



# Environmental Monitoring Handbook

a practical guide for affected  
communities in monitoring  
mining operations



11+

Relationship between  
Cause Layer &  
Effect Layer

515 report for  
11th month  
w/ wife

Beneficial cases  
of Cause Layer

Unbeneficial cases  
of Effect Layer

Commitment from  
Cause Layer  
Cap. members  
of business

Reason of Life  
Attitude from  
Cause Layer

515 of Cause  
Layer

515 of Effect  
Layer

Commitment  
from Cause Layer  
by 515 members

Relationship between  
Cause Layer &  
Effect Layer

PERKEM/ISSUES  
GESO

**about the Environmental  
Monitoring Handbook**

## Background

To monitor compliance of mining companies and their activities to the standards set out in existing laws and policies, Philippine laws and guidelines created various oversight committees. Some of these committees are tasked to monitor environmental compliance of mining companies.

Recognizing that communities are major stakeholders in the issue of mining, these laws and policies mandate the inclusion of communities and civil society organizations (CSOs) in various mining oversight committees.

In general, the oversight committees aim to ensure transparency and accountability in mining. Aside from a CSO representative, these committees have representatives from the government and private sector. There are several types of institutionalized oversight committees that are either particular to a local government area and/or phase(s) in mining.

However, even with these mechanisms being provided for by laws, the PH-EITI Reports confirms the lack of, and in some cases, absence of reports by mining oversight committees. Media has reported on a monitoring team allowing dumping of tailings in the sea because of lack of knowledge on its effect<sup>1</sup>. The seeming inability to effectively monitor mining activities has grave and direct consequences on the community, including biodiversity loss, environmental degradation, and increased vulnerability to hazards.

Given the vital roles mining oversight committees play in ensuring observance of mining regulations and environmental plans by mining companies, it is imperative that members of the committees are armed with the knowledge required to accomplish their tasks.

Bantay Kita believes that symmetrical knowledge is a significant factor for empowerment and meaningful engagement and participation of CSOs in mining oversight committees. BK hopes this Manual is viewed as a comprehensive reference that would help members, particularly civil society representatives in fulfilling their roles and mandate.

The manual has the following major sections:

- A. Legal and policy framework which discusses the laws and policies relevant to mining, mining oversight committees, their roles and responsibilities.
- B. Water and Air Quality Standards which elaborates on the global and Philippine standards related to water and air quality against which values should be interpreted.

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- C. Philippine Mining Situationer which details the present situation of mining in the country. This section specifically focuses on monitoring environmental impacts of gold, copper and nickel mines, being the most common metals extracted in the country. It also details the common pollutants related to gold, copper and nickel mining.
- D. Monitoring which discussed methods of data collection, testing and monitoring, interpretation of results, and measures to take when results do not meet the standards.

### Box 1. How to Use this Handbook

Beyond being a reference for members of mining oversight committees, Bantay Kita aspires that the Manual also serves as a reference for community members and stakeholders who may be interested in conducting environmental monitoring but are not necessarily members of any mining oversight committee.

Thus, the Manual, and the primer and training modules that have been developed based on it, highlights areas where communities can be involved.

By augmenting the availability and accessibility of monitoring reference materials, Bantay Kita seeks to contribute to better oversight of mining activities. Ultimately, we anticipate that our efforts shall help reduce the negative impacts of mining on the community, including biodiversity loss, environmental degradation, and increased vulnerability to hazards.

The contents of this primer is based on the Revised Procedural Manual for DAO 03 – 30 (Implementing Rules and Regulations of PD 1586) issued on August 2007. This manual cannot be used to substitute for the Procedural Manual nor the DAO 03 – 30, and in case of unintended conflicts between this material and the Procedural Manual, the latter should be followed.

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**Legal and Policy**

## Chapter 1. Regulatory Framework

This chapter is intended to introduce readers to the country's legal framework pertinent to monitoring mining operations. This chapter contains environmental policies of the Philippines concerned with how mining operations are regulated as far as protecting the environment and communities are concerned. A section is dedicated to introduce how environmental impact assessments are conducted and another section to introduce how environmental policies mentioned are implemented on the ground. By the end of this chapter, readers will be able to identify how they can better engage in monitoring mining operations.

### Learning Objectives of this Chapter

- Know what are the procedures in conducting an environmental impact assessment as provided by the law
- Understand environmental policies pertinent to monitoring of mining operations in the Philippines
- Identify various mining oversight committees and their composition based on the country's legal framework
- **Learn points of engagement for communities and civil society in mining oversight committees**

Parts of this Chapter:

- Environmental Impact Statement System
  - Procedures to Conduct EIA
  - Environmental Impact Statement
  - Climate Change Adaptation and Disaster Risk Reduction
  - How can communities engage in environmental impact assessments?
- How are mines monitored under the law
- What are mandatory funds
  - Mines Rehabilitation Fund
  - Environmental Guarantee Fund
  - Environmental Monitoring Fund
  - People's Small-Scale Mining Protection Fund
- What are mining oversight committees
  - Contingent Liability and Rehabilitation Fund Steering Committee
  - Mine Rehabilitation Fund Committee

- Multi-Partite Monitoring Team
- Provincial/City Mining Regulatory Board (P/CMRB)

## **What is the Environmental Impact Statement System?**

The Philippine Environmental Impact Statement System (PEISS) was created by Presidential Decree 1586 (PD 1586) passed in 1978. Currently, guidelines are contained in Revised Procedural Manual for DAO 2003-30.

The main objective of the Environmental Impact Assessment (EIA) is to provide adequate information to decision-makers (project proponents and regulating bodies), and the public about the environmental implications of proposed actions before decisions are made. The EIA is meant to be a planning tool, such that environmental concerns are taken into account when planning the project. Through the EIA Process, adverse environmental impacts of proposed actions are considerably reduced through a reiterative review process of project siting, design and other alternatives, and the subsequent formulation of environmental management and monitoring plans.

If the DENR-EMB appraises the proposed project positively, it issues an Environmental Compliance Certificate (ECC). The release of the ECC allows the project to proceed to the next stage of project planning, which is the acquisition of approvals from other government agencies and LGUs, after which implementation of the project can start.

### **Procedures to Conduct the EIA**

The procedure of the EIA can be grouped into five major steps:

1. Screening determines whether a proposed project is covered by PEISS and what documents are required, if they are covered by the law. Figure 1 shows the steps done in screening. The first question to be asked is whether a project is an Environmentally Critical Project (ECP). Four types of projects fall within the ECP category:
  - a. Heavy industries (non-ferrous metal industries, iron and steel mills, petroleum and petrochemical industries, smelting plants)
  - b. Resource Extractive Industries (major mining and quarrying projects, forestry projects, dikes for fishpond development)
  - c. Infrastructure Projects (dams, power plants, reclamation projects, roads and bridges)
  - d. Golf course projects.

From this definition, large-scale mining is considered an ECP, and thus requires an EIS. The threshold levels of what qualifies as large-scale and would require an EIS is contained in the

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Revised Guidelines for the Coverage Screening and Standardized Requirements under PEISS. For example, for coal mining, an annual extraction rate of more than 70,000 MT required an EIS.

If a project is not an ECP, next step is to check whether the location of the project is in an Environmentally Critical Area (ECA).

### **Box 2. List of Areas Classified as Environmentally Critical**

Environmentally critical areas include the following. The agencies that are in-charge of defining the respective area are shown in the parentheses.

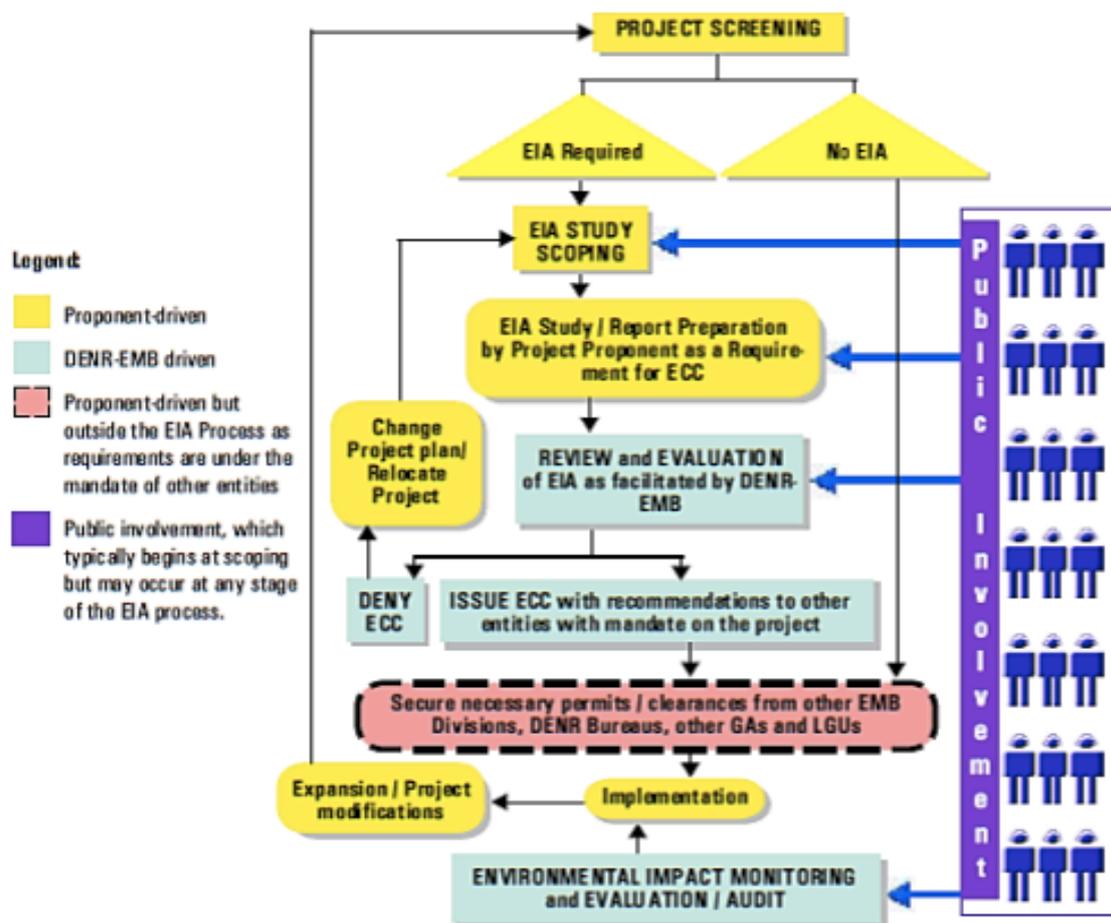
- National parks, watershed reserves, Wildlife preserves, and sanctuaries (DENR-Protected Areas and Wildlife Bureau)
- Aesthetic, potential tourist spots (Department of Tourism)
- Habitat for any endangered or threatened species (DENR-Protected Areas and Wildlife Bureau)
- Has unique historic, archaeological, geologic or scientific interests (National Museum, National Historical Institute, National Commission for Culture and the Arts)
- Traditionally occupied by cultural communities (National Commission on Indigenous Peoples)
- Frequently-visited and or hard-hit by natural calamities (geologic hazards, flood-prone, typhoons, volcanic activities and earthquakes)
- Areas with critical slope (DENR-Mines and Geosciences Bureau)
- Prime agricultural lands (Department of Agriculture)
- Recharge areas of aquifers (National Water Resources Board)
- Water bodies (DENR-Protected Areas and Wildlife Bureau)
- Mangrove areas (DENR-Protected Areas and Wildlife Bureau)
- Coral reef (Bureau of Fisheries and Aquatic Resources)

If the project is in an ECA and is not a project which will enhance the environment, then an Initial Environmental Examination (IEE) is required.

2. In Scoping, stakeholders agree on the most significant issues/impacts of the proposed project. The need for and scope of an Environmental Risk Assessment (ERA) is also done during the scoping session. Scoping is done with the local community through Public Scoping and with a third party EIA Review Committee (EIARC) through Technical Scoping, both with the participation of the DENR-EMB. The process results in a signed Formal Scoping Checklist by the review team, with final approval by the EMB Chief.

3. The EIA Study, the results of which are contained in a report which includes a description of the proposed project and its alternatives, characterization of the project environment, impact identification and prediction, evaluation of impact significance, impact mitigation, formulation of Environmental Management and Monitoring Plan, with corresponding cost estimates and institutional support commitment. An outline of this report, and other required documents are prescribed by EMB which can be found in the Procedural Manual.
  
4. The EIA Reports are reviewed by the EIA Review Committee (EIARC), a committee composed of third party experts commissioned by EMB. EMB evaluates the EIARC recommendations and the public's inputs during public consultations/hearings in the process of recommending a decision on the application. The EIARC Chair signs EIARC recommendations including issues outside the mandate of the EMB. The entire EIA review and evaluation process is summarized in the Review Process Report (RPR) of the EMB, which includes a draft decision document. The decision can either be an issuance of an ECC, CNC (Certificate of Non Coverage) or Denial Letter.
  
5. During the Monitoring, Validation and Evaluation/Audit stage, the performance of the Proponent against the ECC and its commitments in the Environmental Management and Monitoring Plans is assessed to ensure actual impacts of the project are adequately prevented or mitigated.

Figure 1. Screening Procedure and Community Participation in Environmental Impact Assessment



Source: Initiatives to Streamlining the PEISS: A Brief Guide for LGUs. 2007. Environmental Management Bureau

## **Environmental Impact Statement (EIS)**

The Environmental Impact Statement (EIS) contains four major parts:

### **a) Project Description**

Contains the following information about the project: location, scale and project life, rationale for the project, alternatives, phases and components, resource requirements (such as water and power), human resources complement, estimate of waste generation from the most critical project activities and project cost.

### **b) Baseline Environmental Conditions**

Contains information regarding the current conditions of the land, water, air and people within the vicinity of the site before any project activity is undertaken. This is the condition with which the impacts can be compared once the project commences. The focus will be on the aspects which will be most significantly affected by the proposed project.

### **c) Impact Assessment**

Discusses the significant environmental impacts at all stages of the project including from pre-construction, construction/development, operation and decommissioning stages. The impacts considered will be on the land, air, water and socio-economic conditions within the vicinity of the site. All impacts to the environment at all stages of the project, per activity are described. This facilitates in identifying the critical activities that will bring about the most adverse impacts.

### **d) Environmental Management Plan.**

Details the plan on how to actualize the mitigating measures to address the impacts that have been identified. It includes the impacts mitigation plan, areas of public information, education and communication, social development program proposal, environmental monitoring plans (with multi-sectoral public participation for EIS-based projects) and the corresponding institutional and financial requirements/arrangements.

## **EIA Review Committee (EIARC)**

The reviewers' qualifications are defined in Annex 2-8 of the PM. The major qualification is expertise. Reviewers should be familiar with the Philippine EIA Law, and should have had experience in preparing an EIS, or a module of it. Reviewers should not be part of the EIA team or firm that prepared

the EIS under review, or a staff/ employee of the concerned national agency that prepared the EIA document. Further, the reviewers should not be an employee of the proponent.

### **How can communities engage in environmental impact assessments?**

Participation of the public is an essential part of the PEISS. Public participation shall be ensured in several activities. As part of the social preparation process during the pre-Scoping, information, education and communication (IEC) activities of local government unit is required. The IEC serves as a basis for preliminary identification of stakeholders and related issues in preparation for the Scoping proper. Public Scoping is used to gather community inputs which will precede the Technical Scoping of the EIA Review Team with the Proponent.

The conduct of the EIA Study shall include local stakeholders, who may serve as local expert sources, aides/guides and resource persons in primary data collection to optimize access to indigenous knowledge of the environment, or as interviewers/ interviewees in the socio-economic/perception surveys which shall be used as the basis for the subsequent formulation of social development plans, IEC, monitoring plans and other components of the environmental management plans. LGUs and government agencies shall specifically be consulted and involved in the drafting of the project's Social Development Plan (SDP) Framework.

According to the Procedural Manual, "As a form of disclosure of the EIA findings, Public Hearing is required for all new ECPs for which Public Scoping was undertaken and for PEIS-(Programmatic EIS) based applications. A waiver of the Public Hearing requested by the Proponent may be granted by the DENR-EMB subject to the absence of mounting opposition or written request for one with valid basis and Public Consultation may be conducted instead of Public Hearing. The Notice of Public Hearing provides explicit instructions on registration, access to the EIA Report (with Project Fact Sheet written in the local dialect or mixed with the popularly known language of the host communities), preparation of position papers, and on the mechanics of how issues may be received before or during the hearing. Prior to Public Hearings or Public Consultations, the Proponent is required to give copies of the full EIA Report to the EMB RO and host municipalities; copies of Executive Summary to the host barangays; and copies of Project Fact Sheets to other stakeholders for a well-informed participation in the hearing/consultation process.

Once an ECC/CNC is issued, the EIA recommendations are transmitted by the DENR/EMB to the concerned government agencies and local government units to be considered in their decision-

making process. This results in a more integrated, coordinated and participative safeguarding of environmental concerns.”

The public is also included in multi-partite Monitoring Teams (MMT) to be discussed in further sections of this Handbook. The proponent initiates the formation of the team in coordination with the EMB Office within sixty days from receipt of the ECC. It is composed of representatives of the DENR, the Proponent, and the LGU, non-government organizations/people’s organization in the area, and the affected communities /vulnerable groups.

### **Other related documents**

The proponent may be required by the EIARC to prepare additional documents to give more details about potential risks.

These include the following:

- a. Traffic Impact Assessment (TIA) - a tool to manage traffic impacts of projects wherein changes in traffic are quantified and the corresponding mitigating measures are identified. This process ensures that the changes in traffic will be minimal.
- b. An Engineering Geological and Geotechnical Assessment Report (EGGAR) which describes the geological hazards that are present in the project site.
- c. An Environmental Risk Assessment (ERA) which is primarily concerned with safety risks which are characterized by low probability, high consequence, accidental nature and acute effects. An example of this is a dam failure.
- d. An Environmental Health Impact Assessment (EHIA) which describes high probability, low consequence, ongoing or continuing exposure and chronic effects such as pollutants being emitted from factories, or dust emitted from open pit mines.

### **Climate Change Adaptation and Disaster Risk Reduction**

In November 2011, the DENR issued the Technical Guidelines Incorporating Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) in the PEISS. For projects requiring an Environmental Impact Statement (EIS), DRR/CCA-enhanced EIS Screening Forms have been developed as a guide for the scoping process. These screening forms are basically checklists of the required scope of the EIA. The forms also provide guidance on how to incorporate disaster and climate change risks, including the formulation of appropriate mitigation and adaptation options at the project level.

### **How are mines monitored under the law?**

Republic Act 7942 is the governing law that regulates mineral resources development in the country. It declares a policy of state responsibility over the promotion of rational exploration, development, utilization and conservation of natural resources to enhance national growth while effectively safeguarding the environment and protecting the rights of affected communities. It espouses a pro-environment stance and encourages the use of current and best practices in environmental management so as to reduce the impacts of mining and effectively and efficiently protect the environment. The law states that mining activities should be undertaken with due and equal emphasis on economic and environmental considerations, as well as for health, safety, social and cultural concerns<sup>2</sup>.

Before any mining permit/contract is granted under RA 7942 and RA 7076 (Small-Scale Mining Act), the applicant must first obtain an Environmental Compliance Certificate (ECC) as evidence of compliance with PD No. 1586 or the Philippine Environmental Impact Statement System.

Other environmental safeguards required from mining operators or applicants are the Certificate of Environmental Management and Community Relations Record (CEMCRR)/Certificate of Exemption, Environmental Protection and Enhancement Program (EPEP), Environmental Work Program (EWP), and the Final Mine Rehabilitation/ Decommissioning Plan (FMR/DP) or Mine Closure Plan as integrated in the EPEP. The FMR/DP is likewise a mandatory requirement in the ECC. Furthermore, all Contractors/Permit Holders shall incorporate in their mine organization structures a "Mine Environmental Protection and Enhancement Office (MEPEO), which shall set the level of priorities and marshal the resources needed to implement environmental management programs<sup>3</sup>.

Under the Revised Implementing Rules and Regulations of RA No. 7076, a CEMCRR attesting to the small-scale mining contract or mineral processing license applicant's satisfactory environmental management and community relations, is also a mandatory requirement in applying for a small-scale mining contract. Along with the CEMCRR, the applicant/contractor/ processor under RA 7076 must also submit a Potential Environmental Impact Management Plan (PEIMP), an environmental management and rehabilitation plan for the life of the small-scale mining contract/mineral processing license, as approved by the DENR Regional Office.

## What are mandatory funds?

To enable monitoring of mining operations and other environmentally critical areas, mandatory environmental funds are identified to be established by existing laws. These are:

1. Mines Rehabilitation Fund
2. Environmental Guarantee Fund
3. Environmental Monitoring Fund
4. People's Small-Scale Mining Protection Fund

**Mine Rehabilitation Fund (MRF).** A Mines Rehabilitation Fund is established and maintained by each operating Contractor/Permit Holder as a reasonable environmental deposit to ensure availability of funds for the satisfactory compliance with the commitments and performance of the activities stipulated in the EPEP/AEPEP<sup>4</sup> during specific project phase.

The MRF shall be in two forms, namely:

- Monitoring Trust Fund (MTF) - This Fund shall be initiated by the Contractor/Permit Holder and shall be deposited in a mutually acceptable Government depository bank for the exclusive use in the monitoring program approved by the MRF Committee.
- Rehabilitation Cash Fund (RCF)-The Contractor/ Permit Holder shall set up a Rehabilitation Cash Fund for a designated amount to ensure compliance with the approved rehabilitation activities and schedules, including research programs, as defined in the EPEP/AEPEP<sup>5</sup>.

**Environmental Guarantee Fund (EGF).** For projects that have been determined by DENR to pose a significant risk or where the project requires rehabilitation or restoration, an Environmental Guarantee Fund (EGF) is required. Large-scale mining projects are almost always required to have an EGF.

**Environmental Monitoring Fund (EMF).** The EMF is a fund that a proponent establishes in support of the activities of the Multi partite Monitoring Team (MMT). Annex 3-5 of the PM presents the EMF administration and management guidelines based on the framework agreed upon and specified in the MMT MOA.

