, usually expressed in milligrams per liter, parts per million, or percent of saturation. Adequate concentrations of dissolved oxygen are necessary for the life of fish and other aquatic organisms and the prevention of offensive odors. DO levels are considered the most important and commonly employed measurement of water quality and indicator of a water body's ability to support desirable aquatic life. Levels above 5 milligrams per liter (mg O_2/L) are considered optimal and most fish cannot survive for prolonged periods at levels below 3 mg O_2/L. Levels below 1 mg O_2/L are often referred to as *hypoxic* and when O_2 is totally absent *anoxic* (often called anaerobic which technically means *without air*). Secondary and advanced wastewater treatment systems are generally designed to degrade organic matter to ensure adequate dissolved oxygen in waste-receiving waters.

Eutrophication

The process by which lakes and streams are enriched by nutrients (usually phosphorus and nitrogen) which leads to excessive plant growth - algae in the open water, periphyton (*attached* algae) along the shoreline, and macrophytes (the higher plants we often call *weeds*) in the nearshore zone. The less productive a lake is naturally, the more sensitive it is to increased nutrient loads from human-caused disturbances in the watershed.

Excel

Refers to Microsoft's Excel spreadsheet software.

Fix

Convert CO_2 to carbohydrate or N_2 to $NH4^+$ (carbon fixation and nitrogen fixation);

Freshwater

Water containing less than 500 mg/L dissolved common salt, sodium chloride, such as that in groundwater, rivers, ponds, and lakes.

Flow Rate

The rate at which water moves by a given point; in rivers it is usually measured in cubic meters per second (m^3/sec) or cubic feet per second (cfs).

Solubility

The ability the substance to dissolve into another substance.

Geographic Information System (GIS)

A computer system which allows for input and manipulation of geographic data to allow researchers to manipulate, analyze and display the information in a map format.

Geometric Mean

The n^{th} root of the product of a series of n numbers. It is a calculation to determine an average when the set of numbers covers a wide range. Results of bacteriological testing often cover such a large range.

Hydrology

The study of water's properties, distribution and circulation on Earth.

Impervious surfaces

Land surfaces such as roads, parking lots, buildings, etc that prevent rainwater from soaking into the soil. The water increases in velocity causing more erosion; it warms causing potential heat stress for downstream trout; it picks up roadway contaminants; and the loss of vegetation removes a "sink" for dissolved nutrients - plant uptake.

Inflow

Water flowing into a lake.

Inorganic

Substances of mineral, not carbon origin.

Ion

An electrically charged particle.

Lake

An inland body of water, an expanded part of a river, a reservoir formed by a dam, or a lake basin intermittently or formerly covered by water. (NWQSR 2001-2005)

Lake Profile

A graph of a lake variable per depth; where the depth is on the z-axis and the variable is on the x-axis. Depth is the independent variable and the x-axis is the dependent variable.

Land use

The primary or primary and secondary uses of land, such as cropland, woodland, pastureland, forest, water (lakes, wetlands, streams), etc. The description of a particular land use should convey the dominant character of a geographic area and establish the dominant types of human activities which are prevalent in each region.

Landscape

All the natural geographical features, such as fields, hills, forests, and water that distinguish one part of the earth's surface from another part. These characteristics are a result not only of natural forces but of human use of the land as well.

Macrophytes

Higher aquatic plants; in the sense of "higher" evolutionarily than algae and having roots and differentiated tissues; may be emergent (cattails, bulrushes, reeds, wild rice), submergent (water milfoil, bladderwort) or floating (duckweed, lily pads).

Marine Waters

Waters of the ocean that lies beyond the limit of coastal waters and have natural salinity levels of not less than 30 ppt, 95 percent or more of the time. It is synonymous to saline water, or euhaline seas. (RA 8550 - Philippine Fisheries Code of 1998)

Mean Depth

The average depth of a water body; determined by dividing lake volume by the surface area (also called z mean).