**People's Small-Scale Mining Protection Fund (PSSMPF).** The PSSMPF created in Section 20 of RA No. 7076 shall be used primarily for information dissemination and training of small-scale miners on safety, health and environmental protection, and the establishment of Mine Rescue and Recovery Teams, including the procurement of rescue equipment necessary in cases of emergencies, such as landslides, tunnel collapse, or the like. The Fund shall also be made available



to address the needs of the small-scale miners brought about by accidents and/or fortuitous events. The Board shall act as Trustee of the Fund<sup>6</sup>

### **What are mining oversight committees?**

Several interagency oversight committees are established under the Mining Act. The mining oversight committees tasked to perform supervision and environmental monitoring in relation to mining activities are the following:

1. Contingent Liability and Rehabilitation Fund Steering Committee
2. Mine Rehabilitation Fund Committee
3. Multi-Partite Monitoring Team
4. Provincial/City Mining Regulatory Board (P/CMRB)

**The Contingent Liability and Rehabilitation Fund (CLRF) Steering Committee** evaluates and approves/disapproves the submitted EPEP, FMR/DP, and consults with credible experts and advisory bodies, as may be required, to clarify proposals and to discuss the adequacy of control and rehabilitation measures. The CLRF Steering Committee is composed of members from the MGB, Environmental Management Bureau (EMB), Lands Management Bureau, Forest Management Bureau, Bureau of Soils and Water Management, Bureau of Plant Industry, Bureau of Fisheries and Aquatic Resources, and the National Irrigation Administration<sup>7</sup>.

To assist the CLRF Steering Committee, the Technical Working Group (TWG) are given the function to receive, process and evaluates the submitted EPEP and FMR/DP as to its form and substance, imposes additional requirements and documentation deemed necessary and consults with credible experts as well as other advisory bodies that may be required to clarify proposals and to discuss the adequacy of control and rehabilitation measures. The TWG, furthermore, is tasked to conduct annual environmental audit to ensure that the approved EPEPs/ AEPEPs and FMR/DPs shall be strictly implemented by the Contractors/ Permit Holders<sup>8</sup>.

A **Mine Rehabilitation Fund Committee** is created in each region where active mining operations<sup>9</sup>. Its duties and responsibilities include the preliminary evaluation on the submitted EPEP, hiring of credible experts to do independent studies and researches on the environmental, engineering and sociocultural impacts of mining projects, ensuring that the approved EPEPs/AEPEPs are strictly implemented and deputizing a multipartite monitoring team (MMT) to serve as its monitoring arm<sup>10</sup>.

## Functions

1. Conducts preliminary evaluation on the submitted EPEP and consults with credible experts, as may be required, to clarify proposals and to discuss the adequacy of control and rehabilitation measures: Provided, That the MRF Committee shall evaluate and approve/disapprove the submitted EPEP for Industrial Sand and Gravel Permit and Quarry Permit;
2. Manages, operates, monitors and looks after the safety of the MRFs and FMRDFs<sup>11</sup> and that shall be established and deposited in a Government depository bank in accordance with the provisions of these implementing rules and regulations;
3. Resolves issues involving the progressive mine rehabilitation programs that shall be implemented;
4. Hires credible experts to do independent studies and researches on the environmental, engineering and socio-cultural impacts of the projects in order to assist it in making judicious decisions;
5. Ensures that the approved EPEPs/ AEPEPs shall be strictly implemented by the Contractors/Permit Holders;
6. Deputizes an MMT to serve as its monitoring arm with the Regional Office concerned taking the lead role<sup>12</sup>

## Composition

1. Regional Director as Chair;
2. RED of the Department as Co-Chair;
3. Regional Director of the EMB as Member;
4. Representative of the Autonomous Regional Government, where this is applicable, as Member;
5. Representative from the LGU as Member;
6. Representative from the local NGOs and community organizations, including People's Organizations, church or civic organizations, as Member; and
7. Representative of the Contractor/Permit Holder as Member<sup>13</sup>.

## Disbursements

Withdrawal from the MRF shall be made by the Contractor/Permit Holder only with the written instruction to the bank issued by the MRF Committee authorizing the Contractor/Permit Holder to withdraw the amount from the MRF. The amount to be withdrawn shall be in accordance with the

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AEPEP and shall be approved by the MRF Committee, copy furnished the CLRF Steering Committee<sup>14</sup>.

Any one of the following shall be authorized to issue the instruction to the bank on behalf of the MRF Committee:

1. The Chair,
2. The Co-Chair or
3. The designated representative of either (a) or (b).

In the event that none of the above-mentioned persons issues the instruction to the bank after the lapse of thirty (30) calendar days from the time the written request for instruction is received by them, the Contractor/Permit Holder shall have the authority to sign the instruction on behalf of the MRF Committee and to withdraw the amount in accordance with the approved AEPEP<sup>15</sup>.

**A Multipartite Monitoring Team (MMT)** is a multi-sectoral team covered for the primary purpose of monitoring compliance by the proponent with the ECC, the EMP and applicable laws, rules and regulations. Only projects required an EIS<sup>16</sup> are required to form project-specific MMT. The EIS System is concerned primarily with assessing the direct and indirect impacts of a project on the biophysical and human environment and ensuring that these impacts are addressed by appropriate environmental protection and enhancement measures<sup>17</sup>.

For Environmentally Critical Projects (ECPs) with significant potential to cause negative environmental impacts<sup>18</sup>, an MMT shall be formed immediately after the issuance of an ECC. Proponents required to establish an MMT shall put up an Environmental Monitoring Fund (EMF) not later than the initial construction phase of the project<sup>19</sup>.

### Functions

1. Undertake monitoring of compliance with the ECC conditions, the EMP<sup>20</sup> and applicable laws, rules and regulations<sup>21</sup>.
2. Monitoring of compliance with the proponent's ECC issued pursuant to an IEE<sup>22</sup>, and applicable laws, rules and regulations, shall be undertaken by the concerned PENRO and CENRO<sup>23</sup> with support from the Regional Office and/or EMB whenever necessary<sup>24</sup>;
3. Seek the assistance of experts in its monitoring activities<sup>25</sup>;
4. According to the Pro-Forma MOA on the creation of the MMT provided by the EMB, the additional functions of the team are as follows:
  - a. Validate proponent's conduct of self-monitoring;

- b. Receive complaints, gather relevant information to facilitate determination of validity of complaints or concerns about the project and timely transmit to the proponent and EMB recommended measures to address the complaint;
- c. Prepare, integrate & disseminate simplified monitoring reports to community stakeholders;
- d. Make regular and timely submission of MMT Report;
- e. Submit the Compliance Monitoring and Validation Report (CMVR) which shall serve as the MMT Report Form. The CMVR measures the validity and compliance with the ECC, compliance with EMP, Appropriate & effective environmental impact remedial actions or mitigation measures, complaints management, Realistic and sufficient budget for conducting the environmental monitoring and audit activities, and accountability (qualified personnel are charged with the routine monitoring of the project activities in terms of education, training, knowledge and experience of the environmental team).
- f. Measure air quality, water quality, validates hazardous waste management, compliance with good practices in solid waste management, and compliance with good practices in chemical safety management (CEMVR). The CMVR shall be submitted semi-annually to the concerned EMB Regional Office, with the Proponent's CMR/SMR<sup>26</sup> as attachment.
- g. Monitor the proponent's compliance with the conditions stipulated in the ECC, EMP and Environmental Monitoring Plan (EMoP) and committee made in the EIA Report<sup>27</sup>, EPEP, FMR/DP and SDMP<sup>28</sup>;
- h. Submit monitoring/ validation reports following the format as to the:
  - a. MRFC;
  - b. EMB Central office semi-annually; and
  - c. EMB and MGB ROs quarterly
- i. Make available monitoring/ validation reports to interested stakeholders;
- j. Receive complaints, gather relevant information to facilitate determination of validity of complaints or concerns about the project, and transmits to the Proponent concerned, the EMB and MGB ROs, and/ or MRFC, as the case may be, the recommended measures to address the complaints, copy furnished the complainants; and
- k. Develop its Manual of Operations and have it jointly approved by the EMB and MGB ROs concerned, as endorsed by the MRFC.

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- I. As member of the MMT, the representative of the EMB-RO concerned shall lead in the monitoring of compliance with various environmental laws, ECC, EMP and EMoP, while the representative of the MGB-RO concerned shall lead in the monitoring of compliance with the EPEP/ Annual EPEP and FMR/DP<sup>29</sup>.

### Composition

1. Representative from Regional Office as Head
2. Representative from Department Regional Office as Member;
3. Representative from the EMB Regional Office as Member;
4. Representative of the Contractor/Permit Holder as Member.
5. Representative from the affected community(ies) as Member;
6. Representative from the affected ICCs, if any, as Member; and
7. Representative from an environmental NGO<sup>30</sup>.

The MMT for a mining project shall be co-chaired by the EMB-RO and the MGB-RO representatives, respectively<sup>31</sup>.

### Termination

MMTs of projects whose significant environmental impacts do not persist after the construction phase or which impacts could be addressed through the mandates of other government agencies shall be time bound or have a specific term which is not of the same length as the project life.

A **Provincial/City Mining Regulatory Board (P/CMRB)** is under the direct supervision and control of the Secretary and acts as the the implementing agency of the DENR<sup>32</sup>.

### Functions

The Board created under RA No. 7076 shall exercise the following major powers and functions, subject to review by the Secretary:

1. Declares Minahang Bayan (MB);
2. Reserves for the future, mineralized areas/mineral lands for declaration as MB;
3. Awards small-scale mining contracts to small-scale miners organized as individual miner or cooperative of small-scale miners;
4. Formulates its own guidelines and implements rules and regulations related to RA No. 7076;
5. Settles disputes, conflicts or litigations over conflicting claims;
6. Submits to the Department and the Bureau a comprehensive Annual Report of the overall operation of the MB;

7. Performs such other functions as may be necessary to achieve the goals and objectives of RA No. 7076<sup>33</sup>.

All persons undertaking or intending to undertake small-scale mining shall register as small-scale miners with the Board. For the above purpose, the Board shall maintain a registry of small-scale miners within its jurisdiction<sup>34</sup>.

The Board shall have the authority to declare and set aside a Minahang Bayan in mineralized areas onshore suitable for small-scale mining, except in areas closed to mining applications<sup>35</sup>.

Upon receipt of the clearance from the Secretary, the Board shall require the petitioner to secure and submit an ECC for the entire MB. Within seven (7) days from receipt of the ECC, the Board shall declare the proposed MB<sup>36</sup>;

The Board shall accept applications for small-scale mining contracts and determine the reasonable size and shape of the small-scale mining contract area<sup>37</sup>;

The establishment and operation of centralized custom mills to process minerals or ore-bearing materials and mineral processing zones shall be duly designated by the local government unit concerned thru the Board.

In the case where a custom mill or a mineral processing zone shall be located within an area covered by existing mining application or mining permit/contract, the Board shall fix the amount of compensation due the mining applicant or holder of mining permit/contract.

In mining areas where the private sector is unable to establish a custom mill, the Board shall recommend to the Department, thru the Director, the construction of the custom mill, if viable<sup>38</sup>;

An application for a mineral processing license (MPL) shall be filed by a qualified person either personally or through his/her/its duly authorized representative with the Board<sup>39</sup>;

A small-scale mining contract/mineral processing license may be cancelled by the Secretary thru the Board<sup>40</sup>;

The Department, in coordination with the Board and other government agencies concerned, shall extend the following assistance to small-scale miners:

1. Organization of small-scale miners into cooperatives;
2. Technical and financial assistance and social services;

## Empowered Communities

3. Processing and marketing assistance; and
4. Generation of ancillary livelihood activities<sup>41</sup>

The transport of ores/minerals/mineral products and by-products, including gold bullions, from a MB shall be accompanied by an Ore Transport Permit issued by the Board<sup>42</sup>.

The P/CMRB shall accept, process and evaluate applications, determine administrative charges and fees, and decide on the withdrawal of Quarry, Sand and Gravel, Guano, Gemstone Gathering and Small-Scale Mining Permits duly filed with the same<sup>43</sup>.

The Chairman shall submit a quarterly report to the MGB Director copy furnished the concerned MGB Regional Director and, DENR Regional Executive Director, the Undersecretary for Field Operations and the Secretary, containing the accomplishments, issues encountered and resolutions made and other relevant information.

### **Creation**

The following procedure shall be followed in the creation of a Board:

1. The Regional Director shall notify all the sectors and/or organizations concerned of the creation of the Board and solicit nominations for membership from them. Acceptance of nominations shall be based on submitted official nomination documents as determined by the Board.
2. If the nominee comes from an environmental non-government organization, an official accreditation document by the DENR shall be required by the Regional Director. No nomination shall be accepted if the abovementioned documents are not submitted.
3. The Regional Director shall evaluate the nominations and forward to the MGB Director the draft DENR Special Order creating the Board, which shall contain, among others, the proposed composition of the Board.
4. The draft DENR Special order shall be accompanied by all the pertinent accreditation/nomination documents and copies of letters-notice of nominee solicitation. A pro-forma DENR Special Order for the creation of the Board as shown in Annex A hereof shall be adopted in preparing the required draft DENR Special Order
5. The Director shall review the draft Special Order and accompanying documents. If found proper and in order, the Director shall indorse the draft Special Order and accompanying documents to the Secretary, thru the Undersecretary for Field Operations, for approval. Otherwise, the Director shall return all pertinent documents to the Regional Director for rectification and resubmission of the rectified documents.

6. The Undersecretary for Field Operations shall review the same documents and forward appropriate recommendation to the Secretary.
7. The Secretary shall act accordingly on the MGB Director's/Undersecretary's recommendation.
8. The approved DENR Special Order creating the Board shall be disseminated to all sectors/parties concerned<sup>44</sup>.

### **Composition**

The P/CMRB is composed of the Regional Director concerned of the Mines and Geosciences Bureau as Chairperson, and four (4) members composed of duly appointed representatives of the following offices/sectors: Governor or City Mayor, small-scale miners, large-scale miners and environmental nongovernment organizations<sup>45</sup>.

### **Member Qualifications**

1. He/She must be an active and bonafide member of and nominated by the organization he/she represents;
2. He/She must be residing or have established work relating to his/her organization in the province/city covered by the Board;
3. In the absence of nominees from the subject province/city, the Chamber of Mines of the Philippines in the case of large-scale mining, and any other duly organized small-scale mining associations preferably based in neighboring province/s or city/ies in the case of small-scale mining, shall nominate their respective representatives to the Board; and
4. In the absence of a DENR-accredited non-government organization in the subject province/city, the Board may consider nominations by DENR-accredited environmental non-government organization/s based in neighboring province/s or city/ies<sup>46</sup>

## Important Points to Remember

- Mitigating the environmental impacts of mining is stipulated under several major policies of government including the Philippine Environmental Impact Statement System (PD 1586), Republic Act 7942, and Republic Act 7076;
- The legal framework for mining includes provisions on community participation in the monitoring of mines from public consultations during the conduct of environmental impact assessments to participation in mining oversight committees. Communities must harness these provisions to ensure genuine and transparent monitoring of mines;
- There are mandatory environmental funds that needs monitoring to ensure that funding is available in mitigating the impacts on the environment of mineral extraction.

### For Further Readings

- **DENR - EMB, Revised Procedural Manual for DAO 03 – 30 (Implementing Rules and Regulations of Presidential Decree No. 1586, Establishing the Philippine Environmental Impact Statement System), 2007.**
- **DENR – EMB, Technical Guidelines Incorporating DRR and CCA Concerns in the Philippine Environmental Impact Statement System, 2011.**
- **DENR – EMB, Revised Guidelines for Coverage Screening and Standardized Requirements under the Philippine EIS System, 2014.**
- Philippine Extractive Industries Transparency Initiative Contracts Portal ([www.contract.ph-eiti.org](http://www.contract.ph-eiti.org)) disclosed important environmental documents required of mining companies. These are:
  - Environmental Impact Statements
  - Environmental Protection and Enhancement Program
  - Environmental Compliance Certificate
  - Multi-Partite Monitoring Team Quarterly Reports



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**CASE POCLAIN**

PERICOLO  
IN CASO  
DI CAUSTICA  
O ELETTRICA

# **Water and Air Quality Standards**

## Chapter 2. Global Standards in Air Quality Monitoring Standards and Drinking-Water Safety

This chapter summarizes the air quality monitoring standards and drinking water quality parameters set by the World Health Organization (WHO). These guidelines were set by WHO through a series of working group meetings with experts based on their evaluation of current scientific evidence<sup>47</sup>. This chapter is sourced directly from the Guidelines.

### Learning Objectives of this Chapter

- Learn about international air quality guidelines of the World Health Organization for the four most common air pollutants: **particulate matter (PM)**, **ozone (O<sub>2</sub>)**, **nitrogen dioxide (NO<sub>2</sub>)** and **sulfur dioxide (SO<sub>2</sub>)**
- Learn about international water quality guidelines of the World Health Organization and how to design and operationalize a Water Safety Plan

Parts of this Chapter:

- What are international air quality guidelines?
- What are international guidelines for measuring water quality?
  - Water Safety Plan
  - Planning
  - Operational Monitoring
  - Documentation and Communication
  - Surveillance

## What are international air quality guidelines?

The WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide is intended to inform and support the actions of policy makers and to provide appropriate targets for a broad range of policy options for air quality management. Each country sets its own national air quality standards and will differ in their approach, priorities, and other social, political, technological and environmental contexts. These, in turn, will depend on, among other things, the level of development and national capability in air quality management. The standards developed by WHO take into consideration this heterogeneity and recognize the need of national governments to formulate policies based on their own local circumstances before global standards are adopted<sup>48</sup>.

The Air Quality Guidelines provide an assessment of health effects of air pollution and thresholds for health-harmful pollution levels. Ambient (outdoor air pollution) in both cities and rural areas was estimated to cause 3.7 million premature deaths worldwide in 2012; this mortality is due to exposure to small particulate matter of 10 microns or less in diameter (PM<sub>10</sub>), which cause cardiovascular and respiratory disease, and cancers. Ischemic heart disease and strokes cause around 80% of outdoor pollution-related premature deaths, while 14% of deaths were due to chronic obstructive pulmonary disease or acute lower respiratory infections; and 6% of deaths were due to lung cancer.

Reducing outdoor emissions from household coal and biomass energy systems, agricultural waste incineration, forest fires and certain agro-forestry activities (e.g. charcoal production) would reduce key rural and peri-urban air pollution sources in developing regions. Reducing outdoor air pollution also reduces emissions of CO<sub>2</sub> and short-lived climate pollutants such as black carbon particles and methane, thus contributing to the near- and long-term mitigation of climate change.<sup>49</sup>

### WHO Air Quality Guidelines

The Air Quality Guidelines measure the four common air pollutants: particulate matter (PM), ozone (O<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>) and sulfur dioxide (SO<sub>2</sub>).

#### Particulate Matter

WHO encourages countries to set stringent air quality standards and tracking processes through the monitoring of emission reductions and declining concentrations of PM. The numerical guideline provided below reflects the concentrations at which increased mortality responses due to PM air pollution<sup>53</sup>.

PM<sub>2.5</sub>= 10 µg/m<sup>3</sup> annual mean

25 µg/m<sup>3</sup> 24-hour mean

PM<sub>10</sub>= 20 µg/m<sup>3</sup> annual mean

50 µg/m<sup>3</sup> 24-hour mean

There is a broad range of health impacts caused by of airborne particulate matter (PM) to the respiratory and cardiovascular systems. This is experienced by both developed and developing countries but susceptibility to diseases is affected by age or health. The standards set by WHO are:

PM<sub>10</sub> represents the particle mass that enters the respiratory tract, including both the coarse (particle size between 2.5 and 10 µm) and fine particles (measuring less than 2.5 µm) that contribute to health effects seen in urban environments. The former is primarily produced by mechanical processes such as construction activities, road dust re-suspension and wind, whereas fine particles originate primarily from combustion sources. This varies among different countries based on geography, meteorology and PM sources<sup>54</sup>.

Although PM<sub>10</sub> is the more widely reported measure, PM<sub>2.5</sub> can be converted to PM<sub>10</sub> guideline values by application of a PM<sub>2.5</sub>/ PM<sub>10</sub> ratio of 0.5. A PM<sub>2.5</sub>/ PM<sub>10</sub> ratio of 0.5 is typical of developing country urban areas and is at the bottom of the range found in developed country urban areas (0.5–0.8)<sup>55</sup>.

WHO observes that the combustion of wood and other biomass fuels, resulting in PM<sub>2.5</sub>, can be an important source of particulate air pollution in some areas. The toxicity of the products of fossil fuel and biomass combustion give way to similar health effects in both developed and developing countries.

WHO recommends that the annual average PM<sub>2.5</sub> (10 µg/m<sup>3</sup> for PM<sub>2.5</sub> and 20 µg/m<sup>3</sup> for PM<sub>10</sub>) take precedence over the 24-hour average since, at low levels, there is less concern about episodic excursions. The 24-hour average, however, can protect against peaks of pollution that would otherwise lead to substantial excess morbidity or mortality<sup>56</sup>.

WHO likewise set three interim targets (IT) for PM<sub>10</sub> and PM<sub>2.5</sub>. These have been shown to be achievable with successive sustained abatement measures. The ITs can be used in measuring progress of PM exposure reduction.

An annual mean PM<sub>2.5</sub> concentration of 35 µg/m<sup>3</sup> was selected as the IT-1 level. This level corresponds to the highest mean concentrations reported in studies of long-term health effects, and may also reflect higher but unknown historical concentrations that may have contributed to observed health effects. This level has been shown to be associated with significant mortality in the developed world<sup>57</sup>.

The IT-2 interim level of protection is set at 25 µg/m<sup>3</sup> and relies on the studies of long-term exposure and mortality. Reaching the IT-2 value would reduce the health risks of long-term exposure by about 6% (95% CI, 2–11%) relative to IT-1. The recommended IT-3 level is 15 µg/m<sup>3</sup> and places even greater weight on the likelihood of significant effects associated with long-term exposures.

Table 1. WHO Air Quality Guidelines and Interim Targets for PM: Annual Mean Concentrations

|                            | PM <sub>10</sub><br>(µg/m <sup>3</sup> ) | PM <sub>2.5</sub><br>(µg/m <sup>3</sup> ) | Basis for the selected level                        |
|----------------------------|--|---|---|
| Interim target-1<br>(IT-1) | 70                                       | 35  | These levels are associated with about a 15% higher |

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|                             |    |    |  |
|-----------------------------|----|----|--|
|                             |    |    | Long-term mortality risk relative to the AQG level.  |
| Interim target-2 (IT-2)     | 50 | 25 | In addition to other health benefits, these levels lower the risk of premature mortality by approximately 6% [2–11%] relative to the IT-1 level.   |
| Interim target-3 (IT-3)     | 30 | 15 | In addition to other health benefits, these levels reduce the mortality risk by approximately 6% [2–11%] relative to the IT-2 level.   |
| Air quality guideline (AQG) | 20 | 10 | These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to PM <sub>2.5</sub> . |

Table 2. WHO Air Quality Guidelines and Interim Targets for Particulate Matter: 24-hour Concentration

|                            | PM <sub>10</sub><br>(µg/m <sup>3</sup> ) | PM <sub>2.5</sub><br>(µg/m <sup>3</sup> ) | Basis for the selected level   |
|----------------------------|--|---|--|
| Interim target-1<br>(IT-1) | 150                                      | 75  | Based on published risk coefficients from multi-center studies and meta-analyses (about 5% increase of short-term mortality over the AQG value).   |
| Interim target-2<br>(IT-2) | 100                                      | 50  | Based on published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over the AQG value). |
| Interim target-3<br>(IT-3) | 75                                       | 37.5                                      | Based on published risk coefficients from multi-center studies and meta-analyses (about 1.2% increase in short-term mortality over the AQG value). |

## Empowered Communities

|                             |    |    |   |
|-----------------------------|----|----|---|
| Air quality guideline (AQG) | 50 | 25 | Based on relationship between 24-hour and annual PM levels. |
|-----------------------------|----|----|---|

### Ozone

$$O_3 = 100 \mu\text{g}/\text{m}^3 \text{ 8-hour mean}$$

Ozone is formed in the atmosphere by photochemical reactions in the presence of sunlight and precursor pollutants, such as the oxides of nitrogen (NO<sub>x</sub>) and volatile organic compounds (VOCs). It is destroyed by reactions with NO<sub>2</sub> and is deposited to the ground. If ozone concentrations rise above the guideline value, health effects at the population level become numerous and severe. Areas with high human activities or are affected by high temperatures are vulnerable to these impacts.

Epidemiological time-series studies have yielded positive, small, though convincing, associations between daily mortality and ozone levels, which are independent of the effects of particulate matter. Based on the studies, the increase in the number of attributable deaths brought forward is estimated to be 1–2% on days when the 8-hour mean ozone concentration reaches 100  $\mu\text{g}/\text{m}^3$  over that when ozone levels are at a baseline level of 70  $\mu\text{g}/\text{m}^3$  (the estimated background ozone level)<sup>58</sup>.

The 8-hour IT-1 level for ozone is set at 160  $\mu\text{g}/\text{m}^3$  at which changes in lung function and lung inflammation have been recorded in controlled chamber tests in healthy young adults undertaking intermittent exercise. WHO studies have shown that at 8-hour concentrations exceeding 240  $\mu\text{g}/\text{m}^3$ , significant health effects can be observed. Adults may start to experience significant reductions in lung function, as well as airway inflammation that would cause symptoms and alter performance. Moreover, time-series evidence have shown that exposure to concentrations of ozone of this magnitude, would result in a rise in the number of attributable deaths brought forward of 5–9%, relative to exposures at the estimated background level<sup>59</sup>.

Table 3. WHO Air Quality Guideline and Interim Target for Ozone: 8-hour Concentrations

|  | Daily maximum 8-hour mean ( $\mu\text{g}/\text{m}^3$ ) | Basis for selected level |
|--|--|--------------------------|
|  |  |                          |

|                         |     |   |
|-------------------------|-----|---|
| High levels             | 240 | Significant health effects; substantial proportion of vulnerable populations affected.  |
| Interim target-1 (IT-1) | 160 | <p>Important health effects; does not provide adequate protection of public health.</p> <p>Exposure to this level of ozone is associated with:</p> <ul style="list-style-type: none"> <li>• physiological and inflammatory lung effects in healthy exercising young adults exposed for periods of 6.6 hours;</li> <li>• Health effects in children (based on various summer camp studies in which children were exposed to ambient ozone levels).</li> <li>• An estimated 3–5% increase in daily mortality (based on findings of daily time series studies).</li> </ul> |

### Nitrogen Dioxide

$\text{NO}_2 = 40 \mu\text{g}/\text{m}^3$  annual mean  
 $200 \mu\text{g}/\text{m}^3$  1-hour mean

Most atmospheric NO is emitted as  $\text{NO}_2$ , which is rapidly oxidized by ozone to  $\text{NO}_2$ . Nitrogen dioxide, in the presence of hydrocarbons and ultraviolet light, is the main source of tropospheric ozone and of nitrate aerosols, which form an important fraction of the ambient air  $\text{PM}_{2.5}$  mass. Nitrogen dioxide has been found to be a toxic gas with significant health effects in animal and human experimental studies. It has also been a marker for the cocktail of combustion-related pollutants, such as those emitted by road traffic or indoor combustion sources<sup>60</sup>.

Bronchitic symptoms of asthmatic children have been shown to increase in association with annual  $\text{NO}_2$  concentration. Likewise, reduced lung function growth in children is linked to elevated  $\text{NO}_2$ .

New studies have shown that  $\text{NO}_2$  can have a higher spatial variation than other traffic-related air pollutants, for example, particle mass. Thus, it is unclear to what extent the health effects observed in epidemiological studies are attributable to  $\text{NO}_2$  itself or to the other primary and secondary combustion-related products it usually appears alongside with. However, since  $\text{NO}_2$  concentrations in ambient air are routinely measured while those of other correlated combustion-derived pollutants are not, it is advised by WHO that an annual average limit value for  $\text{NO}_2$  be established<sup>61</sup>.

### Sulfur Dioxide

$\text{SO}_2 = 20 \mu\text{g}/\text{m}^3$  24-hour mean  
 $500 \mu\text{g}/\text{m}^3$  10-minute mean

Studies conducted on exercising asthmatics indicate that a few of them experienced changes in pulmonary function and respiratory symptoms after periods of exposure to  $\text{SO}_2$  as short as 10 minutes. Based on this evidence, it is recommended that a  $\text{SO}_2$  concentration of  $500 \mu\text{g}/\text{m}^3$  should not be exceeded over averaging periods of 10 minutes duration<sup>62</sup>.

A major reduction in the sulfur content of fuels has been achieved in Hong Kong over a very short period of time. This was linked to substantial reductions in health effects (e.g. childhood respiratory

disease and all-age mortality). Unfortunately, there is little evidence and relative uncertainty as to whether SO<sub>2</sub> is the pollutant responsible for the observed adverse effects or whether it is a surrogate for ultrafine particles or some other correlated substance. Both Germany and the Netherlands reduced their SO<sub>2</sub> concentrations, but although mortality also decreased with time, the association between SO<sub>2</sub> and mortality was not declared to be causal in either case<sup>63</sup>.

Table 4. WHO Air Quality Guidelines and Interim Targets for SO<sub>2</sub>: 24-hour and 10-minute Concentrations

|                             | 24-hour average (µg/m <sup>3</sup> ) | 10-minute average (µg/m <sup>3</sup> ) | Basis for selected level   |
|-----------------------------|--------------------------------------|--|--|
| Interim target-1 (IT-1)     | 125                                  | -                                      | -  |
| Interim target-2 (IT-2)     | 50                                   | -                                      | Intermediate goal based on controlling either motor vehicle emissions, industrial emissions and/or emissions from power production. This would be a reasonable and feasible goal for some developing countries (it could be achieved within a few years) which would lead to significant health improvements that, in turn, would justify further improvements (such as aiming for the AQG value). |
| Air quality guideline (AQG) | 20                                   | 500                                    |  |



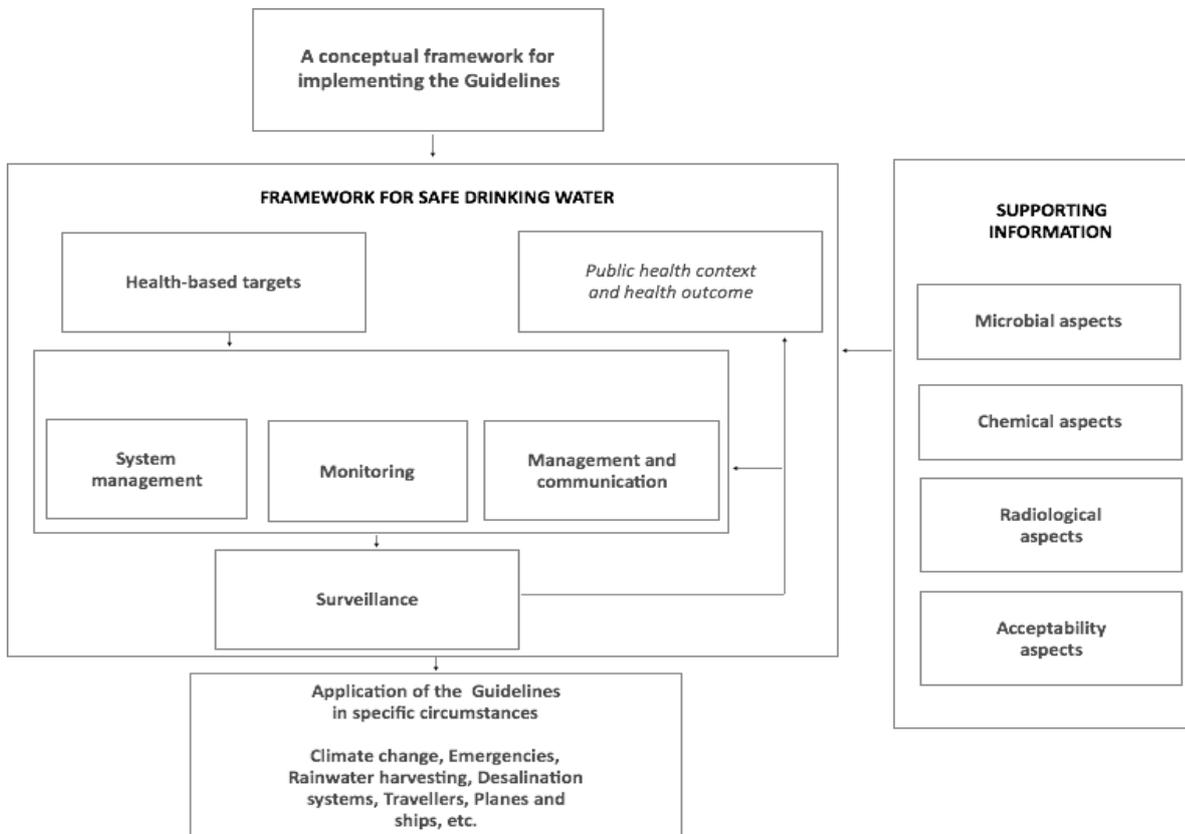
### **What are guidelines for measuring water quality?**

For water quality, WHO does not prescribe standards, rather it set guidelines to support the development and implementation of risk management strategies that will ensure the safety of drinking-water supplies. The nature and form of drinking-water standards may vary among countries and regions, therefore a universal approach is not advisable. Furthermore, national standards established take into account the needs and capacities of the country in developing a regulatory framework. This is the reason WHO believes that the use of a risk–benefit approach (qualitative or quantitative) in the establishment of national standards and regulations would better benefit governments<sup>64</sup>.

WHO suggest strategies that may be undertaken at the national, local or regional level using the scientific basis provided in the Guidelines. WHO advises governments to consider the guidelines it within the context of local or national environmental, social, economic and cultural conditions<sup>65</sup>. The strategies produced can then be integrated into a legislative and regulatory framework to address local requirements and circumstances.

Access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection<sup>66</sup>. It is at the heart of any health and development initiative in every level of governance. Investments in water supply and sanitation reduces the risk of contracting diseases and can yield net economic benefits as health-care costs outweigh the costs of undertaking the interventions.

The main objective of coming out with the Guidelines is to ensure public safety and public health. Newborns, children, and the sick elderly are those who are most vulnerable to water-borne diseases. Consumption of unsafe drinking water may expose a community to the risk of outbreaks of intestinal and other infectious diseases. Outbreaks of waterborne disease are particularly to be avoided because of their capacity to result in the simultaneous infection of a large number of persons<sup>67</sup>. Essential to drinking-water safety are the pinpointing health-based targets (HBT) by a competent health authority, instituting adequate and properly managed systems (adequate infrastructure, proper monitoring and effective planning and management) and creating a system of independent surveillance. Below is a conceptual framework or steps that can be taken in ensuring drinking-water safety:

Figure 2. Conceptual Framework for Implementing the Guidelines for Drinking Water Quality<sup>68</sup>

### Health-Based Targets

Health-based targets are measurable health, water quality or performance objectives that are established based on a judgment of safety and on risk assessment of waterborne hazards protection and treatment processes. HBTs should assist in determining specific interventions appropriate to delivering safe drinking-water, including control measures such as source protection and treatment processes<sup>69</sup>.

WHO list four types of HBTs that are applicable to all types of hazards and water supplies:

- 1) Health outcome targets (e.g. tolerable burdens of disease);
- 2) Water quality targets (e.g. guideline values for chemical hazards);
- 3) Performance targets (e.g. log reductions of specific pathogens);
- 4) Specified technology targets (e.g. application of defined treatment processes).

Table 5. Nature and Application of Health-based Targets

| Type of target       | Nature of target                     | Typical applications   | Notes  |
|----------------------|--------------------------------------|--|--|
| Health outcome       | Defined tolerable burden of disease  | High-level policy target set at national level, used to inform derivation of performance, water quality and specified technology targets | These Guidelines define a tolerable burden of disease of $10^{-6}$ DALY per person per year  |
|                      | No adverse effect or negligible risk | Chemical or radiological hazards   | Derived from international chemical or radionuclide risk assessments   |
| Water quality        | Guideline values                     | Chemical hazards   | Based on individual chemical risk assessments  |
|                      |                                      | Microbial water quality targets are not normally applied   | <i>Escherichia coli</i> is used as an indicator of faecal contamination and to verify water quality  |
|                      |                                      | Radiological water quality targets are not normally applied  | Radiological screening levels are applied  |
| Performance          | Specified removal of hazards         | Microbial hazards (expressed as log reductions)  | Specific targets set by water supplier based on quantitative microbial risk assessment and health outcome targets or generic targets set at national level   |
|                      |                                      | Chemical hazards (expressed as percentage removal)   | Specific targets set by water supplier based on chemical guideline values or generic targets set at national level   |
| Specified technology | Defined technologies                 | Control of microbial and chemical hazards  | Set at national level; based on assessments of source water quality, frequently underpinned by established or validated performance of the specified technology (e.g. requirement of filtration for surface water) |

HBTs should be realistic, measurable, based on scientific data and relevant to local conditions (including economic, environmental, social and cultural conditions) and financial, technical and institutional resources. They should be incorporated into the public health policy of the country and informed by the current public health status, exposure of persons to hazardous chemicals, health trends and the role of drinking water in the transmission of infectious diseases. In setting HBTs, water quality should not be taken in vacuum: consideration needs to be given to other sources of hazards, including food, air, person-to-person contact and consumer products, as well as poor sanitation and personal hygiene because water is not the only source of microbial, radiological and chemical hazards<sup>70</sup>.

A common metric in measuring health hazards adopted by WHO is the disability-adjusted life year (DALY). The Guidelines define a tolerable burden of disease of  $10^{-6}$  DALY per person per year.

The basic principle of the DALY is to weigh each health impact in terms of severity within the range of 0 for good health to 1 for death. The weighting is then multiplied by duration of the effect and the number of people affected. In the case of death, duration is regarded as the years lost in relation to normal life expectancy. Using this approach, a mild diarrhea with a severity weighting of 0.1 and lasting for 7 days results in a DALY of 0.002, whereas death resulting in a loss of 30 years of life equates to a DALY of 30.

Hence, DALY = YLL (years of life lost) + YLD (years lived with a disability or illness). For example, infection with rotavirus (in developed countries) causes:

- Mild diarrhea (severity rating of 0.1) lasting 7 days in 97.5% of cases;
- Severe diarrhea (severity rating of 0.23) lasting 7 days in 2.5% of cases;
- Rare deaths of very young children in 0.015% of cases.

The DALY per case can then be calculated as follows:

$$\begin{aligned} \text{DALY} &= (0.1 \times 7/365 \times 0.975) + (0.23 \times 7/365 \times 0.025) + (1 \times 70 \times 0.00015) \\ &= 0.0019 + 0.0001 + 0.0105 \\ &= 0.0125 \end{aligned}$$

Infection with *Cryptosporidium* can cause watery diarrhea (severity weighting of 0.067) lasting for 7 days with extremely rare deaths in 0.0001% of cases. This equates to a DALY per case of 0.0015<sup>71</sup>.

## Water Safety Plans

A water safety plan (WSP) is a comprehensive risk assessment and risk management approach that takes into account every step in the water supply, from catchment to consumption. There are three components to a WSP provided in Box 3.

Usually, it is the agency responsible for the drinking-water supply that forms the WSP, however, if there is no formal service provider, local or national authority should be source of information and guidance in matter relating to the appropriate management of community and individual drinking-water supplies<sup>72</sup>.

**Box 3. Three Components of a Water Safety Plan**

- 1) A system assessment to determine whether the drinking-water supply chain (up to the point of consumption) as a whole can deliver water of a quality that meets identified targets. This also includes the assessment of design criteria of new systems;
- 2) Identifying control measures in a drinking-water system that will collectively control identified risks and ensure that the health-based targets are met. For each control measure identified, an appropriate means of operational monitoring should be defined that will ensure that any deviation from required performance is rapidly detected in a timely manner;
- 3) Management and communication plans describing actions to be taken during normal operation or incident conditions and documenting the system assessment, including upgrade and improvement planning, monitoring and communication plans and supporting programmes.

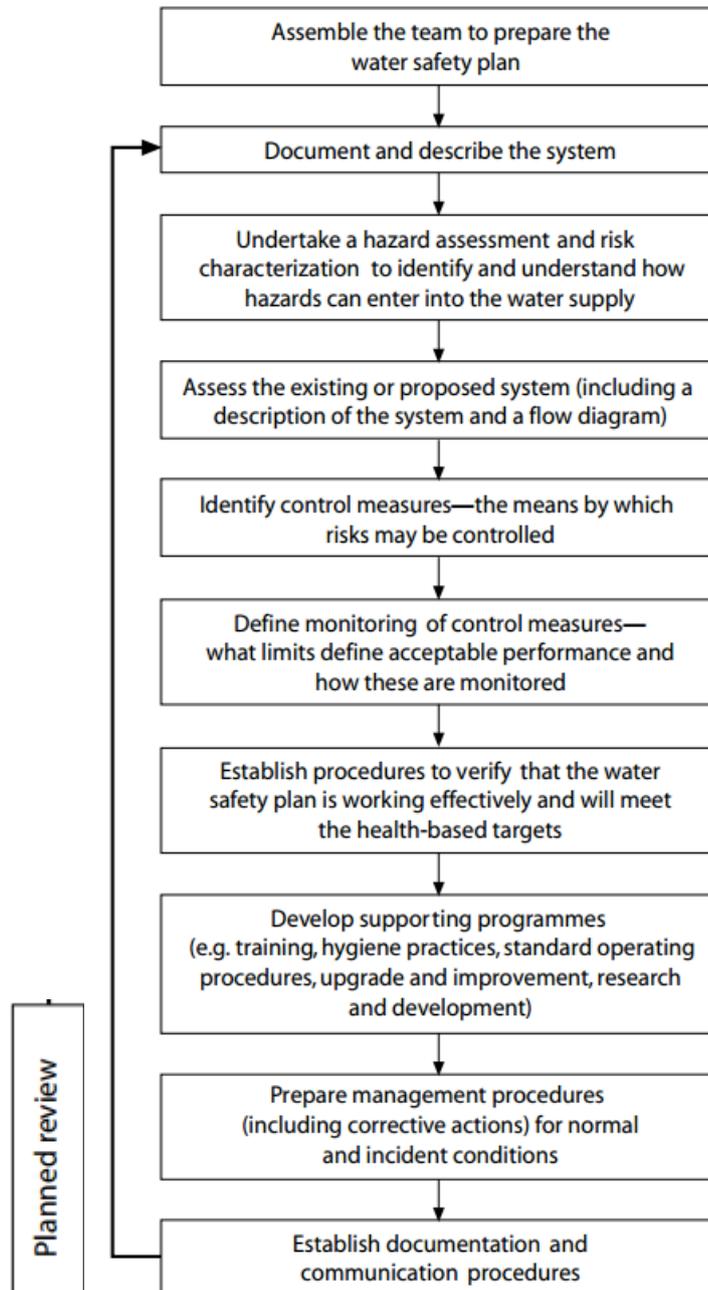
4)

5)

6)

WHO has underlined the steps below that may be taken in crafting a WSP. This, however, is a flexible approach, which can be customized according to the capacity of the service provider<sup>74</sup>:

Figure 3. Steps in Crafting WSP



Proper communication and exchange of information between and among authorities, providers and surveillance watchdogs is necessary in implementing A WSP. It is recommended that a multidisciplinary team of experts with a thorough understanding of the drinking-water system be formed. The members of this team should be involved in every stage in the water supply chain. The

## Empowered Communities

team could include engineers, catchment and water managers, water quality specialists, environmental or public health or hygiene professionals, and a wide range of stakeholders<sup>75</sup>.

Protecting the water source should be the first step in ensuring drinking-water safety. This will also minimize operation cost and the amount of treatment required<sup>76</sup>. Water treatment processes include disinfection and the physical removal of contaminants, but hazards may be introduced during the treatment phase. To avoid this, control measures should be introduced such as retreatment, coagulation, flocculation, sedimentation, filtration and disinfection<sup>77</sup>. Once the water has been treated, its good quality should be maintained as it is being distributed. Water distribution involves many kilometers of pipe, storage tanks, and interconnections with industrial users, hence the system is at risk of microbial and chemical contamination. Similarly, calamities and natural disasters may affect the water distribution system<sup>78</sup>.

To simplify the assessment and evaluation of the drinking water system, each step should be presented in an accurate system description, diagramed in a flowchart or similar visual aids. The system description should include an overview of the entire water system, including characterization of the source, identification of potential pollution sources in the catchment, measures for resource and source protection, treatment processes, storage and mechanisms for distribution. The hazards identified and risks associated with each hazard should be both real and potential. Priorities for risk management and reduction can be established and documented<sup>79</sup>.

The risks should be described by their likelihood of occurrence (e.g. certain, possible, rare) and evaluating the severity of consequences if the hazard occurred (e.g. insignificant, major, catastrophic) and differentiated between important and less important hazards or hazardous events. The approach used typically involves a semi quantitative matrix<sup>80</sup>.