Metabolism

The chemical and physical processes continually going on in living organisms and cells, by which the energy is provided for cellular processes and activities, and new material is assimilated to repair waste.

Micronutrient

Trace nutrients required by microrganisms or zooplankton such as molybdenum and cobalt; nitrogen and phosphorus are considered to be macronutrients.

Mixture

An aggregate of two or more substances that are not chemically united.

Napalm

The name given to any of a number of flammable liquids used in warfare often jellied gasoline. It is the thickener in such liquids, which when mixed with gasoline makes a sticky incendiary gel.

Non-point Source

Any source of pollution not identifiable to a point source to include, but not limited to, runoff from irrigation or rainwater that picks up pollutants from farms and urban areas. [NWQSR 2001-2005, RA 9275]; Diffuse source of pollutant(s); not discharged from a pipe; associated with land use such as agriculture or contaminated groundwater flow or on-site septic systems.

Nutrient loading

Discharging of nutrients from the watershed (basin) into a receiving water body (lake, stream, wetland); expressed usually as mass per unit area per unit time (kg/ha/yr or lbs/acre/year).

Organic

Substances which contain carbon atoms and carbon-carbon bonds.

Outflow

Water flowing out of a lake.

Outliers

Data points that lie outside of the normal range of data. Ideally, outliers must be determined by a statistical test before they can be removed from a data set.

Oxygen

An odorless, colorless gas; combines to form water; essential for aerobic respiration.

Parameter

A particular physical, chemical, or biological property that is being measured.

Periphyton

Attached algae; the green slime that attaches shoreline and bottom vegetation and the brown stuff attached to rock surfaces.

Pesticide

A chemical substance or biological agent used against pests including insects, plant pathogens, weeds, mollusks, birds, mammals, fish, nematodes, and microbes that compete with humans for food, destroy property, spread disease or are a nuisance.

Petri dish

A shallow, round glass dish + lid used for culturing microorganisms.

pH

A measure of the concentration of hydrogen ions.

pH Profile

A graph of the pH level per depth; where the depth is on the z-axis and pH level is on the x-axis. Depth is the independent variable and the x-axis is the dependent variable.

pH Scale

A scale used to determine the alkaline or acidic nature of a substance. The scale ranges from 1-14 with 1 being the most acidic and 14 the most basic. Pure water is neutral with a pH of 7.

Philippine Waters

All water bodies within the Philippine territory such as lakes, rivers, streams, creeks, brooks, ponds, swamps, lagoons, gulfs, bays, and seas and other bodies of water now existing or which may hereafter exist in the provinces, cities, municipalities, and barangays and the waters around, between, and connecting the islands of the archipelago regardless of their breadth and dimensions, the territorial sea, the sea beds, the insular shelves, and all other waters over which the Philippines has sovereignty and jurisdiction including the 200-nautical miles Exclusive Economic Zone and the continental shelf.
(RA 8550 - Philippine Fisheries Code of 1998)

Phosphorus

Key nutrient influencing plant growth in lakes. Soluble reactive phosphorus (PO_4^{-3}) is the amount of phosphorus in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

Photosynthesis

The process by which green plants convert carbon dioxide (CO_2) dissolved in water to sugars and oxygen using sunlight for energy. Photosynthesis is essential in producing a lake's food base, and is an important source of oxygen for many lakes.

Phytoplankton

Microscopic floating plants, mainly algae, that live suspended in bodies of water and that drift about because they cannot move by themselves or because they are too small or too weak to swim effectively against a current.

Plankton

Plants, animals, and bacteria that drift through lakes and the oceans

ppm

Part-per-million; equivalent to a milligram per liter (mg/l)

Pressure (p)

The force exerted per unit area.