Below is an example of a semi quantitative approach. Simple scoring matrices are informed by technical information from guidelines, scientific literature and industry practice as well as well-informed “expert” observations based on knowledge and experience of WSP team members, supported by peer review or benchmarking<sup>81</sup>.

Table 6. Example of a Simple Scoring Matrix for Ranking Risks

| Likelihood        | Severity of consequences |       |          |       |              |
|-------------------|--------------------------|-------|----------|-------|--------------|
|                   | Insignificant            | Minor | Moderate | Major | Catastrophic |
| Almost certain    | 5                        | 10    | 15       | 20    | 25           |
| Likely            | 4                        | 8     | 12       | 16    | 20           |
| Moderately likely | 3                        | 6     | 9        | 12    | 15           |
| Unlikely          | 2                        | 4     | 6        | 8     | 10           |
| Rare              | 1                        | 2     | 3        | 4     | 5            |

|             |     |        |       |           |
|-------------|-----|--------|-------|-----------|
| Risk score  | < 6 | 6–9    | 10–15 | > 15      |
| Risk rating | Low | Medium | High  | Very high |

Descriptors, on the other hand, may be used to determine the likelihood of occurrence and severity of the hazard. The Guidelines recommend that a “cut-off” point must be determined, above which all risks will require immediate attention<sup>82</sup>.

Table 7. Examples of Definitions of Likelihood and Severity Categories that can be used in Risk Scoring

| Item                         | Rating | Definition                  |
|------------------------------|--------|-----------------------------|
| <i>Likelihood categories</i> |        |                             |
| Almost certain               | 5      | Once per day                |
| Likely                       | 4      | Once per week               |
| Moderately likely            | 3      | Once per month              |
| Unlikely                     | 2      | Once per year               |
| Rare                         | 1      | Once every 5 years          |
| <i>Severity categories</i>   |        |                             |
| Catastrophic                 | 5      | Public health impact        |
| Major                        | 4      | Regulatory impact           |
| Moderate                     | 3      | Aesthetic impact            |
| Minor                        | 2      | Compliance impact           |
| Insignificant                | 1      | No impact or not detectable |

Control measures to be applied to risks should be able to identify existing control measures for each significant hazard or hazardous event from catchment to consumer, evaluate whether the control

measures, when considered together, are effective in reducing risk to acceptable levels, and evaluate alternative and additional control measures if improvement is required. These control measures should apply the multiple-barrier principle so that if one barrier fails, there will be others on standby thus reducing the likelihood of contaminants passing through<sup>83</sup>.

### **Operational Monitoring**

Operational monitoring is a planned and routine set of activities used to determine if control measures continue to work effectively and if health based targets are being met. The parameters set for operational monitoring should show how effective each control measure is, establish a timely indication of performance, be readily and easily measured and provide the opportunity for an appropriate response. These control measures should have operational limits that will signal the need to implement predetermined corrective actions. Examples of parameters include measurable variables, such as chlorine residuals, pH and turbidity, or observable factors, such as the integrity of vermin-proof screens<sup>84</sup>.

The Guidelines have provided a range of parameters that may be used in operational monitoring such as:

- For source waters, these include turbidity, ultraviolet absorbency, algal growth, flow and retention time, color, conductivity, local meteorological events and integrity of protective (e.g. fences) or abstraction infrastructures (e.g. well seals);
- For treatment, parameters may include disinfectant concentration and contact time, ultraviolet intensity, pH, light absorbency, membrane integrity, turbidity and color;
- In piped distribution systems, operational monitoring parameters may include the following:
  - Chlorine residual monitoring;
  - Oxidation–reduction potential (or redox potential) measurement;
  - Heterotrophic bacteria present in a supply can be a useful indicator of changes, such as increased microbial growth potential, increased biofilm activity, extended retention times or stagnation and a breakdown of integrity of the system.Pressure measurement and turbidity are also useful operational monitoring parameters in piped distribution systems<sup>85</sup>.

Table 8. Examples of Operational Monitoring Parameters that can be used to Monitor Control Measures

| Operational parameter                          | Raw water | Coagulation | Sedimentation | Filtration | Disinfection | Distribution system |
|--|-----------|-------------|---------------|------------|--------------|---------------------|
| pH   |           | ✓           | ✓             |            | ✓            | ✓                   |
| Turbidity (or particle count)                  | ✓         | ✓           | ✓             | ✓          | ✓            | ✓                   |
| Dissolved oxygen                               | ✓         |             |               |            |              |                     |
| Stream/river flow                              | ✓         |             |               |            |              |                     |
| Rainfall                                       | ✓         |             |               |            |              |                     |
| Colour   | ✓         |             |               |            |              |                     |
| Conductivity (total dissolved solids)          | ✓         |             |               |            |              |                     |
| Organic carbon                                 | ✓         |             | ✓             |            |              |                     |
| Algae, algal toxins and metabolites            | ✓         |             |               |            |              | ✓                   |
| Chemical dosage                                |           | ✓           |               |            | ✓            |                     |
| Flow rate                                      |           | ✓           | ✓             | ✓          | ✓            |                     |
| Net charge                                     |           | ✓           |               |            |              |                     |
| Streaming current value                        |           | ✓           |               |            |              |                     |
| Headloss                                       |           |             |               | ✓          |              |                     |
| Ct (disinfectant concentration x contact time) |           |             |               |            | ✓            |                     |
| Disinfectant residual                          |           |             |               |            | ✓            | ✓                   |
| Oxidation–reduction potential                  |           |             |               |            | ✓            |                     |
| DBPs   |           |             |               |            | ✓            | ✓                   |
| Heterotrophic bacteria                         |           |             |               |            | ✓            | ✓                   |
| Hydraulic pressure                             |           |             |               |            |              | ✓                   |

After operation monitoring has been implemented, the safety of drinking-water being supplied to consumers should be verified. This is undertaken by surveillance agencies and even by water suppliers. For microbial verification, testing is typically for fecal indicator bacteria in the product of the water system. For chemical safety, testing for chemicals of concern may be done during distribution or the point of consumption. If the drinking water does not meet the water quality targets, the WSP should allow for investigation and corrective action, such as boil water advisories<sup>86</sup>.

### Documentation and Communication

The WSP and the activities undertaken under the plan should be properly documented to be able to track adherence to the WSP, its progress, and to identify its point of weaknesses. The documentation should include among others:

- A description and assessment of the drinking-water system, including programmes to upgrade and improve existing water delivery;
- The plan for operational monitoring and verification of the drinking-water system
- Water safety management procedures for normal operation, incidents (specific and general) and emergency, including communication plans; and
- A description of supporting programmes<sup>87</sup> such as controlling access to treatment plants, catchments and reservoirs, developing verification protocols for the use of chemicals and materials in the drinking-water supply, research and development and training and educational programmes for personnel involved in activities that could influence drinking-water safety.

Likewise, records should be kept detailing the validation, verification, and outcomes of incident investigations, and methods and procedures used. The records can serve as indicators of trends and when a periodic review can be made<sup>88</sup>.

In communicating the WSP, care must be taken to guarantee that prompt advisories are released should there be any significant incidents within the drinking-water supply. Summary information and annual reports should also be made available to the public and grievance mechanisms established to address the complaints of a community<sup>89</sup>.

### Surveillance

A collaborative multiagency effort is advised to ensure that agencies responsible for water safety in every phase are involved in maintaining water quality standards. This requires participation not only from government agencies, but also from service providers, local and civil watchdogs such as civil society organizations and private water providers. All stakeholders should be encouraged to coordinate their planning and management activities when appropriate.

Surveillance requires a systematic programme of surveys, which may include auditing, analysis, sanitary inspection and institutional and community aspects. It should cover the whole of the drinking-water system, including sources and activities in the catchment, transmission infrastructure, treatment plants, storage reservoirs and distribution systems<sup>90</sup>.

Surveillance and quality control should be performed by separate entities or agencies to avoid any conflict of interests. The Guidelines advise:

- National agencies to provide a framework of targets, standards and legislation to enable and require suppliers to meet defined obligations;
- Agencies involved in supplying water for consumption by any means to ensure and verify that the systems they administer are capable of delivering safe water and that they routinely achieve this;
- A surveillance agency to be responsible for independent (external) surveillance through periodic audit of all aspects of safety and/or verification testing.

Even if in practice such delineation of duties is not often met, it is important to develop clear strategies and structures for implementing water safety plans, quality control and surveillance, collating and summarizing data, reporting and disseminating the findings and taking remedial action. Clear lines of accountability and communication are essential<sup>91</sup>.

The data collected during surveillance may be used as a basis or a mechanism in:

- Establishing national priorities;
- Establishing subnational/regional priorities;
- Auditing of WSPs and upgrading;
- Ensuring community operation and maintenance;
- Establishing public awareness and information channels; and
- Implementing programmes for household water treatment and safe storage

The surveillance should be able to provide corrective measures and prevent problems within the drinking-water system from reoccurring. Penalties may encourage compliance with national or local legislation in relation to water safety, but the Guidelines recommend that agencies invest in a positive and supportive relationship with suppliers, with the application of penalties used as a last resort<sup>92</sup>.

### **Important Points to Remember**

- The World Health Organization prescribes international guidelines on measuring air quality and water quality;
- The WHO provides air quality guidelines to assess health effects of air pollution and measure relevant water quality parameters to ascertain whether levels are within acceptable thresholds;
- A Water Safety Plan (WSP) is necessary tool to ensure water sources of communities are of drinking water quality and that communities need to ensure parameters relevant are measured;

## Chapter 3. Water and Air Quality Monitoring Standards in the Philippines

This chapter introduces and discusses pertinent provisions under RA 8749 or the Philippine Clean Air Act of 1999, its IRR, and the Water Quality Monitoring Manual of EMB-DENR in relation to prescribed air and water quality standards. It is to be used as a reference should legal standards need to be consulted. The contents of this chapter are presented as they were drafted, filtered only to correspond to concepts or measurements relevant to air and water quality monitoring in mining-affected areas.

### Learning Objectives of this Chapter

- Learn about air quality guidelines and air quality indices of the Philippines under the Clean Air Act for suspended particulate matter, sulfur dioxide, nitrogen dioxide, ozone, carbon monoxide, and lead
- Learn about the Environmental Management Bureau's **Water Quality Monitoring Manual** and general classifications of water usage and relevant quality parameters, effluent standards analysis, and their thresholds

### Parts of this Chapter

- What are Air Quality Standards of the Philippines
  - National Ambient Air Quality Guideline Values
  - Attainment Areas
  - Pollution from Stationary Sources
  - Visible Emission Standards for Smoke and Opacity
  - Air Quality Indices
- What are Water Quality Standards of the Philippines
  - Water Quality Monitoring Manual
  - Water Monitoring Plan
  - Classification of Water Usage and its Beneficial Use
  - General Provisions on Water Classification
  - Water Quality for Fresh Water
  - Water Quality for Coastal and Marine Waters
  - Effluent Standards: Toxic and Other Deleterious Substance
  - Methods of Water Quality Analysis
  - Methods of Analysis for Effluents as per Industry

## What are standards of air quality applied in the Philippines?

RA 8749 declares that the State shall pursue a policy of balancing development and environmental protection. This is in line with the policy of the Mining Act of 1995 which is anchored on sustainable development in mining.

The Clean Air Act recognizes the following:

- The right of human beings to breath clean air.
- Their right to utilize and enjoy all natural resources according to the principle of sustainable development.
- To bring action to enjoyn all activities in violation of environmental laws and regulations.
- To compel the rehabilitation and cleanup of affected area.
- To seek compensation and the imposition of penal sanctions against violators of environmental laws.

To meet these ends, Congress incorporated air quality standards and guidelines in the implementing rules and regulations of RA 8749.

### National Ambient Air Quality Guideline Values

Pursuant to Section 12 of RA 8749, the initial set of National Ambient Air Quality Guideline Values<sup>93</sup> necessary to protect public health and safety and general welfare are laid down in Table 9.

Table 9. National Ambient Air Quality Guideline Values<sup>94</sup>

| Pollutants  | Short Term <sup>a</sup> |      |                       | Long Term <sup>b</sup> |      |                     |
|---|-------------------------|------|-----------------------|------------------------|------|---------------------|
|   | µg/NCM                  | ppm  | Averaging Time        | µg/NCM                 | ppm  | Averaging Time      |
| Suspended Particulate Matter <sup>c</sup> –<br>TSP<br>PM-10 | 230 <sup>d</sup>        |      | 24 hours              | 90                     |      | 1 year <sup>c</sup> |
|   | 150 <sup>f</sup>        |      | 24 hours              | 60                     |      | 1 year <sup>c</sup> |
| Sulfur Dioxide <sup>c</sup>                                 | 180                     | 0.07 | 24 hours              | 80                     | 0.03 | 1 year              |
| Nitrogen Dioxide  | 150                     | 0.08 | 24 hours              |                        |      |                     |
| Photochemical Oxidants as<br>Ozone                          | 140                     | 0.07 | 1 hour                |                        |      |                     |
|   | 60                      | 0.03 | 8 hours               |                        |      |                     |
| Carbon Monoxide   | 35 mg/NCM               | 30   | 1 hour                |                        |      |                     |
|   | 10 mg/NCM               | 9    | 8 hours               |                        |      |                     |
| Lead <sup>g</sup>   | 1.5                     |      | 3 months <sup>g</sup> | 1.0                    |      | 1 year              |

## Table 9 Notes:

- a. Maximum limits represented by ninety-eight percentile (98%) values not to exceed more than once a year;
- b. Arithmetic mean;
- c. SO<sub>2</sub><sup>95</sup> and Suspended Particulate matter<sup>96</sup> are sampled once every six days when using the manual methods. A minimum of twelve sampling days per quarter or forty-eight sampling days each year is required for these methods. Daily sampling may be done in the future once continuous analyzers are procured and become available;
- d. Limits for Total Suspended Particulate Matter (TSP)<sup>97</sup> with mass median diameter less than 25-50 µm;
- e. Annual Geometric Mean;
- f. Provisional limits for Suspended Particulate Matter with mass median diameter less than 10µm and below until sufficient monitoring data are gathered to base a proper guideline; and
- g. Evaluation of this guideline is carried out for 24-hour averaging time and averaged over three moving calendar months. The monitored average value for any three months shall not exceed the guideline value.

The applicable methods for sampling and measurement of the above pollutants are as follows:

- TSP - High Volume – Gravimetric, USEPA 40 CFR, Part 50, Appendix B<sup>98</sup>;
- PM<sub>10</sub> - High Volume with 10 micron particle-size inlet; Gravimetric, USEPA 40 CFR, Part 50, Appendix J<sup>99</sup>;
- Sulfur Dioxide - Gas Bubbler and Pararosaniline Method (West and Gaeke Method), or Flame Photometric Detector, USEPA 40CFR, Part 50, Appendix A<sup>100</sup>;
- Nitrogen Dioxide - Gas Bubbler Griess-Saltzman, or Chemiluminescence Method, USEPA 40 CFR, Part 50, Appendix F<sup>101</sup>;
- Ozone - Neutral Buffer Potassium Iodide (NBKI), or Chemiluminescence Method, USEPA 40 CFR, Part 50, Appendix D<sup>102</sup>;
- Carbon Monoxide - Non-dispersive Infra-red Spectrophotometry (NDIR), USEPA 40 CFR, Part 50, Appendix C<sup>103</sup>; and
- Lead - High Volume and Atomic Absorption Spectrophotometry, USEPA 40 CFR, Part 50, Appendix G<sup>104</sup>.

An analyzer based on the principles and methods cited above will be considered a reference method only if it has been designated as a reference method in accordance with 40 CFR, Part 53<sup>105</sup>. Other equivalent methods approved by the Bureau may be adopted<sup>106</sup>.

### Attainment Areas

The Environmental Management Bureau shall delineate areas where the existing ambient air quality is at or below (that is, complies with) National Ambient Air Quality Guideline Values and shall designate such areas as “attainment areas.”

Designation of attainment areas will be based on monitoring data collected using the reference methods and/or other relevant information, including meteorological data, and data covering existing nearby sources.

The DENR through the EMB will designate attainment and non-attainment areas, and will review and revise these designations from time to time as relevant data become available<sup>107</sup>.

Any existing source in an attainment area making a change or modification to its process or production which results in an increase of potential emissions equal to or greater than the following shall be considered significant and subject to rules on new or modified sources for the affected pollutants under RA 8749.

- Carbon Monoxide 100 tons per year;
- Nitrogen Oxides 40 tons per year;
- Sulfur Dioxide 40 tons per year;
- TSP 25 tons per year;
- PM<sub>10</sub> 15 tons per year;
- Volatile Organic Compounds 40 tons per year; and
- Hydrogen Sulfide 10 tons per year<sup>108</sup>.

New or modified sources in attainment areas must comply with Air Pollution and Ambient Air Quality Standards<sup>109</sup> pertaining to the source<sup>110</sup>.

No new source may be constructed or existing source modified if emissions from the proposed source or modification will, based on computer dispersion modeling, result in excess of the National Ambient Air Quality Guideline Values; or an increase in existing ambient air levels above the levels shown below:

Table 10: Ambient Air Levels

|   |                               |
|---|-------------------------------|
| PM <sub>10</sub> , annual arithmetic mean | 17 micrograms per cubic meter |
| PM <sub>10</sub> , 24-hr maximum          | 30 micrograms per cubic meter |

|  |                               |
|--|-------------------------------|
| Sulfur Dioxide, annual arithmetic mean   | 20 micrograms per cubic meter |
| Sulfur Dioxide, 24-hr maximum            | 91 micrograms per cubic meter |
| Nitrogen Dioxide, annual arithmetic mean | 25 micrograms per cubic meter |

In the case of multiple point sources at a single facility, the net emissions from all affected sources shall be included in a single increment analysis<sup>111</sup>.

New and modified sources shall install and operate, according to manufacturer specifications, continuous emission monitoring systems (CEMS) for each applicable pollutant listed as an affected pollutant that has the potential to emit in quantities equal to or greater than 100 tons per year.

The CEMS shall be applied as follows:

Sources shall install and operate a CEMS for carbon dioxide and oxygen that meets criteria provided in USEPA 40 CFR Part 60 Appendix B, Performance Specification 3<sup>112</sup>. Additionally, each source shall, as appropriate meet the following requirements:

- A. Particulate matter: Sources shall install and operate a CEMS for opacity<sup>113</sup> that meets criteria provided in USEPA 40 CFR Part 60 Appendix B, Performance Specification 1.

The owner shall have the additional requirement of establishing a calibration curve showing the relationship between opacity as measured by the CEMS and mass particulate emission rate as determined by Method 5. The calibration curve shall cover the full range of reasonably expected operating conditions and/or process rates of the source and shall consist of at least three data points, one at maximum permitted operations, one at maximum design capacity, and one at 80% of the maximum permitted rate. The Bureau may waive one test point if the permitted rate and maximum design capacity rate are the same.

- B. Sulfur Dioxide and Nitrogen Oxides: Sources shall install and operate a CEMS for these parameters that meet criteria provided in USEPA 40 CFR Part 60 Appendix B, Performance Specification 2.
- C. Carbon Monoxide: Sources shall install and operate a CEMS for this parameter that meets criteria provided in USEPA 40 CFR Part 60 Appendix B, Performance Specification 4 or 4A.

- D. Hydrogen Sulfide: Sources shall install and operate a CEMS for this parameter that meets criteria provided in USEPA 40 CFR Part 60 Appendix B, Performance Specification 7.

### **Pollution from Stationary Sources**

Air pollutants can come from both natural and anthropogenic sources, but anthropogenic air pollutants dominate the atmosphere of areas primarily undergoing industrialization. For management purposes, air pollution sources can be classified as stationary, mobile or area, as described in RA 8749.

Stationary source are any building or immobile structure, facility or installation which emits or may emit any air pollutant, and may be defined generally as individual points of air emissions (e.g. smokestacks). Under the RA 8749, all industries classified as a stationary source should perform their own emissions monitoring and report the results to the DENR. All stationary sources of air emissions must comply with National Emission Standards for Sources Specific Air Pollution (NESSAP) and Ambient Air Quality Standard (AAQS) pertaining to the source. Upon compliance to standards, the DENR issues a Permit to Operate (PTO) to these industries prior to their operation<sup>114</sup>.

For any trade, industry, process, fuel-burning equipment or industrial plant emitting air pollutants, the concentration at the point of emission shall not exceed the limits set in Table 11.

Table 11- National Emission Standards for Source Specific Air Pollutants (NESSAP)

| POLLUTANT   | STANDARD APPLICABLE TO SOURCE  | MAXIMUM PERMISSIBLE LIMITS (mg/NCM)                          | METHOD OF SAMPLING <sup>a</sup>          | METHOD OF ANALYSIS <sup>a</sup>                        |
|---|--|--|--|--|
| Antimony and its Cmpds.                                   | Any source   | 10 as Sb   | USEPA Methods 1 through 5 or 29          | AAS <sup>b</sup> or per sampling method                |
| Arsenic and its Cmpds.                                    | Any source   | 10 as As   | USEPA Methods 1 through 5 or 29          | AAS <sup>b</sup> or per sampling method                |
| Cadmium and its Cmpds.                                    | Any source   | 10 as Cd   | USEPA Methods 1 through 5 or 29          | AAS <sup>b</sup> or per sampling method                |
| Carbon Monoxide   | Any industrial source  | 500 as CO  | USEPA Method 3 or 10                     | Orsat Analysis or NDIR                                 |
| Copper and its Cmpds.                                     | Any industrial source  | 100 as Cu  | USEPA Methods 1 through 5 or 29          | AAS <sup>b</sup> or per sampling method                |
| Hydrofluoric Acid and Fluoride Compounds                  | Any source other than manufacture of Aluminum from Alumina   | 50 as HF   | USEPA Method 13 or 14 as appropriate     | As per sampling method                                 |
| Hydrogen Sulfide  | i) Geothermal power plants<br>ii) Geothermal Exploration And Well Testing<br>iii) Any source other than (i) and (ii) | <sup>c, d</sup><br><br><sup>e</sup><br>7 as H <sub>2</sub> S | USEPA Method 11, 15 or 16 as appropriate | Cadmium Sulfide Method or per sampling method          |
| Lead  | Any trade, industry or process   | 10 as Pb   | USEPA Methods 1 through 5 or 12 or 29    | AAS <sup>b</sup> or per sampling method                |
| Mercury   | Any source   | 5 as elemental Hg  | USEPA Methods 1 through 5 or 29 or 101   | AAS <sup>b</sup> / Cold-Vapor Technique or Hg Analyzer |
| Nickel and its Cmpds. Except Nickel Carbonyl <sup>f</sup> | Any source   | 20 as Ni   | USEPA Methods 1 through 5 or 29          | AAS <sup>b</sup> or per sampling method                |

| POLLUTANT                         | STANDARD APPLICABLE TO SOURCE   | MAXIMUM PERMISSIBLE LIMITS (mg/NCM)   | METHOD OF SAMPLING <sup>a</sup>                     | METHOD OF ANALYSIS <sup>a</sup>                      |
|-----------------------------------|---|---|---|--|
| NO <sub>x</sub>                   | 1) Manufacture of Nitric Acid<br>2) Fuel burning steam generators<br>a) Existing Source<br>b) New Source<br>i) Coal-fired<br>ii) Oil-fired<br>3) Diesel-powered electricity generators<br>4) Any source other than (1), (2) and (3)<br>a) Existing Source<br>b) New Source  | 2,000 as acid & NO <sub>2</sub> calculated as NO <sub>2</sub><br>1,500 as NO <sub>2</sub><br>1,000 as NO <sub>2</sub><br>500 as NO <sub>2</sub><br>2,000 as NO <sub>2</sub><br>1,000 as NO <sub>2</sub><br>500 as NO <sub>2</sub> | USEPA Methods 1 through 4 and Method 7              | Phenol-disulfonic acid Method or per sampling method |
| Particulates                      | 1) Fuel Burning Equipment<br>a) Urban <sup>f</sup> and Industrial Area <sup>h</sup><br>b) Other Area <sup>i</sup><br>2) Cement Plants (kilns, etc.)<br>3) Smelting Furnaces<br>4) Other Stationary Sources <sup>j</sup>   | 150<br>200<br>150<br>150<br>200   | USEPA Methods 1 through 5                           | Gravimetric per sampling method                      |
| Phosphorus Pentoxide <sup>k</sup> | Any source  | 200 as P <sub>2</sub> O <sub>5</sub>  | USEPA Methods 1 through 5 or 29                     | Spectrophotometry or per sampling method             |
| Sulfur Oxides                     | 1) Existing Sources<br>a) Manufacture of Sulfuric Acid and Sulf(on)ation Process<br>b) Fuel Burning Equipment<br>c) Other Stationary Sources <sup>l</sup><br>2) New Sources<br>a) Manufacture of Sulfuric Acid and Sulf(on)ation Process<br>b) Fuel Burning Equipment<br>c) Other Stationary Sources <sup>l</sup> | 2,000 as SO <sub>3</sub><br>1,500 as SO <sub>2</sub><br>1,000 as SO <sub>3</sub><br>1,500 as SO <sub>3</sub><br>700 as SO <sub>2</sub><br>200 as SO <sub>3</sub>  | USEPA Methods 1 through 4 and 6 or 8 as appropriate | As per sampling method                               |
| Zinc and its Compounds            | Any source  | 100 as Zn   | USEPA Methods 1 through 5 or 29                     | AAS <sup>b</sup> or per sampling method              |

Table 11 Notes:

- a. Other equivalent methods approved by the Department may be used;
- b. Atomic Absorption Spectrophotometry;
- c. All new geothermal power plants starting construction by 01 January 1995 shall control H<sub>2</sub>S emissions to not more than 150 g/GMW-Hr;
- d. All existing geothermal power plants shall control H<sub>2</sub>S emissions to not more than 200 g/GMW-Hr;
- e. Best available control technology for air emissions and liquid discharges. Compliance with air and water quality standards is required;
- f. Emission limit of Nickel Carbonyl shall not exceed 0.5 mg/NCM;

- g. Urban Area means a poblacion or central district of cities or municipalities having at least 50,000 population, or twin political subdivisions with contiguous boundary which essentially form one community whose population is more than 50,000 inhabitants. Inside these centers or population are some scattered industrial establishments;
- h. Industrial Area means a well-defined, exclusive land use area in various stages of development that are primarily established for industrial subdivisions, manufacturing and other industry mixes with provisions for common support infrastructures, facilities and services such as roads, water supply, power supply, communication systems, housing, storm drainage, sanitary sewerage systems, industrial wastewater treatment facilities, etc. These areas which are usually from 200 to 500 hectares in size as registered with the (Housing and Land Use Regulatory Board (HLURB) or any other duly authorized government entities as industrial estates, parks or area. Export processing zones also fall under this category of land use;
- i. Other Areas means all areas other than an urban or industrial area.
- j. Other Stationary Sources (particulates) means a trade, process, industrial plant, or fuel burning equipment other than thermal power plant, industrial boilers, cement plants, incinerators, smelting furnaces;
- k. Provisional guideline; and
- l. Other Stationary Sources (sulfur oxides) refers to existing and new stationary sources other than those caused by the manufacture of sulfuric acid and sulfonation process, fuel burning equipment and incineration<sup>115</sup>.

### **Visible Emission Standards for Smoke and Opacity**

Visible opacity standards for smoke are as follows:

- A. The opacity of light or dark smoke emitted from any emission point in all stationary sources shall be such that, when compared in the appropriate manner with the Ringelmann Chart<sup>116</sup> method, or using USEPA Method 9 (40 CFR, Part 60, Appendix A), or an equivalent method approved by the Department through the Bureau, visible emissions shall not appear darker than shade 1 on the Ringelmann Chart, nor exceed 20% opacity using USEPA Method 9.
- B. Exceptions to the requirements stated herein may be allowed under the following circumstances:

The opacity limit hereinbefore prescribed shall not apply to the emission of dark smoke for less than five (5) minutes in a period of one (1) hour provided that the total period of such emission shall not exceed an aggregate of fifteen (15) minutes in any twenty-four (24) hours; provided further, that at no time should the opacity be darker than shade 3 of the chart; and provided finally, that this provisions shall not apply to cases of dark emissions resulting from cold-start and up-set conditions.

Measurements of opacity shall be made in the manner specified by the approved method employed for this purpose<sup>117</sup>.

Where no emission or ambient standard is prescribed hereof for a specific air pollutant that is potentially harmful to public health and/or public welfare, the owner or operator of an industrial plant or stationary source shall conduct its operation or process by the best practicable means as may be necessary to prevent or minimize air pollution through the employment of cleaner production technology and sound environmental management practices.

The absence of the ambient air or emission standard for a specific air pollutant shall not preclude the Department through the Bureau to take appropriate action to control such pollutants to assure the health, welfare and comfort of the general population<sup>118</sup>.

#### Source Specific Ambient Air Quality Standards

For any industrial establishment or operation, the discharge of air pollutants that result in airborne concentrations in excess of the National Ambient Air Quality Standards shown in Table 12 shall not be permitted.

Sampling shall be done at the location of highest expected concentration. Location shall be determined using dispersion modeling. Bureau-approved techniques shall be followed in developing sampling plans.

For example, the Bureau’s Air Quality Monitoring Manual specifies that sampling shall be done at an elevation of at least two (2) meters above the ground level, and shall be conducted either at the property line or at a downwind distance of five (5) to twenty (20) times the stack height, whichever is more stringent.

However, the Bureau may approve the adoption of a different procedure in the choice of the location of the monitoring equipment depending upon the physical surrounding and other relevant factors in the area where the sampling is to be conducted.

Table 12 - National Ambient Air Quality Standards for Source Specific Air Pollutants from Industrial Sources/Operations

| Pollutants   | Concentration <sup>a</sup> |      | Averaging Time (min) | Method of Analysis/Measurement <sup>c</sup>             |
|--|----------------------------|------|----------------------|---|
|  | µg/NCM                     | Ppm  |                      |   |
| Ammonia  | 200                        | .028 | 30                   | Nesslerization / Indo Phenol                            |
| Carbon Disulfide   | 30                         | 0.01 | 30                   | Tischer Method  |
| Chlorine and Chlorine cmpds expressed as CL <sub>2</sub> | 100                        | 0.03 | 5                    | Methyl Orange   |
| Formaldehyde   | 50                         | 0.04 | 30                   | Chromotropic Acid method or MBTH<br>Colorimetric method |
| Hydrogen Chloride  | 200                        | 0.13 | 30                   | Volhard Titration with Iodine solution                  |
| Hydrogen Sulfide   | 100                        | 0.07 | 30                   | Methylene Blue  |
| Lead   | 20                         |      | 30                   | AAS <sup>b</sup>  |
| Nitrogen Dioxide   | 375                        | 0.20 | 30                   | Griess-Saltzman   |
|  | 260                        | 0.14 | 60                   |   |
| Phenol   | 100                        | 0.03 | 30                   | 4-Aminoantipyrine                                       |
| Sulfur Dioxide   | 470                        | 0.18 | 30                   | Colorimetric-Pararosaline                               |
|  | 340                        | 0.13 | 60                   |   |
| Suspended Particulate Matter – TSP                       | 300                        | --   | 60                   | Gravimetric   |
|  | PM-10                      | 200  | 60                   |   |
| Antimony   | 0.02 mg/NCM                | --   | 30                   | AAS <sup>b</sup>  |
| Arsenic  | 0.02 mg/NCM                | --   | 30                   | AAS <sup>b</sup>  |
| Cadmium  | 0.01 mg/NCM                | --   | 30                   | AAS <sup>b</sup>  |

| Pollutants    | Concentration <sup>a</sup>  |     | Averaging Time (min) | Method of Analysis/Measurement <sup>c</sup> |
|---------------|---|-----|----------------------|---|
|               | µg/NCM  | Ppm |                      |   |
| Asbestos      | 2 x 10 <sup>6</sup><br>Particulates/NCM<br>M<br>(over 5 micrometer in size) | --  | 30                   | Light Microscopy                            |
| Sulfuric Acid | 0.3 mg/NCM  | --  | 30                   | Titration                                   |
| Nitric Acid   | 0.4 mg/NCM  | --  | 30                   | Titration                                   |

Table 12 Notes:

- a. Ninety-eight percentile (98%) values of 30-min. sampling measured at 25oC and one atmosphere pressure;
- b. Atomic Absorption Spectrophotometry; and
- c. Other equivalent methods approved by the Department through the Bureau may be used<sup>119</sup>.

### What are air quality indices<sup>120</sup> in the Philippines?

The following shall describe the six (6) levels of air quality for suspended particulates, sulfur dioxide, photochemical oxidants or ozone, carbon monoxide, and nitrogen dioxide anywhere in the Philippines. **Levels above those indicated**, with the exception of TSP, shall be considered Emergency:

(a) Particulate Matter (µg/m<sup>3</sup>)

(1) Total Suspended Particulates – (24-Hour Average)

|                                |                 |
|--------------------------------|-----------------|
| Good                           | 0 - 80          |
| Fair                           | 81 - 230        |
| Unhealthy for sensitive groups | 231 - 349       |
| Very Unhealthy                 | 350 - 599       |
| Acutely unhealthy              | 600 - 899       |
| Emergency                      | 900 – and above |

(2) PM<sub>10</sub> [24-hour]

|                                |           |
|--------------------------------|-----------|
| Good                           | 0 – 54    |
| Fair                           | 55 – 154  |
| Unhealthy for sensitive groups | 155 – 254 |
| Very Unhealthy                 | 255 – 354 |
| Acutely unhealthy              | 355 – 424 |
| Emergency                      | 425 – 504 |

## (b) Sulfur Dioxide (ppm) [24-hour]

|                                |               |
|--------------------------------|---------------|
| Good                           | 0.000 – 0.034 |
| Fair                           | 0.035 – 0.144 |
| Unhealthy for sensitive groups | 0.145 – 0.224 |
| Very Unhealthy                 | 0.225 – 0.304 |
| Acutely unhealthy              | 0.305 – 0.604 |
| Emergency                      | 0.605 – 0.804 |

## (c) Ozone (ppm)

[8-hour]

|                                |                  |
|--------------------------------|------------------|
| Good                           | 0.000 – 0.064    |
| Fair                           | 0.065 – 0.084    |
| Unhealthy for sensitive groups | 0.085 – 0.104    |
| Very Unhealthy                 | 0.105 – 0.124    |
| Acutely unhealthy              | 0.125 – 0.374    |
| Emergency                      | ( <sup>1</sup> ) |

<sup>1</sup> When 8-hour O<sub>3</sub> concentrations exceed 0.374 ppm, AQI values of 301 or higher must be calculated with 1-hour O<sub>3</sub> concentrations.

[1-hour]<sup>2</sup>

|                                |               |
|--------------------------------|---------------|
| Good                           | -             |
| Fair                           | -             |
| Unhealthy for sensitive groups | 0.125 – 0.164 |
| Very Unhealthy                 | 0.165 – 0.204 |
| Acutely unhealthy              | 0.205 – 0.404 |
| Emergency                      | 0.405 – 0.504 |

<sup>2</sup> Areas are generally required to report the AQI based on 8-hour ozone values. However, there are a smaller number of areas where an AQI based on 1-hour ozone values would be more precautionary. In these cases, in addition to calculating the 8-hour ozone index value, the 1-hour index value may be calculated and the maximum of the two values is reported.

(d) Carbon Monoxide (ppm) [8-hour]

|                                |             |
|--------------------------------|-------------|
| Good                           | 0.0 – 4.4   |
| Fair                           | 4.5 – 9.4   |
| Unhealthy for sensitive groups | 9.5 – 12.4  |
| Very Unhealthy                 | 12.5 – 15.4 |
| Acutely unhealthy              | 15.5 – 30.4 |
| Emergency                      | 30.5 – 40.4 |

(e) Nitrogen Dioxide (ppm) [1-hour]

|                                |                  |
|--------------------------------|------------------|
| Good                           | ( <sup>3</sup> ) |
| Fair                           | ( <sup>3</sup> ) |
| Unhealthy for sensitive groups | ( <sup>3</sup> ) |
| Very Unhealthy                 | ( <sup>3</sup> ) |
| Acutely unhealthy              | 0.65 – 1.24      |
| Emergency                      | 1.25 – 1.64      |

<sup>3</sup> NO<sub>2</sub> has no 1-hour term NAAQG.

Table 13. Pollutant-Specific Cautionary Statements for the General Public

(a) Particulate Matter (µg/m<sup>3</sup>)

TSP and PM<sub>10</sub> [24-hour]

|                                |   |
|--------------------------------|---|
| Good                           | None  |
| Fair                           | None  |
| Unhealthy for sensitive groups | People with respiratory disease, such as asthma, should limit outdoor exertion.   |
| Very unhealthy                 | Pedestrians should avoid heavy traffic areas. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. People should voluntarily restrict the use of vehicles.                        |
| Acutely unhealthy              | People, should limit outdoor exertion. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. Motor vehicle use may be restricted. Industrial activities may be curtailed.          |
| Emergency                      | Everyone should remain indoors, (keeping windows and doors closed unless heat stress is possible). Motor vehicle use should be prohibited except for emergency situations. Industrial activities, except that which is vital for public safety and health, should be curtailed. |

## (b) Sulfur Dioxide (ppm) [24-hour]

|                                |   |
|--------------------------------|---|
| Good                           | None  |
| Fair                           | None  |
| Unhealthy for sensitive groups | People with respiratory disease, such as asthma, should limit outdoor exertion.   |
| Very unhealthy                 | Pedestrians should avoid heavy traffic areas. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. People should voluntarily restrict the use of vehicles.                        |
| Acutely unhealthy              | People, should limit outdoor exertion. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. Motor vehicle use may be restricted. Industrial activities may be curtailed.          |
| Emergency                      | Everyone should remain indoors, (keeping windows and doors closed unless heat stress is possible). Motor vehicle use should be prohibited except for emergency situations. Industrial activities, except that which is vital for public safety and health, should be curtailed. |

## (c) Ozone (ppm)

|                                |   |
|--------------------------------|---|
| Good                           | None  |
| Fair                           | None  |
| Unhealthy for sensitive groups | People with respiratory disease, such as asthma, should limit outdoor exertion.   |
| Very unhealthy                 | Pedestrians should avoid heavy traffic areas. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. People should voluntarily restrict the use of vehicles.                        |
| Acutely unhealthy              | People, should limit outdoor exertion. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. Motor vehicle use may be restricted. Industrial activities may be curtailed.          |
| Emergency                      | Everyone should remain indoors, (keeping windows and doors closed unless heat stress is possible). Motor vehicle use should be prohibited except for emergency situations. Industrial activities, except that which is vital for public safety and health, should be curtailed. |

(d) Carbon Monoxide (ppm)

|                                |   |
|--------------------------------|---|
| Good                           | None  |
| Fair                           | None  |
| Unhealthy for sensitive groups | People with cardiovascular disease, such as angina, should limit heavy exertion and avoid sources of CO, such as heavy traffic.   |
| Very unhealthy                 | People should stay indoors and rest as much as possible. Unnecessary trips should be postponed. People should voluntarily restrict the use of vehicles and avoid sources of CO, such as heavy traffic. Smokers should refrain from smoking. |

|                   |   |
|-------------------|---|
| Acutely unhealthy | People with cardiovascular disease, such as angina, should avoid exertion and sources of CO, such as heavy traffic, and should stay indoors and rest as much as possible. Unnecessary trips should be postponed. Motor vehicle use may be restricted. Industrial activities may be curtailed. |
| Emergency         | Everyone should avoid exertion and sources of CO, such as heavy traffic; and should stay indoors and rest as much as possible.  |

(e) Nitrogen Dioxide (ppm)

|                                |   |
|--------------------------------|---|
| Good                           | None  |
| Fair                           | None  |
| Unhealthy for sensitive groups | People with respiratory disease, such as asthma, should limit outdoor exertion.   |
| Very unhealthy                 | Pedestrians should avoid heavy traffic areas. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. People should voluntarily restrict the use of vehicles.                        |
| Acutely unhealthy              | People should limit outdoor exertion. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. Motor vehicle use may be restricted. Industrial activities may be curtailed.           |
| Emergency                      | Everyone should remain indoors, (keeping windows and doors closed unless heat stress is possible). Motor vehicle use should be prohibited except for emergency situations. Industrial activities, except that which is vital for public safety and health, should be curtailed. |



## **What are water quality standards in the Philippines?**

On February 2008, the DENR-EMB came out with a Water Quality Monitoring Manual (WQM) as 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 of the manual was 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. It was intended to be used by the technical staff of the EMB, Laguna Lake Development Authority (LLDA), MGB and other agencies or individuals under the DENR. Users may also include other government regulators and implementers such as the Bureau of Fisheries and Aquatic Resources (BFAR), Department of Public Works and Highways (DPWH), National Irrigation Administration (NIA), LGUs, consultancy firms, industries, government-recognized NGOs, monitoring groups such as the MMTs, or other volunteer groups, students, and researchers<sup>121</sup>.

The WQM states that whatever the objective and methodology, ambient water quality monitoring would always proceed according to the steps shown in Table 14<sup>122</sup>.

Table 14. Water Quality Monitoring Manual

| Step | Activity  |   | Responsibility                    |
|------|---|---|-----------------------------------|
| 1    | Preparation of a monitoring plan to ensure that all the requirements for monitoring are met.                                      | <br>EMS 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) | <br>Sampling                     | Field personnel/<br>sampling team |
| 3    | Field tests and measurements; e.g., pH, temperature, dissolved oxygen, flow measurements; sample preservation                     | <br>Field testing                | Field personnel/<br>sampling team |
| 4    | Record field observations, on-site test results and field activities on the field book, field data form and COC form              | <br>Recording Field Observations | Field personnel/<br>sampling team |
| 5    | Pre-treatment, preservation, storage and transport of samples to the laboratory   | <br>Packing and Transport       | Field personnel/<br>sampling team |
| 6    | Analysis of samples in the laboratory   | <br>Laboratory Testing         | Laboratory personnel              |
| 7    | Data processing, interpretation, analysis and storage   | <br>Documentation              | Encoder/head of monitoring team   |
| 8    | Preparation of report   | <br>Reporting                  | Head of monitoring team           |

### Water Monitoring Plan<sup>123</sup>

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.

**Box 4. Five Components of a Water Monitoring Plan**

- 1) Background Information;
- 2) Objectives of Monitoring;
- 3) Monitoring Stations;
- 4) Water Quality Parameters for Measurement;
  - The parameters to be monitored should be specified. Choose the parameters according to the objective of monitoring.
  - 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.
- 5) 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.

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### Classification of Water Usage and its Beneficial Use<sup>124</sup>

There are two classifications of water as defined by Water Quality Monitoring Manual. These are:

- Fresh Surface Waters
- Coastal and Marine Waters

A. Fresh Surface Waters (rivers, lakes, reservoirs, etc.) as shown in Table 15.

Table 15. Classification of Fresh Surface Water based on Type and Usage

|                 |   |
|-----------------|---|
| <b>Class AA</b> | <b>Public Water Supply Class I.</b> This class is intended primarily for waters having watersheds which are uninhabited and otherwise protected and which require only approved disinfection in order to meet the National Standards for Drinking Water (NSDW) of the Philippines.                              |
| <b>Class A</b>  | <b>Public Water Supply Class II.</b> For sources of water supply that will require complete treatment (coagulation, sedimentation, filtration and disinfection) in order to meet the NSDW.  |
| <b>Class B</b>  | <b>Recreational Water Class I.</b> For primary contact recreation such as bathing, swimming, skin diving, etc. (particularly those designated for tourism purposes).  |
| <b>Class C</b>  | <ol style="list-style-type: none"> <li>1) <b>Fishery Water</b> for the propagation and growth of fish and other aquatic resources;</li> <li>2) <b>Recreational Water Class II</b> (Boatings, etc.)</li> <li>3) <b>Industrial Water Supply Class I</b> (For manufacturing processes after treatment).</li> </ol> |
| <b>Class D</b>  | <ol style="list-style-type: none"> <li>1) For agriculture, irrigation, livestock watering, etc.</li> <li>2) <b>Industrial Water Supply Class II</b> (e.g. cooling, etc.)</li> <li>3) Other inland waters, by their quality, belong to this classification.</li> </ol>   |

B. Coastal and Marine Waters<sup>125</sup> as shown in Table 16.

Table 16. Classification of Coastal and Marine Water based on Type and Usage

|                 |   |
|-----------------|---|
| <b>Class SA</b> | <ol style="list-style-type: none"> <li>1) Waters suitable for the propagation, survival and harvesting of shellfish for commercial purposes;</li> <li>2) Tourist zones and national marine parks and reserves established under Presidential Proclamation No. 1801; existing laws and/or declared as such by appropriate government agency.</li> <li>3) Coral reef parks and reserves designated by law and concerned authorities.</li> </ol> |
| <b>Class SB</b> | <ol style="list-style-type: none"> <li>1) <b>Recreational Water Class I</b> (Areas regularly used by the public for bathing, swimming, skin diving, etc.);</li> <li>2) <b>Fishery Water Class I</b> (Spawning areas for <u>Chanos chanos</u> or "Bangus" and similar species).</li> </ol>   |
| <b>Class SC</b> | <ol style="list-style-type: none"> <li>1) <b>Recreational Water Class II</b> (e.g. boating, etc.);</li> <li>2) <b>Fishery Water Class II</b> (Commercial and sustenance fishing);</li> <li>3) Marshy and/or mangrove areas declared as fish and wildlife sanctuaries;</li> </ol>  |
| <b>Class SD</b> | <ol style="list-style-type: none"> <li>1) <b>Industrial Water Supply Class II</b> (e.g. cooling, etc.);</li> <li>2) Other coastal and marine waters, by their quality, belong to this classification.</li> </ol>  |

**General Provisions on Water Classification**

- a. Classification of a water body according to a particular designated use or uses does not preclude use of the water for other purposes that are lower in classification provided that such use does not prejudice the quality required for such waters.
- b. Water classifications are arranged in the order of the degree of protection required, with Class AA and SA having generally the most stringent water quality, respectively, for fresh surface waters and marine/coastal waters; and Class D and SD waters have the least stringent water quality for fresh surface waters and marine waters, respectively.