Primary Productivity

The productivity of the photosynthesizers at the base of the food chain in ecosystems. This refers to the yield of new biomass (plant) growth during a specified time period. The entire year's accumulation is termed annual production. In the open water of lakes it is typically estimated by measured growth rates of phytoplankton (algae), either via O_2 accumulation in light relative to dark bottles of lake water or by the uptake of added radioactive carbon dioxide in sealed bottles of lake water.

Productivity

The time rate of production of biomass for a given group of organisms; essentially the net growth rate of organisms.

Profile

A vertical, depth-by-depth characterization of a water column, usually at the deepest part of a lake.

Respiration

The metabolic process by which organic carbon molecules are oxidized to carbon dioxide and water with a net release of energy. Aerobic respiration requires, and therefore consumes, molecular oxygen (algae, *weeds*, zooplankton, benthic invertebrates, fish, many bacteria, people). Certain bacteria can use nitrate in place of oxygen (denitrifiers) or sulfate (sulfate reducers), but only under anaerobic (anoxic) conditions - typically present only in the sediments or in the hypolimnion after prolonged oxygen depletion has occurred.

River

A natural waterway usually formed by water derived from precipitation and flows from higher ground to lower ground.

Saturation

The point at which a substance has the maximum amount of another substance at a given temperature and pressure.

Secchi Disk

A disk with a 4-6 inch radius that is divided into 4 equal quadrates of alternating black and white colors. It is lowered into a section of shaded water until it can no longer be seen and then lifted back up until it can be seen once again. Averaging the two depths gives the clarity of the water.

Sedimentation

The removal, transport, and deposition of detached soil particles by flowing water or wind. Accumulated organic and inorganic matter on the lake bottom. Sediment includes decaying algae and weeds, precipitated calcium carbonate (marl), and soil and organic matter eroded from the lake's watershed.

Shoreline

The zone where lake and land meet. Shorelands are defined as the lands 1000 ft from the ordinary high water level.

Solubility

The ability of a substance to dissolve into another; also see gas solubility.

Solute

A substance which can be dissolved into another substance.

Solution

A homogenous mixture of two substances.

Solvent

A substance which has the ability to dissolve another;.

Specific conductance

A measure of the ability of water to conduct an electrical current as measured using a 1-cm cell and expressed in units of electrical conductance (EC), i.e. siemans (uS or mS) at 25 C.

Stream

A body of water with a detectable current, confined within a bed and banks.

Stratification

An effect where a substance or material is broken into distinct horizontal layers due to different characteristics such as density or temperature.

Substrate

Attachment surface or bottom material in which organisms can attach or live-within; such as rock substrate or sand or muck substrate or woody debris or living macrophytes.

Suspended Sediment (SS or Total SS[TSS])

Very small particles which remain distributed throughout the water column due to turbulent mixing exceeding gravitational sinking.

TDS

Total dissolved salts or solids in a volume of water; usually in mg/l; estimated by EC (electrical conductivity).

Temperature

A measure of whether a substance is hot or cold.

Temperature Profile

A graph of the temperature per depth; where the depth is on the z-axis and temperature is on the x-axis.

Topography

Configuration of physical surface of land; includes relief imprints and locations of all man-made and natural features.

Total Dissolved Solids (TDS)

The amount of dissolved substances, such as salts or minerals, in water remaining after evaporating the water and weighing the residue.

Tributary

Feeder stream.

Turbidity

A measure of the degree to which light is scattered by suspended particulate material and soluble colored compounds in the water. It provides an estimate of the the muddiness or cloudiness of the water due to clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton, and microscopic organisms.

Water body

Any significant accumulation of water, usually covering the Earth or another planet. The term *body of water* most often refers to large accumulations of water, such as oceans, seas, and lakes, but it may also include smaller pools of water such as ponds, puddles or wetlands. Rivers, streams, canals, and other geographical features where water moves from one place to another are not always considered bodies of water.

Water column

A conceptual column of water from lake surface to bottom sediments.

Water sample

A sample taken from one of the following sources drinking, surface, ground, storm runoff, industrial or domestic wastewater.

Water Density

The ratio of water's mass to its volume; water is most dense at four degrees Celsius.

Watershed

All land and water areas that drain toward a river or lake; also called Drainage Basin or Water Basin.

Winkler Titration Kit

A "wet" chemistry analytical procedure used to determine the oxygen content of water via the Winkler reaction.

Zooplankton

The animal portion of the living particles in water that freely float in open water, eat bacteria, algae, detritus and sometimes other zooplankton and are in turn eaten by planktivorous fish.

REFERENCES

1. American Society for Testing and Materials (1993). *Standard method for open-channel flow measurement of water with thin-plate weirs.* (ASTM Document no. D5424)

2. Bartram, J. and Balance, R. (1996). *Water Quality Monitoring. A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes.* United Nations Environmental Protection/World Health Organization

3. DENR Administrative Order No. 2005-10. (2005). *Implementing Rules and Regulations of the Philippine Clean Water Act of 2004 (Republic Act 9275).* Environmental Management Bureau, Department of Environment and Natural Resources.

4. French, R.H. (1986). *Open Channel Hydraulics*. Mc. Graw Hill

5. Gupta, R.S. (1989). *Hydrology and Hydraulic System* (pp.264-274). Prentice Hall (Engelwood Cliff, New Jersey).

6. Guerrero J.L., et.al. (1996). Laguna de Bay: *Philippine Technical Information Series (PTIS) No. 1.* Department of Science and Technology. Information Resource and Analysis Division, Science and Technology Information Institute.

7. Herschy, R.W. (1978). *Hydrometry: Principles and Practices.* New York. John Wiley and Sons, Ltd.

8. International Organization of Standards (ISO 4359). (1999). *Technical Corrigendum 1 for: Liquid flow measurement in open channels - Rectangular, trapezoidal, and U-shaped flumes.* Reference number: ISO 4359:1983/Cor.1: 1999(E).

9. Metcalf and Eddy. (2003). *Wastewater Engineering, Treatment and Reuse* (4th Ed.). New York. Mc Graw Hill.

10. Mitchell, M. & Stapp, W. *Field Manual for Water Quality Monitoring.* 2050 Delaware, Ave., Ann Arbor, Michigan 48103.

11. Nader, Glenn, et.al. *Water Quality Monitoring.*

12. Odenbach, R. (2001). *Standard Operating Procedures for Water Quality Monitoring.* Minnesota, USA: Red Lake Water District

13. Parmley, R. O. (1992). *Hydraulics Field Manual.* New York: *Mc.* Graw Hill, Inc.

14. Resources Information Standards Committee (1998, March). *Ambient Freshwater and Effluent Sampling Manual*. Province of British Columbia.

15. Sara, M. N. (2003). *Site Assessment and Remediation Handbook* (2nd Edition). Lewis Publishers, Washington, D.C.

16. *Standard Methods for the Examination of Water and Wastewater. (1995)*. (19th Edition). 1015 Fifteenth Street, NW, Washington, D.C. 20005, Method 5520B and Method 5520F. American Public Health Association.

17. Umaly, R.C, and Cuvin, L.A. (1998). [Limnology*: Laboratory and Field Guide*]. *Physico-Chemical Factors. Biological Factors,* Metro Manila, Philippines: National Bookstore

18. U.P. Science Research Foundation. (1986). *Manila Bay Monitoring Program,* Final Report", National Pollution Control Commission.

19. Walpole, R.E., and Mayers, R.H. (1993). *Probability and Statistics for Engineers and Scientists, 5th Edition*. New York: Macmillan Publishing Company.

20. *Water Body Classification Report, Danao River*. (2004) Department of Environment and Natural Resources. Environmental Management Bureau, Region 6.

21. *Water Quality Monitoring Manual*. (1990). Department of Environment and Natural Resources, Environmental Management Bureau.

22. *Water Quality Field Sampling*, from www.qasr_sec_03.2006.