## Empowered Communities

- c. The main objective of the water quality criteria is to maintain the minimum conditions necessary to assure the suitability of water for its designated use or classification.
- d. Any person regulated under these rules or having a substantial interest in this chapter may seek reclassification of waters by filing a petition with the DENR giving all necessary information to support the petition.
- e. All reclassifications of water shall be adopted, only after public notice and hearing and upon affirmative findings by the DENR Regional Office concerned that:
  - i. The proposed reclassification will establish the present and future most beneficial use of the waters;
  - ii. Such a reclassification is clearly in the public interest, and
  - iii. The proposed designated use is attainable, upon consideration of environmental, technological, social, economic and institutional factors.

### **Box 5. Minimum Water Quality Parameters to be Measured**

For purposes of classification or reclassification the following minimum water quality parameters are to be considered:

1. Dissolved oxygen (DO)
2. pH
3. Biochemical Oxygen Demand (BOD<sup>127</sup>)
4. Total Coliform Organisms

**Water Quality for Fresh Water**

- A. Conventional and Other Pollutants Affecting Aesthetics and Oxygen Demand.– Parameters and limits or specifications according to classification and use of the receiving body of water (RBW) are laid out in Table 17<sup>128</sup>.

Table 17. Water Quality Criteria for Conventional and Other Pollutants Contributing to Aesthetics and Oxygen Demand for Fresh Waters

| PARAMETER  | UNIT           | CLASS<br>AA        | CLASS<br>A           | CLASS<br>B           | CLASS<br>C           | CLASS<br>D <sup>(a)</sup> |
|--|----------------|--------------------|----------------------|----------------------|----------------------|---------------------------|
| Color  | PCU            | 15                 | 50                   | (c)                  | (c)                  | (c)                       |
| Temperature <sup>(a)</sup><br>(max. rise in deg.<br>Celcius) | °C rise        |                    | 3                    | 3                    | 3                    | 3                         |
| pH (range)   |                | 6.5 - 8.5          | 6.5 - 8.5            | 6.5 - 8.5            | 6.5 - 8.5            | 6.0 - 9.0                 |
| Dissolved Oxygen <sup>(a)</sup><br>(Minimum)                 | % satn<br>mg/L | 70<br>5.0          | 70<br>5.0            | 70<br>5.0            | 60<br>5.0            | 40<br>3.0                 |
| 5-Day 20°C BOD   | mg/L           | 1                  | 5                    | 5                    | 7(10)                | 10(15)                    |
| Total Suspended<br>Solids                                    | mg/L           | 25                 | 50                   | <sup>(b)</sup>       | <sup>(b)</sup>       | <sup>(b)</sup>            |
| Total Dissolved<br>Solids                                    | mg/L           | 500 <sup>(b)</sup> | 1,000 <sup>(b)</sup> | -                    | -                    | 1,000 <sup>(b)</sup>      |
| Surfactants (MBAS)   | mg/L           | nil                | 0.2(0.5)             | 0.3(0.5)             | 0.5                  | -                         |
| Oil/Grease<br>(Petroleum Ether<br>Extracts)                  | mg/L           | nil                | 1                    | 1                    | 2                    | 5                         |
| Nitrate as Nitrogen  | mg/L           | 1.0                | 10                   | nr                   | 10 <sup>(b)</sup>    | -                         |
| Phosphate as<br>Phosphorus                                   | mg/L           | nil                | 0.1 <sup>(b)</sup>   | 0.2 <sup>(b)</sup>   | 0.4 <sup>(b)</sup>   | -                         |
| Phenolic<br>Substances as<br>Phenols                         | mg/L           | nil                | 0.002                | 0.005 <sup>(b)</sup> | 0.02 <sup>(b)</sup>  | -                         |
| Total Coliforms  | MPN/<br>100 mL | 50 <sup>(m)</sup>  | 1,000 <sup>(m)</sup> | 1,000 <sup>(m)</sup> | 5,000 <sup>(m)</sup> | -                         |
| Or Fecal Coliforms   | MPN/<br>100 mL | 20 <sup>(m)</sup>  | 100 <sup>(m)</sup>   | 200 <sup>(m)</sup>   | -                    | -                         |
| Chloride as Cl   | mg/L           | 250                | 250                  | -                    | 350                  | -                         |
| Copper   | mg/L           | 1.0                | 1.0                  | -                    | 0.05 <sup>(a)</sup>  | -                         |

B. Toxic and other Deleterious Substances. - The maximum limits for these types of pollutants according to classifications or use of the receiving body of water are found in Table 18<sup>129</sup>.

Table 18. Water Quality Criteria for Toxic and Other Deleterious Substances for Fresh Waters (for the protection of public health)

| PARAMETER                               | UNIT | CLASS<br>AA | CLASS<br>A | CLASS<br>B | CLASS<br>C | CLASS<br>D |
|---|------|-------------|------------|------------|------------|------------|
| Arsenic <sup>(i)</sup>                  | mg/L | 0.05        | 0.05       | 0.05       | 0.05       | 0.01       |
| Cadmium <sup>(i)</sup>                  | mg/L | 0.01        | 0.01       | 0.01       | 0.01       | 0.05       |
| Chromium <sup>(i)</sup><br>(hexavalent) | mg/L | 0.05        | 0.05       | 0.05       | 0.05       | ----       |
| Cyanide                                 | mg/L | 0.05        | 0.05       | 0.05       | 0.05       | ----       |
| Lead <sup>(i)</sup>                     | mg/L | 0.05        | 0.05       | 0.05       | 0.05       | ----       |
| Total Mercury <sup>(i)</sup>            | mg/L | 0.002       | 0.002      | 0.002      | 0.002      | 0.002      |
| Organophosphate                         | mg/L | nil         | nil        | nil        | nil        | nil        |
| Aldrin                                  | mg/L | 0.001       | 0.001      | -          | -          | -          |
| DDT                                     | mg/L | 0.05        | 0.05       | -          | -          | -          |
| Dieldrin                                | mg/L | 0.001       | 0.001      | -          | -          | -          |
| Heptachlor                              | mg/L | nil         | nil        | -          | -          | -          |
| Lindane                                 | mg/L | 0.004       | 0.004      | -          | -          | -          |
| Toxaphane                               | mg/L | 0.005       | 0.005      | -          | -          | -          |
| Methoxychlor                            | mg/L | 0.10        | 0.10       | -          | -          | -          |
| Chlordane                               | mg/L | 0.003       | 0.003      | -          | -          | -          |
| Endrin                                  | mg/L | nil         | nil        | -          | -          | -          |
| PCB                                     | mg/L | 0.001       | 0.001      | -          | -          | -          |

### Water Quality for Coastal and Marine Waters

- A. Conventional and Other Pollutants Affecting Aesthetics and Oxygen Demand- The criteria for Class SA, SB, SC and SD are found in Table 19.

Table 19. Water Quality Criteria for Conventional and Other Pollutants Affecting Aesthetics and Exerting Oxygen Demand for Coastal and Marine Waters

| PARAMETER                                   | UNIT           | CLASS SA<br>(c) | CLASS SB<br>(c) | CLASS SC<br>(c) | CLASS SD<br>(c) |
|---|----------------|-----------------|-----------------|-----------------|-----------------|
| Color                                       | PCU            |                 |                 |                 |                 |
| Temperature (d) (max. rise in deg. Celsius) | °C rise        | 3               | 3               | 3               | 3               |
| pH (range)                                  |                | 6.5 - 8.5       | 6.0 - 8.5       | 6.0 - 8.5       | 6.0 - 9.0       |
| Dissolved Oxygen (e)<br>(Minimum)           | % satn<br>mg/L | 70<br>5.0       | 70<br>5.0       | 70<br>5.0       | 50<br>2.0       |
| 5-Day 20°C BOD                              | mg/L           | 3               | 5               | 7(10)           | -               |
| Total Suspended Solids                      | mg/L           | (f)             | (g)             | (g)             | (h)             |
| Surfactants (MBAS)                          | mg/L           | 0.2             | 0.3             | 0.5             | -               |
| Oil/Grease (Petroleum Ether Extract)        | mg/L           | 1               | 2               | 3               | 5               |
| Phenolic Substances as Phenols              | mg/L           | nil             | 0.01            | (1)             | -               |
| Total Coliforms                             | MPN/<br>100 mL | 70(m)           | 1,000(m)        | 5,000(m)        | -               |
| Fecal Coliforms                             | MPN/<br>100 mL | nil             | 200(m)          | -               | -               |
| Copper                                      | Mg/L           | -               | 0.02(n) (e)     | 0.05 (e)        | -               |

B. Toxic and Other Deleterious Substances- The maximum limits for toxic and other deleterious substances for waters classified as Class SA, SB, SC and SD waters are found in Table 20<sup>130</sup> .

Table 20. Water Quality Criteria for Toxic and Other Deleterious Substances for Coastal and Marine Waters (for the Protection of Public Health)

| PARAMETER                               | UNIT | CLASS<br>SA | CLASS<br>SB | CLASS<br>SC | CLASS<br>SD |
|---|------|-------------|-------------|-------------|-------------|
| Arsenic <sup>(1)</sup>                  | mg/L | 0.05        | 0.05        | 0.05        | -           |
| Cadmium <sup>(1)</sup>                  | mg/L | 0.01        | 0.01        | 0.01        | -           |
| Chromium <sup>(1)</sup><br>(hexavalent) | mg/L | 0.05        | 0.1         | 0.1         | -           |
| Cyanide                                 | mg/L | 0.05        | 0.05        | 0.05        | -           |
| Lead <sup>(1)</sup>                     | mg/L | 0.05        | 0.05        | 0.05        | -           |
| Total Mercury <sup>(1)</sup>            | mg/L | 0.002       | 0.002       | 0.002       | -           |
| Organophosphate                         | mg/L | nil         | nil         | nil         | -           |
| Aldrin                                  | mg/L | 0.001       | -           | -           | -           |
| DDT                                     | mg/L | 0.05        | -           | -           | -           |
| Dieldrin                                | mg/L | 0.001       | -           | -           | -           |
| Heptachlor                              | mg/L | nil         | -           | -           | -           |
| Lindane                                 | mg/L | 0.004       | -           | -           | -           |
| Toxaphane                               | mg/L | 0.005       | -           | -           | -           |
| Methoxychlor                            | mg/L | 0.10        | -           | -           | -           |
| Chlordane                               | mg/L | 0.003       | -           | -           | -           |
| Endrin                                  | mg/L | nil         | -           | -           | -           |
| PCB                                     | mg/L | 0.001       | -           | -           | -           |

**Effluent Standards: Toxic and Other Deleterious Substance**

A. The maximum limits for the protection of public health are laid down in Table 21 <sup>131, 132</sup>.

Table 21- Effluent Standards: Toxic and Other Deleterious Substance <sup>133</sup>

| Parameter             | Unit | Protected Waters |   | Protected Waters |       | Inland Waters |       | Marine Waters |       | Marine Waters |      |
|-----------------------|------|------------------|---|------------------|-------|---------------|-------|---------------|-------|---------------|------|
|                       |      | Category I       |   | Category II      |       | Class C       |       | Class SC      |       | Class SD      |      |
|                       |      | (Class AA & SA)  |   | (Class A,B & SB) |       | OEI           | NPI   | OEI           | NPI   | OEI           | NPI  |
| Arsenic               | mg/L | b                | b | 0.2              | 0.1   | 0.5           | 0.2   | 1.0           | 0.5   | 1.0           | 0.5  |
| Cadmium               | mg/L | b                | b | 0.05             | 0.02  | 0.1           | 0.05  | 0.2           | 0.1   | 0.5           | 0.2  |
| Chromium (hexavalent) | mg/L | b                | b | 0.1              | 0.05  | 0.2           | 0.1   | 0.5           | 0.2   | 1.0           | 0.5  |
| Cyanide               | mg/L | b                | b | 0.2              | 0.1   | 0.3           | 0.2   | 0.5           | 0.2   | -             | -    |
| Lead                  | mg/L | b                | b | 0.2              | 0.1   | 0.5           | 0.3   | 1.0           | 0.5   | -             | -    |
| Mercury (Tot.)        | mg/L | b                | b | 0.005            | 0.005 | 0.005         | 0.005 | 0.005         | 0.005 | 0.05          | 0.01 |
| PCB                   | mg/L | b                | b | 0.003            | 0.003 | 0.003         | 0.003 | 0.003         | 0.003 | -             | -    |
| Formaldehyde          | mg/L | b                | b | 2.0              | 1.0   | 2.0           | 1.0   | 2.0           | 1.0   | -             | -    |

B. Effluent Standards: Conventional and Other Pollutants in Protected Waters are found in [Table 22](#).<sup>134</sup>

Table 22 - Effluent Standards: Conventional and Other Pollutants in Protected Waters<sup>135</sup>

| Parameter                                     | Unit    | Protected Waters |   |                   |         | Inland Waters    |                  |
|---|---------|------------------|---|-------------------|---------|------------------|------------------|
|   |         | Category I       |   | Category II       |         | Class C          |                  |
|   |         | (Class AA & SA)  |   | (Class A, B & SB) |         | OEI              | NPI              |
| Color   | PCU     | b                | b | 150               | 100     | 200 <sup>c</sup> | 150 <sup>c</sup> |
| Temperature (max rise in deg. Celsius in RBW) | °C rise | b                | b | 3                 | 3       | 3                | 3                |
| pH (range)                                    |         | b                | b | 6.0-9.0           | 6.0-9.0 | 6.0-9.0          | 6.5-9.0          |
| COD   | Mg/L    | b                | b | 100               | 60      | 150              | 100              |
| Settleable Solids (1-hour)                    | Mg/L    | b                | b | 0.3               | 0.3     | 0.5              | 0.5              |
| Total Suspended Solids                        | Mg/L    | b                | b | 70                | 50      | 90               | 70               |
| Total Dissolved Solids                        | Mg/L    | b                | b | 1,200             | 1,000   | -                | -                |
| Surfactants (MBAS)                            | Mg/L    | b                | b | 5.0               | 2.0     | 7.0              | 5.0              |

|                                      |           |   |   |       |       |        |        |
|--------------------------------------|-----------|---|---|-------|-------|--------|--------|
| Oil/Grease (Petroleum Ether Extract) | Mg/L      | b | b | 5.0   | 5.0   | 10.0   | 5.0    |
| Phenolic Substances as Phenols       | Mg/L      | b | b | 0.1   | 0.05  | 0.5    | 0.1    |
| Total Coliforms                      | MPN/100mL | b | b | 5,000 | 3,000 | 15,000 | 10,000 |

C. Effluents Standards: Conventional and Other Pollutants in Inland Waters Class D, Coastal Waters Class SC and SD and other Coastal Waters not yet Classified) can be found in Table 23.

Table 23 - Effluents Standards: Conventional and Other Pollutants in Inland Waters Class D, Coastal Waters Class SC and SD and other Coastal Waters not yet Classified

| Parameter                                      | Unit      | Inland Waters      |                    | Coastal Waters   |                  | Class SD & Other Coastal Waters |         |
|--|-----------|--------------------|--------------------|------------------|------------------|---------------------------------|---------|
|  |           | (Class D)          |                    | (Class SC)       |                  | Not Classified                  |         |
|  |           | OEI                | NPI                | OEI              | NPI              | OEI                             | NPI     |
| Color  | PCU       | ---                | ---                |                  | c                | c                               | c       |
| Temperature (max. rise in deg. Celsius in RBW) | °C rise   | 3                  | 3                  | 3                | 3                | 3                               | 3       |
| pH (range)                                     |           | 5.0-9.0            | 6.0-9.0            | 6.0-9.0          | 6.0-9.0          | 5.0-9.0                         | 5.0-9.0 |
| COD  | mg/L      | 250                | 200                | 250              | 200              | 300                             | 200     |
| 5-Day 20 °C BOD                                | mg/L      | 150                | 120                | 120 <sup>d</sup> | 100              | 150 <sup>d</sup>                | 120     |
| Total Suspended Solids                         | mg/L      | 200                | 150                | 200              | 150              | g                               | f       |
| Total Dissolved Solids                         | mg/L      | 2,000 <sup>h</sup> | 1,500 <sup>h</sup> | -                | -                | -                               | -       |
| Surfactants (MBAS)                             | mg/L      | -                  | -                  | 15               | 10               | -                               | -       |
| Oil/Grease (Petroleum Ether Extract)           | mg/L      | -                  | -                  | 15               | 10               | 15                              | 15      |
| Phenolic Substances as Phenols                 | mg/L      | -                  | -                  | 1.0 <sup>i</sup> | 0.5 <sup>i</sup> | 5.0                             | 1.0     |
| Total Coliforms                                | MPN/100mL | j                  | j                  | -                | -                | -                               | -       |

D. Effluent Standards for BOD for Strong Industrial Wastes.

- a. Interim Requirements for Old or Existing Industries. - For strong industrial wastewaters with high BOD and where the receiving body of water is Class C, D, SC and SD in

accordance with Section 68, as amended, of the 1978 NPCC Rules and Regulations, the interim effluent requirements for old industries which will be applicable within the period indicated in Table 24.

- b. Effluents from domestic sewage and industrial wastewater treatment plants not covered under Section 6 of these Regulations, when discharged into receiving waters classified as Class A, B, C, D, SA, SB, SC, and SD in accordance with Section 68, as amended, of the 1978 NPCC Rules and Regulations shall not contain the following pollutants in concentrations greater than those indicated in previous tables.

Table 24 - Interim Effluent Standards for BOD Applicable to Old or Existing Industries Producing Strong Industrial Wastes, (1990-1994)<sup>136</sup>

| Industry Classification Based on BOD of Raw Wastewaters Produced | Maximum Allowable Limits in mg/L, according to Time Period and Receiving Body of Water |                            |                            |                            |
|--|--|----------------------------|----------------------------|----------------------------|
|  | Effectivity date - Dec. 31, 1991   |                            | Jan. 1, 1992-Dec. 31, 1994 |                            |
|  | Inland Waters  | Coastal Waters             | Inland Waters              | Coastal Waters             |
|  | (Class C & D)  | (Class SC & SD)            | (Class C & D)              | (Class SC & SD)            |
| 1. Industries producing BOD within 3,000 to 10,000 mg/L          | 320<br>or<br>95% removal   | 650<br>or<br>90% removal   | 200<br>or<br>97% removal   | 320<br>or<br>95% removal   |
| 2. Industries producing BOD within 10,000 to 30,000 mg/L         | 1,000<br>or<br>95% removal   | 2,000<br>or<br>90% removal | 600<br>or<br>97% removal   | 1,000<br>or<br>95% removal |
| 3. Industries producing more than or 30,000 mg/L                 | 1,500<br>or<br>95% removal   | 3,000<br>or<br>90% removal | 900<br>or<br>97% removal   | 1,500<br>or<br>95% removal |

- c. Requirements for New Industries. - Upon the effectivity of these regulations, new/proposed industries, or those old/existing industries that are yet to construct their wastewater treatment facilities, which are producing or treating strong wastewaters shall comply with the requirements in Table 25 below. By January 1995, this Table shall be applicable to all industries producing strong wastes.

Table 25 - Effluent Standards for New\* Industries Producing Strong Wastes upon Effectivity of these Regulations, and for All Industries Producing Strong Wastes starting January 1, 1995<sup>137</sup>.

| Industry Classification<br>Based on BOD of Raw<br>Wastewater | Maximum Allowable Limits in mg/L<br>Based on Receiving Body of Water |                    |
|--|--|--------------------|
|  | Inland Waters  | Coastal Waters     |
|  | (Class C & D)  | (Class SC & SD)    |
| 1. Industries producing within<br>3,000 to 10,000 mg BOD/L   | 130 or 98% removal   | 200 or 97% removal |
| 2. Industries producing within<br>10,000 to 30,000 mg BOD/L  | 200 or 99% removal   | 600 or 97% removal |
| 3. Industries producing more<br>than 30,000 mg BOD/L         | 300 or 99% removal   | 900 or 97% removal |

**Mixing Zone : Requirements<sup>138</sup>**

A mixing zone is the place where the effluent discharge from a point source mixes with a receiving body of water. The area or extent of the zone shall be determined by the discharger and approved by the Department on a case-to case basis.

The following general conditions shall govern the location and extent of the mixing zone:

- A. No mixing zone or combination of mixing zones shall be allowed to significantly impair any of the designated uses of the receiving body of water.
- B. A mixing zone shall not include an existing drinking water supply intake if such mixing zone would significantly impair the purposes for which the supply is utilized.
- C. A mixing zone for rivers, streams, etc., shall not create a barrier to the free migration of fish and aquatic life.
- D. A mixing zone shall not include a nursery area of indigenous aquatic life nor include any area designated by the Department of Environment and Natural Resources for shellfish harvesting, tourist zones and national marine parks and reserves, coral reef parks and reserves and declared as such by the appropriate government agency
- E. In general, the length of the mixing zone or plume in rivers or similar waterways shall be as short as possible and its width shall be preferably not more than one-half of the width of the waterway.
- F. In discharging hot effluents from power plants, mineral ore milling and similar generators of large volume of liquid wastes the permissible size of the mixing zone shall be determined through modeling taking into consideration

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the size, hydraulic and hydrological data of the receiving body of water and the design and siting of the wastewater outfall.

- G. For the protection of aquatic life resources, the mixing zone must not be used for, or be considered as a substitute for wastewater treatment facility.

### **Additional Requirements**<sup>139</sup>

- A. No effluent shall cause the quality of the receiving body of water to fall below the prescribed quality in accordance with its classification or best usage.
- B. Where the combined effect of a number of individual effluent discharges causes one or more water quality parameters to exceed the prescribed limits, the maximum permissible concentrations of such parameters shall be reduced proportionately so as to maintain the desired quality.
- C. When discharging effluents into coastal waters, the location and design of the submarine outfall shall be based on prevailing oceanographic and wind conditions so that discharged materials shall not find their way back to the shore and that there shall be minimum deposition of sediments near and around the outfall.
- D. Effluents discharged into protected inland and coastal waters Category II, such as Class A, B, and SB, shall meet the requirements of Section 4 and 5 above.
- E. Starting January 1, 1995, old or existing industries shall comply with the standards set for new industries in these regulations.
- F. For a period to be determined by the Department Secretary and provided that the resulting effect on receiving waters does not pose an immediate threat to life, public health, safety or welfare or to animal or plant life or property, any existing industry that produces strong wastes which cannot meet the limits for BOD in Tables 24 and 25, maybe allowed to operate and be issued a temporary permit to operate on condition that it pays first a penalty fee for polluting a receiving body of water in the amount equivalent to five pesos (PhP 5.00) per kilogram of BOD discharged per day in excess of the allowable effluent limit provided further that the calculated fine shall not exceed PhP5,000 per day in accordance with PD 984 and its implementing rules and regulations. (Conversion Factor: 1 mg/L = 1 g/cu.m.)
- G. Each discharger covered under these regulations shall monitor its effluent and its effect on the receiving body of water regularly in order to ensure compliance with Sections 4, 5 and 6 hereof and Section 69, as amended, of the 1978 NPCC Rules and Regulations.

**Methods of Water Quality Monitoring**

For purposes of these regulations, any water sample taken for the purpose of classification or for determining compliance with the water quality criteria shall be analyzed in accordance with the methods enumerated in Table 26.

The table also applies to determine compliance to effluent<sup>140</sup> regulations

Table 26. Method of Analysis for Water Quality Monitoring

| PARAMETER               | METHOD OF ANALYSIS   |
|-------------------------|--|
| ARSENIC                 | Silver Diethyldithiocarbamate Method (Colorimetric)                                      |
| BOD5                    | Azide Modification (Dilution Technique)  |
| BORON                   | Carmine Method (Colorimetric Method)   |
| CADMIUM                 | Atomic Absorption Spectrophotometry (Washing with concentrated HNO <sub>3</sub> , + HCl) |
| CHLORINATEDHYDROCARBONS | Gas Chromatography (ECD)   |
| CHROMIUM                | (Hexavalent) Diphenyl Carbazide Colorimetric Method                                      |
| COLOR                   | Visual Comparison Method (Platinum Cobalt Scale)   |
| CYANIDE                 | Specific Ion Electrode Method  |
| DISSOLVED OXYGEN        | Azide Modification (Winkler Method), Membrane Electrode (DO meter)                       |
| FECAL COLIFORMS         | Multiple-Tube Fermentation Technique or Membrane Filter                                  |
| LEAD                    | Atomic Absorption Spectrophotometry  |
| NITRATE AS NITROGEN     | Brucine Method for Saline Waters, specific Ion Electrode Meter for Fresh Water           |

|                                |   |
|--------------------------------|---|
| OIL AND GREASE                 | Gravimetric Method (Petroleum Ether Extraction)         |
| ORGANO PHOSPHORUS COMPOUNDS    | Gas Chromatography (FPD)                                |
| POLYCHLORINATED BIPHENYL (PCB) | Gas Chromatography (ECD) pH Glass Electrode Method      |
| PHENOLIC SUBSTANCES            | Chloroform Extraction Method                            |
| PHOSPHATE ASPHOSPHORUS         | Stannous Chloride Method                                |
| SETTLEABLE SOLIDS              | Imhoff Cone Method                                      |
| SURFACTANTS                    | (MBAS) Methylene Blue Method (Colorimetric)             |
| TEMPERATURE                    | Use of Mercury-Filled Thermometer                       |
| TOTAL COLIFORMS                | Multiple-Tube Fermentation Technique or Membrane Filter |
| TOTAL MERCURY                  | Cold Vapor Technique (Mercury Analyzer, AAS)            |
| TOTAL SUSPENDED SOLIDS         | Gravimetric Method                                      |

### Methods of Analysis for Effluents

Any domestic or industrial effluent discharged into any body of water or watercourse shall be analyzed in accordance with the latest edition of the "Philippine Standard Methods for Air and Water Analyses", the "Standard Method for the Examination of Water and Wastewater" published jointly by the American Public Health Association, the American Waterworks Association and the Water

Pollution Control Federation of the United States, or in accordance with such other methods of analysis as the Department may prescribe.

The approved methods of analysis are the same as those in Table 26.

Table 27. Relevant Wastewater Parameters per Industry

| TYPE OF INDUSTRY                            | RELEVANT WASTEWATER PARAMETERS  |
|---|---|
| MINERAL ORE PROCESSING<br>(Mining Industry) | Suspended Solids, Heavy Metals (Hg, Cn, Cd, etc.), Arsenic                          |
| THERMAL POWER GENERATION                    | BOD5, Color, Chromium, Oil and Grease, pH, Phosphate, Suspended Solids, Temperature |

### Important Points to Remember

- The Clean Air Act and Clean Water Act of the Philippines set standards and thresholds which identifies what are allowable levels for certain parameters. Beyond these set thresholds need to be acted upon;

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- The National Emission Standards for Source Specific Air Pollutants (NESSAP) identifies certain pollutants and sets relevant methods of sampling and analysis and also maximum permissible limits for each;
- Standards to be followed in water quality monitoring is based on its classification and usage<sup>2</sup>. The higher its class, the stricter standards become. Methods of analysis also vary by parameter or element being measured.



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# **Mining Situationer**

## **Chapter 4. Mining Situationer in the Philippines: Focus on Copper, Gold, and Nickel Mining**

This chapter is intended to introduce readers to the Philippine Mining Context – background and issues of pollution and health hazards. This is done on a per commodity basis with a section dedicated to nickel and another for copper & gold which are the most commonly mined mineral in the country. By the end of this chapter, participants will have a better understanding of mining's larger context in the country.

### **Learning Objectives of this Chapter**

- Learn about gold & copper and nickel deposits in the Philippines and the mining methods applied to extract these minerals
- Learn about pertinent issues on pollution and health hazards caused by extraction of the mentioned minerals

#### Parts of this Chapter

- Extraction of Copper-Gold
  - Copper-Gold Deposits
  - Mine Operations and Methods
- Extraction of Nickel
  - Nickel Deposits
  - Mine Operations
- Pollution from Mine Operations
  - Soil Pollution
  - Water Pollution
  - Air Pollution
  - Noise Pollution

## **Extraction of Copper-Gold in the Philippines**

### **Copper-Gold deposits**

The copper-gold deposits of the Philippines are formed through the complex geological processes that ultimately formed the Philippine archipelago. Mineralization proceeded directly or indirectly from chemical processes that formed different ores from the magma, or the molten rock material, found deep under the rocks that form the archipelago. The type and distribution of minerals formed depend on the varying chemical composition and weight of the magma.

Most of the copper-gold deposits formed along the mountain and volcanic belts that dot the archipelago, in deposits known as copper porphyry. These form as large intrusive rock bodies that hardened within the crust. Another type of mineralization common in the Philippines is the epithermal- to mesothermal gold deposits. These form through hydrothermal deposition mainly of gold within faults.

The primary gold-producing areas in the Philippines are found in the Baguio, Benguet, Masbate, Camarines Norte, Bulacan, Negros, Surigao, and Davao gold districts. These areas have been mined since prehistoric times. Copper mineralization in the Philippines, on the other hand, follows two distinct trends: one follows a north-south direction while the other follows a northeast-southeast trend. The north-south zone follows the west coast through Zambales, Batangas, then to Mindoro, Panay, Negros, Cebu, down to Mindanao, where Tampakan, one of the biggest copper-gold deposits in the world, is located. The northeast-southwest trend begins in Bicol, starting from Catanduanes, then to Rapu-Rapu, then Masbate, Negros, Tawi-tawi, going all the way to Borneo. These copper deposits also yield gold as their byproduct.

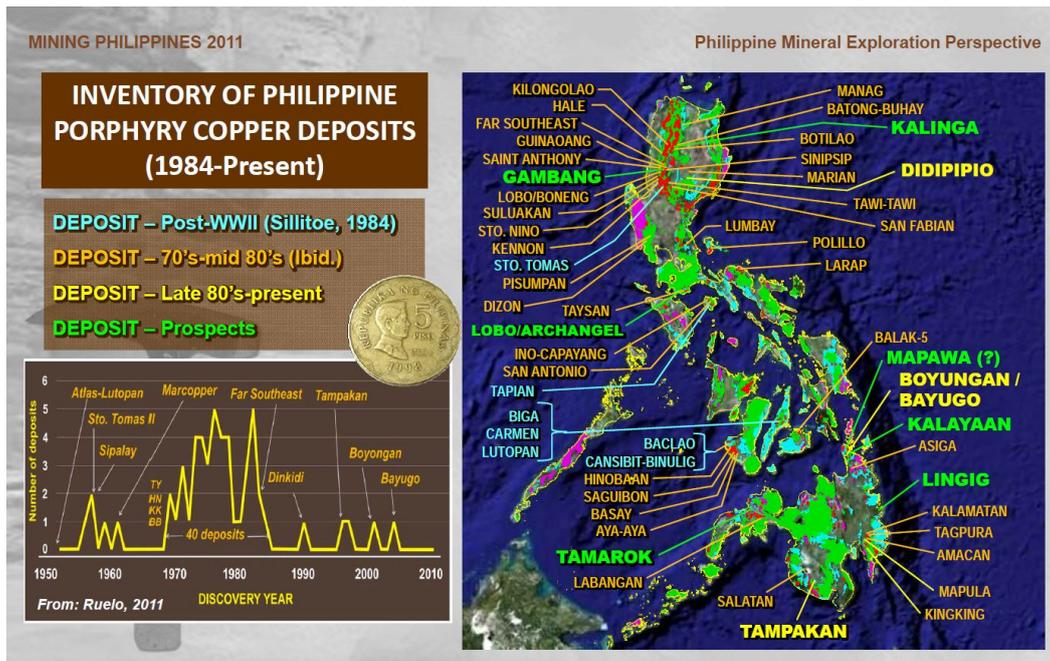


Figure 4. Porphyry Copper Deposits in the Philippines<sup>141</sup>

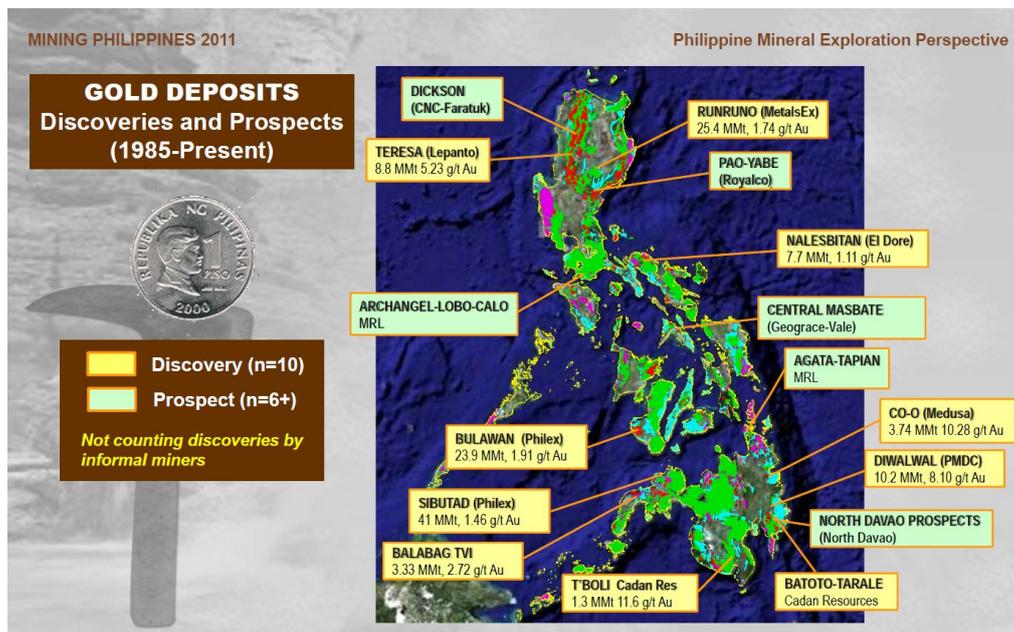


Figure 5. Gold Deposits in the Philippines<sup>142</sup>

**Extracting copper and gold**

The mining of metals, especially gold and copper, was an important feature of the culture of the peoples in the Philippines even prior to Spanish rule. Gold, in particular, was an important material for ornamentation, religious ceremonies, and everyday trade in the prehistoric Philippines. This is evidenced by the extensive archaeological finds in Rizal, Surigao, Palawan, among others. The

earliest estimated date when mining of gold has been practiced in the Philippines goes as far back as 500 BC. The early Filipinos used primitive methods in mining ore from rock or sediment deposits up to the extraction of these metals.

Extensive prospecting and mining for gold, copper, and other base metals only came about during the American era. During this period, stakes were claimed in the deposits in Benguet, particularly in Baguio and Mankayan, as well as in the old mining districts of Paracale-Mambulao, Aroroy, Surigao, and Nueva Ecija. This story of the Philippine mining industry's growth is most sensationally told as the story of how Baguio transformed from a mountainous wilderness to a bustling metropolis as a result of the gold rushes during the 1930s.

Today, the mining of copper and gold is mainly done by large-scale mining companies found all throughout the Philippines. Virtually all large-scale gold mining companies employ cyanidation processes, which uses the toxic but easily degradable cyanide, to leach away gold particles from the ore. Copper mining companies use various methods, most commonly gravity concentration and flotation processes, to produce a copper concentrate. Copper smelting is almost non-existent in the Philippines, with the exception of the Philippine Associated Smelting and Refining Corporation (PASAR) in Isabel, Leyte, the sole copper smelting plant in the country.

Commonly found surrounding these established large-scale mines, as well as in other highly-mineralized areas such as Mt. Diwata in Mindanao, are smaller mines operated by small-scale miners who mine gold using primitive methods such as panning, a method that uses gravity to separate the heavier gold from lighter rock, and amalgamation, a method wherein mercury is used to dissolve gold and then heated to leave the gold behind. There also are "small-scale" miners who operate small planta that use technologies similar to large-scale mines, such as cyanidation, but usually without monitoring by the appropriate government agencies. (Bugnosen, 2001)

### **Mine Operations and Methods**

1. **Large Scale Operations.** The large scale extraction of Gold and Copper is done either on the surface (open pit) or underground (stoping, caving, etc.). In the Philippines, 9 of the 44 currently operating metallic mines produce Gold and Copper<sup>143</sup>.

### **OPEN PIT/SURFACE MINING**

Open pit mining is a mechanical extraction method, where a relatively thick deposit is mined in benches or terraces, although thin deposits may require only a single bench or face. This method of mining is often used to exploit a near-surface deposit or one that has a low stripping ratio. It often requires a large capital investment but generally results in high productivity, low operating cost, and good safety conditions<sup>144</sup>.

There are currently 4 operating Copper-Gold open pit operations in the Philippines, namely: the Didipio Copper-Gold Project (Oceana Gold Philippines Inc.), the Toledo Copper Project (Carmen Copper Corporation), the Siana Gold Project (Greenstone Resources Corporation) and the Masbate Gold Project (Phil. Gold Processing & Refining Corporation). (Mines & Geosciences Bureau 2015)

### **UNDERGROUND MINING**

Underground mining is a wide array of various mining methods which are generally classified into 3 categories: Unsupported, Supported, and Caving. The method to be used is dependent on several factors, such as the position of the deposit, the characteristics of the country and host rocks, and the grade and tonnage of the ore. However, safety conditions are relatively poorer in underground mines, and also requiring additional auxiliary requirements, such as ventilation and climate control. The cost of mining is different from method to method, but is generally cheaper at the cost of lower production, compared to surface mining<sup>145</sup>.

There are currently 5 operating Copper-Gold underground mining operations in the Philippines, namely: the Victoria Gold Project (Lepanto Consolidated Mining Corporation), the Acupan Contract Mining Project (Benguet Corporation), the Co-O Gold Project (Philsaga Mining Corporation), the APEX Maco Operation (APEX Mining Company, Inc.), and the Padcal Copper-Gold Operation (Philex Mining Corporation). (Mines & Geosciences Bureau 2015)

### **MILL OPERATIONS**

For both surface and underground operations, the ore coming from mining operations (known as run-of-mine) is generally taken to the mill, where it will undergo mineral processing in order to produce the company's specified copper-gold product. It could be raw ore, bars or ingots.

In the mill, gold and copper initially have the same processing procedures but tend to diverge once it reaches the point where the metal has to be extracted. They both go comminution (crushing and grinding), sizing ("sieving"), as well as other preliminary steps such as gravity separation, and more.

All of these are done in order to get the ore to a size where it is most applicable and cost-effective to draw out the metals. For Copper, the metal is primarily floated to separate it from the gangue minerals. For gold, cyanide leaching is typically used to extract the metal.

- 2. Small Scale Operations.** Small-scale Mining or Artisanal mining refers to mining activities carried out by individuals, groups, families or cooperatives with minimal or no mechanization, often in the informal (sometimes illegal) sector of the market. However, there is still no clear line between large-scale and small-scale mining. The very definition of the term small-scale mining is still under debate worldwide<sup>146</sup>.

RA 7076, or the People's Small-Scale Mining Act, however, is the law that governs small-scale mining in the Philippines. It defined small-scale mining as: "mining activities which rely heavily on manual labor using simple implement and methods and do not use explosives or heavy mining equipment". Also encapsulated in this law is the creation of "Minahang Bayan" or "People's Small-Scale Mining Area", which are locations where small-scale mining can be done.

In the Philippines, small-scale gold mining accounted for 1 billion pesos of the 204.7 billion pesos of the gross production value in mining last 2014, based on the receipts of the Bangko Sentral ng Pilipinas. (Mines & Geosciences Bureau 2015) However, this is most likely only a fraction of the true production value in small-scale mining as most small-scale miners sell their gold in the so-called "black market" to avoid taxation.

## Nickel

### Occurrence of Nickel Deposits

Nickel comprises 0.01 – 0.02% of the Earth’s crust. Nickel ores are commonly associated with impurity metals such as iron, copper, cobalt, and chromium. There are two types of ore deposits, first are the sulfidic deposits, the primary mineral of which is pentlandite  $(Ni,Fe)_9S_8$ ; second are the lateritic deposits. The global production of nickel accounts 30% from sulfides deposit and 70% from lateritic deposits.

Nickel sulphide can be further classified as hydrothermal nickel sulphide or magmatic nickel sulphide. Hydrothermal nickel sulphide usually occur in silicified zones of serpentinite rocks. On the other hand, magmatic type of nickel sulphide deposit is closely associated with chromites and platinum group of elements. In the Philippines, sulphidic nickel deposits can be found in Central Palawan and some places in Zambales.

Nickel laterites are formed due to intensive weathering of olivine-rich ultramafic rocks. It can be subcategorized into two: limonite type or the oxide laterites and saprolite type or the silicate type. Nickeliferous limonite has the form  $(Ni,Fe)O(OH)$  and is observed to be red or yellow-orange in appearance. Saprolite on the other hand forms beneath the limonite zone and has a higher Ni content. See Figure 7 for the profile of a tropical laterite deposit. A vast limonite deposit can be found in New Caledonia, Indonesia and in the Philippines. Currently, the Philippines is the leading nickel producer in the world. Since 2008, we are continuously increasing the production of nickel. The Philippines is the primary supplier to China’s nickel pig iron industry. Figure 6 compares the nickel production of the top nickel producing countries from 2008 to 2014<sup>147</sup>.

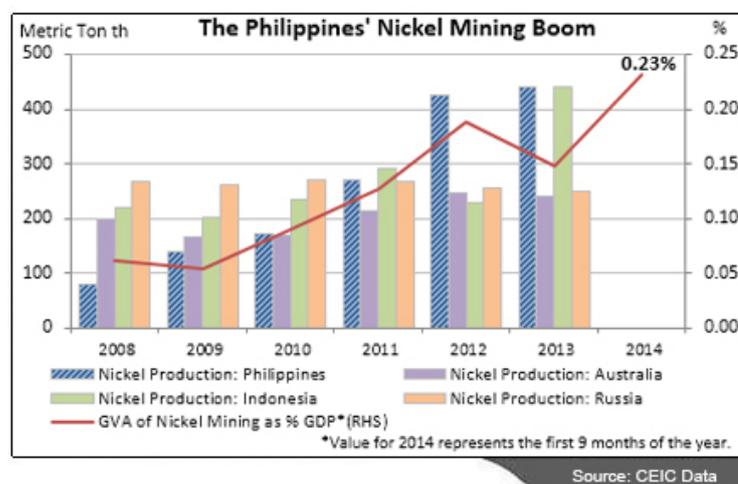


Figure 6. Nickel production from 2008 to 2013.

In the Philippines, nickel ores are located along the ophiolite or ultramafic rock belts. On the west, it stretches from Zambales to Mindoro Island, and on the Palawan Island. On the east, it stretches from Polillo Island all the way down to Davao Oriental. (see Figure 7)



Figure 7. Principal locations of the Nickel deposits in the Philippines.

Currently, there are 28 registered nickel mines in the Mines and Geosciences Bureau (MGB). Only 2 of which are with a processing plant using HPAL (high pressure acid leach) process. Of these 27 mines, 4 are located in Zambales, 3 in Palawan, 9 in Dinagat Island, 5 in Surigao del Norte, 4 in Surigao del Sur, 1 in Agusan del Norte and 1 in Agusan del Sur. (Mines & Geosciences Bureau 2015).

Lateritic nickel mining, since the ore is only a few meters from the top soil, is surface mined. This is when the perception of mining as an industry that damages the environment sets in. However, there is no lush vegetation on these areas. The primary problem of nickel mining is the siltation and dust. Also, problems with the Indigenous People (IP's) may also arise since some mining operations are within the IP's ancestral domains. These problems will be discussed further later.

## Mine Operations

There are currently 27 nickel mines presently operating in the Philippines. All of these are large-scale mines that fall under mineral production sharing agreement (MPSA) with the government. (Mines & Geosciences Bureau 2015).

Both lateritic and sulphidic type of nickel deposits occur in the Philippines. Extraction of the latter is usually done underground. However, since the stripping ratio of nickel deposits in the Philippines are generally low, it is more economical to extract nickel ores by surface (open-pit) mining. Indeed, all of the 27 nickel mines that are currently operating in the country use surface method of mining. Philippines is relatively abundant with nickel laterite. Indeed, the largest nickel producing companies mine lateritic nickel ores, namely: Taganito Mining Corporation and Rio Tuba Nickel Mining Corporation. Other nickel laterite companies are Marcventures Mining And Development, Pacific Nickel Philippines Inc., Adnama Mining Resources Incorporated. (Please check: Sentence fragment)

### **Mill Operations**

There are two nickel processing plants in the Philippines, namely: Coral Bay HPAL Project and Taganito HPAL Project. Both processing plants use high pressure acid leach and produce mixed nickel-cobalt sulphide as their final product.

Low-grade limonite ores from Rio Tuba Nickel Project and Taganito Nickel Project are utilized as feed for Coral Bay HPAL and Taganito HPAL plants, respectively. (Nickel Asia)



## **Pollution from Mine Operations**

Pollutants from a typical copper-gold mine comes from two sources: mine operations, and mill operations. Both have the capacity to contaminate the local soil, water and air, if left unchecked. In this part of the handbook we will be discussing how these contaminants are released into our environment.

As stated before, mine operations would entail the extraction of the ore mineral from the source rock, whether it is in an open pit, or in an underground mine. Doing this requires the breakage and transport of rock, through processes such as drilling, blasting, and hauling, to name a few.

It is important to note that most, if not all, of the contaminants from mine operations come from the rock that is being mined itself. This is especially true for copper-gold deposits in the Philippines as they are associated with a group of minerals called sulfides which have significant amounts, as the name suggests, of sulfur and its other forms, such as sulfuric acid and sulfhydric acid. Other contaminants that could come from the sulfidic rock strata are arsenic from arsenopyrites, zinc from sphalerites, lead from galenas, as well as other trace elements that might otherwise be present.

When the rock strata are disturbed, the aforementioned contaminants can be released, in forms such as acid mine drainage, mine waste, or contamination due to improper handling of ore. Water is the main medium by which these chemicals can contaminate the local environment. It could seep into the local water table, into the surrounding soil, or even flow into a nearby river. It is therefore of utmost importance for mining companies and small-scale miners to mitigate and control the various liquids that seep out from mining operations.

In addition to the contaminants from the rock strata, chemicals that are directly associated with mining equipment are also present in mine operations. These include the petroleum products used by heavy machinery, various chemicals released by blasting, and other substances from auxiliary operations.

Two other mode of pollution that could result from mine operations, but are not necessarily in the form of harmful chemicals, are dust pollution, siltation, and noise. This is more applicable to surface mining, as dust can directly be spread by the wind. Both are basically the introduction of very small rock particles into the air (dust) and the water (silt). They are produced from the breaking and transport of the rock. These particles can then be transported through the local area, causing harm to both the environment and the people living nearby.

## Empowered Communities

After comminution is a whole suite of processes that would draw out the copper and/or gold from the ore either from chemical attack or gravity settling, or both. The two main modes of acquiring valuable metal through the use of chemicals are cyanidation, and the use of mercury. The use of mercury in metal extraction is banned, meaning that the ones who are making use of this substance are mostly illegal small-scale miners.

Aside from cyanide and mercury, there are other possibly harmful chemicals that are used in mills, although they are present in small amounts relative to cyanide.

**Soil Pollution.** Aside from water and air pollution, it is also important to monitor the introduction of contaminants into nearby soil, otherwise known as soil pollution. One thing to note about soil pollution is that it is generally only indirectly caused by mine operations, requiring an adjacent-polluted medium such as air and water to contribute to the contamination.

Mining is a very dynamic factor that affects soil quality. Soil contamination due to mining related activities can either result from windblown dust or chemical spill or residue. Soil pH, salinity and metal content that are necessary in allowing vegetation may not be attained. Common indicators of soil quality include: aggregate stability, available water capacity, bulk density, infiltration, slaking, soil crack, and soil structure.

For example, in river systems, pollutants coming from a mine can potentially seep into soil that is found downstream and render it contaminated. Even worse is if the river serves as a source of irrigation for agricultural lands, soil pollution can render the local farms barren, or render their produce unsafe to consume.

**Water Pollution.** Water pollution in the mining sites primarily comes from the use of various chemicals to extract the precious metals and dissolution of minerals in the rock by water. Common phenomena in the mines leading to water pollution are acid mine drainage, heavy metal contamination, dissolution of processing chemicals, and erosion and sedimentation. Acid mine drainage happens when the sulfides in rocks are exposed in air. This exposure in air causes the sulfides to oxidize. Dissolution of this sulfides in water produces the sulfuric acid which will then be carried by rainwater to surrounding water bodies thus degrading the water quality. Heavy metal contamination, on the other hand, happens when ores containing arsenic, cobalt, cadmium, copper, lead, silver, and zinc are exposed to water. These metals will be dissolved in the water causing pollution.

Pollution due to processing chemicals are the most common in mines which does not conform to the water quality management. Leakage of chemicals used in the metal extraction can reach the bodies of water. Erosion and sedimentation is the disturbance of the soil and rock in the course of the mining process. When substantial amount of soil and rock particles being eroded settle in nearby water bodies, the sediments can clog rivers, destroy watershed vegetation and aquatic habitats.

For most operations, wastewater from both mine and mill operations are stored in leaching ponds or tanks protected by dams to prevent leakage. Because of this, majority of the possible environmental damage that mining could incur will be due to the failure of these storage facilities. Thus companies and small-scale miners alike should invest a significant amount in these storage facilities so as to avoid environmental disasters.

In nickel mining areas, the predominant problem that may arise is siltation. Siltation is caused by the increase of concentration of particulate matter, most of which are in the size range of silt or clay (0.002 mm). The increase in turbidity will affect the physical characteristics of the water body such as color, temperature and pH. It will also affect the dissolved oxygen in the water which will affect the living organism living in the body of water. Other pollutants which can affect the water quality are heavy metal content and oil and grease from machineries.



Figure 8. An islet off the coast of Claver, Surigao del Norte, once was bordered by white sand is now surrounded by orange silt. (<http://www.miils.org>)

**Air Pollution.** Air quality is one of the major environmental issues in areas near mining activities. The American Society for Testing and Materials defines dust as the general term for any solid particulate capable of being temporarily suspended in air or in other gasses. Disturbance of the earth, milling of the ores, and transport of the ores usually releases free dusts in the atmosphere contributing to the pollution.

Furthermore, machineries used during the operation also releases gaseous compounds. Contributing further to the pollution are the metal-extracting processes that releases gases such as carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), sulfur trioxide (SO<sub>3</sub>), nitrogen dioxide (NO<sub>2</sub>), nitrogen monoxide (NO) gaseous mercury, and cyanides. The said gases not only contribute to air pollution but water and soil pollution too as these gasses combine with rain water to form acid rain that will acidify bodies of water, and soil. Long term exposure to these pollutants can cause fatal respiratory diseases such as lung cancer, pneumoconiosis, silicosis, emphysema, progressive massive fibrosis, bronchitis, renal disease and others. Not only does pollution affect health of the mine workers and of the nearby community but it also distresses atmospheric visibility in the area, safety of mine workers and of the communities, efficiency of the mining operations, and aesthetics of the surrounding environment.

Uncontrolled mining activities produce large quantities of pollutants being released into the air. Blasting, drilling, and transport of ores in an open pit mine contributes primarily to suspended particulates in the immediate atmosphere and accounts to 15-20 % of the total emissions of the

mine. These particulates contain small particles of the minerals and may consist of silica, and minerals of heavy metals such lead, copper, and mercury which pose significant health effects<sup>148</sup>. Blasting of ores in underground mines, however, produces less suspended particulates because: (1) blasting occurs in a closed environment and fugitive dusts are contained underground; and (2) intercession of ground water binds the particulates keeping the dusts as a collective mixture of dust and water.

Milling of ores to further reduce their size and hasten metal extraction processes also releases particulates in the air. But unlike blasting in open pits, milling produces far less particulates as milling happens in a closed facility where escape of fugitive dusts should be regulated.

Transport of the ores through haul loads, and movement in conveyors may emit fugitive dusts up to 42% of the company's total fugitive dust emissions if not controlled. This figure however can be easily reduced to 5% by use of covers over the conveyors and water sprays to suppress escape of dusts in the hauls. Storage of the ores in silos contribute the least amount of fugitive dusts as these storage facilities are equipped with dust collectors.

In general, dust is formed when particulates become airborne with the action of wind turbulence, and mechanical disturbance. People who work in mines are generally exposed to pollutants that are emitted through air. Major contributors to air pollution that is associated to mining are:

Particulates can be in the form of solid and/or liquid droplets that are suspended in the air. The US EPA National ambient air quality standard diameter for particulate matter is less than 10 microns (MINEO Consortium 2000). Generally, particulates are released as fugitive dust and flue dust.

Significant amount of these fugitive particulates are produced during the operation phase of mining. This is very distinguishable in nickel mine since its material is generally loose. These materials contain small-size particles that can be easily transported by wind. It is during operations (blasting, excavation (loading and hauling), transportation, comminution and waste management operations) wherein small-size materials are more vulnerable to wind dispersion, that fugitive dusts are produced. On the other hand, flue dusts are the ones that are emitted from plant processes such smelting and roasting. Flue residues often have high metal concentrations. Through time, significant amount may settle and accumulate on the ground and may actually cause soil contamination.

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Processes such as combustion of fuel (in excavators, trucks, vehicles) and mineral processing are the ones that generate gas emissions. Nickel processing plants in the Philippines includes purification (zinc removal and sulfurization) of mixed sulphide which involves H<sub>2</sub>S gas. If not isolated properly, it may leak and cause serious health problem.

While large-scale mining companies deal with dusts and particulates, small-scale miners are exposed to a more serious and more toxic pollution of elemental mercury. The process of amalgamation called retorting uses mercury to dissolve small particles of gold in ores to form an amalgam. The amalgam is then heated to boil away the mercury leaving the gold in the reaction vessel. Since the mercury was boiled away, it escapes into the atmosphere as vapor at its most hazardous and toxic form. Mercury emission from this kind of activity is estimated to be 1000 tons of mercury per year which accounts to 30% of world's total mercury emissions attributed to human activities<sup>149</sup>.

Cyanide leaching is another method used by both large and small-scale miners to extract gold where metallic gold is dissolved in water with the aid of cyanide. However, the recovery of the dissolved gold also recovers the cyanide. The recovered cyanide then goes to the tailing ponds which makes the water toxic. Concerns about air pollution starts to rise when the water containing the cyanide becomes acidic and releases the cyanides as gaseous and highly toxic hydrogen cyanide (HCN).

*Mitigation and Prevention of Health Hazards.* Ventilation provides the best use of the clear and immediate air in the surroundings and is mainly used in closed facilities. This process reduces the dust concentration by diluting the dust and displacing it. However, this process deals only with the problems in the surface level. Additional problem arises as for the destination of the displaced dusts.

Water spray is the most practical way of dust suppression. Adequate wetting of the vast majority of the dusts ensures that the dusts stay attached to the surface of the broken material and are not released into the air. Consultation with the engineers should be made in order to design the most effective spray system for a specific case. Factors that need to be determined are methods of atomization, location of nozzles, controlling the droplet size, and method of water application. Water spray works best in the lines of blasting, drilling, and transport of the ores. Additives in the water sometimes are included to boost the dust suppression. Chemical additives such as calcium and zinc chloride are also used. These chlorides are very efficient in attracting water thus water remains within the proximity of the dusts. Surfactants, such sodium dodecyl sulfate, may also be added to improve

the wetting ability of the water, and to form foams that are more efficient in holding the particulates better.

Dust suppression in the storage facilities such as silos can be done by dust collectors. Dust collecting equipment is just a filtration system designed to capture dusts in the closed facility. These methods of dust suppression is applicable for use by mining companies and their workers. However, the immediate community who is far less capable of acquiring the resources to combat dust should be knowledgeable and well equipped.

Vegetative buffer zones, about 20-m wide, planted with tall, leafy leaves, can act as filter between the mining area and community. Also, communities are not allowed within at least a 500 m radius from open pits to protect them from imminent fly rocks.

Suffering from sudden spike of dust particulates in the area can be countered by covering the nose with a damp cloth. A gas mask with adsorbent cartridge available in local hardware is sufficient to filter out dust particulates and minimal gaseous compounds. For continued high concentrations of dust particulates however, it is advisable that evacuation is done.

**Noise Pollution.** The common definition of noise is any unwanted or disturbing sounds from the surroundings. Sounds become noise when they interfere in daily human activities. In the context of mining, the sounds caused by the machinery become noise when residents near the mining site are disturbed, distracted, or annoyed. Most of the time, these noises are too loud that residents complain of sleeplessness, and inability to hear normal conversations. Such phenomena can have a major consequence on one's overall health such as stress, hearing loss, and sleep disruption.

The level of noise intensity or loudness is measured via a noise dosimeter and is interpreted in terms of decibels (dB). Normal conversation typical hits the range of 60-70 dB while operating a grass mower can record 110 dB. In the Philippines, noise standards are set by the Department of Labor and Employment (DOLE)'s Occupational Health and Safety Administration standards to protect the workers. The US Occupational Safety and Health Administration suggests that noise levels lower than 90 dB are safe. Beyond 90 dB, only allowed prescribed number of hours of exposure is suggested.

Unlike other types of pollution mentioned above, noise pollution is conveniently measured by a dosimeter. The equipment can be bought for those who need heavy duty and long term monitoring

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of noise. Alternatively, applications can be downloaded and installed to smart phones. Noise detection however may not be that accurate due to quality of microphones that vary depending on the manufacturer. Calibration may help obtain accurate results but more or less, those applications can give a good estimate of noise.

## Important Points to Remember

- The Philippines is host to significant copper-gold and nickel deposits and several mining operations. These mining operations utilize various mining methods dependent on the mineral ore. The three most commonly used methods in the country are open-pit mining or surface mining, underground mining, and mill operations for processing.
- Pollution can arise from mining operations. The most common that are needed to be monitored are soil pollution, water pollution, air pollution, and noise pollution. The type/s of pollution that occurs in the immediate environment of the operation varies based on the method used and mineral being mined out.

### For Further Readings

- Mines and Geosciences Bureau Website: [www.mgb.gov.ph](http://www.mgb.gov.ph)
- Philippine Extractive Industries Transparency Initiative Country Reports  
Link to the website: [www.ph-eiti.org](http://www.ph-eiti.org)



# **Mining Monitoring**

## Chapter 5. Monitoring of Mining Operations

This chapter introduces readers to the procedures and necessary tools to undertake mining monitoring. Step on how to design a monitoring plan and its components are discussed in subsequent subsections of this chapter. By the end of this chapter, readers will have a better idea of how to organize and design a mining monitoring plan. The monitoring plan in this chapter is not to be confused with the Water Monitoring Plan discussed in previous chapters.

### Learning Objectives of this Chapter

- Learn how to design a monitoring plan including what it should include and what variables are to be accounted for in implementing one
- Learn about practical tips in setting frequency of sampling, identifying sampling sites, and planning for the actual monitoring

Parts of this Chapter:

- The Monitoring Plan
  - The Scientific Method
  - Variables to be considered per for each type of pollution
- Setting Frequency of Monitoring
- Identifying Sampling Sites
- Planning for Sampling Event

### **The Monitoring Plan**

To ensure that the monitoring is specific, targeted and cost effective, a monitoring plan should be developed. A monitoring plan is the document that details the actions, responsibilities and timeframes that will meet the monitoring objectives. It is a plan that describes the processes and activities that will be undertaken in order to achieve a successful monitoring. It is a critical document to prepare all involved parties well and to avoid wasting human and financial resources.

Evaluating soil and water quality for Environmental Impact Assessment is more than the execution of daily monitoring, sampling, and quantitative analyses of samples. The entire process involves careful planning and strategizing the proper procedure, selecting the appropriate methodologies and equipment, as well as interpretation of data to ensure the efficiency and effectivity of the monitoring scheme.

The scientific method is a step-by-step procedure that entails a multi-factorial approach to a particular problem. It is a systematic approach that starts with identifying a problem, down to experimentation and drawing conclusions. The scientific method will employ throughout this manual and shall consist of the following steps:

1. Identifying the Problems – the first step to any problem is to first identify what you are dealing with. In the context of mine-impacted communities, the right questions must be asked. Identifying which processes cause which effects is the key to understanding a phenomenon and eventually will lead to formulating the right methodology and solution.

Relevant questions such as, “What are the visible changes in the area?” “Did people start getting sick after some time of drinking water or consuming aquatic animals?” are among the few questions that may give an idea about what exactly we are dealing with.

2. Background Research and Formulating a Hypothesis – once the problem is identified, a hypothesis or a scientific guess may be drawn, such as listing down possible suspect processes that may be causing a problem. For example, in a stream affected by acid mine drainage (AMD), one hypothesis that can be made is that waste rocks that bear sulfides are possibly being discarded in streams where they react with water and produce Sulfuric acid. It also helps to do a research about similar problems that may have occurred in other areas to minimize the hypotheses that need to be proven.

3. Setting the Objectives – the next question to ask would be, “What exactly are we trying to prove or look for?” Set the scope and limitations of the monitoring activity – remember, you can’t cover everything all at once. Identify only the important things.
4. Selection of an Appropriate Methodology - Find out if there are other areas that have experienced or encountered same, or if not, similar problems. Study their approach and modify, if needed, based on the context of your own experience. Do not be limited to one methodology – sometimes, a hybrid of different methodologies is necessary to address the problem. The appropriate methodology also encompasses planning the areas covered and frequency of monitoring, which parameters need to be measured, and the instrumentation needed.
5. Execution of the Chosen Methodology – the actual conduct of monitoring which is heavily reliant on how the plans are made. During execution, equipment and sample care is primary as this will ensure credible results of the monitoring.
6. Data Acquisition and Results Interpretation – Record all data in a monitoring sheet or Excel file for future analysis. Be keen and observant with any unusual changes or fluctuations in trends of data taken as these may imply significant findings. If unusual changes in data patterns are observed, read about possible explanations or better yet, seek the help of an expert for interpretations.
7. Communicating Results – After results from monitoring have been acquired and interpreted, the next thing to do is to make sure the data reach the right audience. Inclusivity is an important matter to be considered. Discuss the findings with all stake holders, from the communities affected to the mine operators and the government units concerned. Remember as well, sure that you get your findings across the audience in a way it would be understood. Laymanize terms if needed, but never compromise the interpretation
8. Formulating Solutions - Formulating solutions should be a multi-sectoral and multi-faceted approach, where all stake holders are involved. The solution may be another monitoring phase, or may proceed directly to remediation and rehabilitation of mine-impacted areas.

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Before a monitoring plan is drafted, it is advisable to conduct a preliminary survey of the area of interest. A preliminary survey will allow the monitoring team to identify prospective sampling sites and appropriate sampling methods according to the test/s to be conducted. The survey may also show other activities happening in the area that could also be affecting the environment, aside from the main mining operations. For example, a survey of the tributaries that convey water to the water body of interest could show other sources of water contaminants. Also, preliminary data is needed to provide the baseline for succeeding sample collections

Table 28. Variables to be considered for each type of pollution in the preliminary survey.

|               | Water  | Air  | Noise   |
|---------------|--|--|---|
| Sampling site | <p>Map of the area and lay out of the mine</p> <p>Accessibility of the site</p> <p>Possible areas affected by the pollution</p> <p>Entry of water and discharge points of effluent water</p> <p>Identification of bodies of water where wastewater is discharged and its general flow pattern to identify upstream and downstream points</p> <p>Weather patterns in the site</p> | <p>Map of the area and lay out of the mine</p> <p>Accessibility of the site</p> <p>Possible areas affected by the pollution</p> <p>Current and previous locations of airsheds which can be used as sampling sites</p> <p>Weather patterns and wind direction in the site</p> | <p>Map of the area and lay out of the mine</p> <p>Accessibility of the site</p> <p>Possible areas affected by the pollution</p> |

|   |   |   |  |
|---|---|---|--|
| Relevant activities and nuisance in the site      | Other small-scale mining, industrial, agricultural, or construction operations in the area. | Other mining, industrial, agricultural, or construction operations in the area. Natural obstructions or man-made facilities that affect air fluidity and dust dispersion. | Other mining, industrial, agricultural, or construction operations in the area. Presence of noise-cancelling devices or obstructions |
| Existing pollution levels and on-going monitoring | Mine's wastewater treatment strategy<br>History of pollution and data                       | History of pollution and data<br>Location of previous and existing airsheds   | History of pollution and data  |
| Sampling time                                     | Time, duration, interval, frequency and averaging of the data collected                     | Time, duration, interval, frequency and averaging of the data collected   | Time, duration, interval, frequency and averaging of the data collected  |

Once this information has been gathered through the preliminary survey, the monitoring plan can be drafted.

Generally, the plan should reflect the following:

- The framework of activities such as the anticipated relationships between the activities, outputs, outcomes, concerned personnel and many others.
- Expected measures, definitions, history of data, and baseline data and their corresponding sources.
- Monitoring schedule and timeline.
- Cost estimates for the monitoring and evaluation activities.
- List of possible partnerships and cooperation that can help execute the process.
- Communication plan on how to disseminate the results.
- Ethical considerations when implementing the monitoring framework.

## Empowered Communities

The elements of a monitoring plan should include the following:

1. Duration of sampling
2. Sampling points
3. Frequency and patterns of sampling
4. Method of sampling
5. Responsible person

Take note, that while the scientific method is a step-by-step process, repetition of some steps might be necessary especially when the original experimental design does not affirm the initial hypotheses, or if new objectives are set from obtaining results.

The sampling procedure should also provide baseline data (e.g. water quality of upstream areas or quality prior to mining activities) for which the monitoring data will be compared to. Gather samples/perform on-site testing at mixing zones (i.e. the point where mine water joins the main water body). An alternative to this would be to use past baseline studies from either the mining company or an independent source. It is important to measure the difference between baseline and actual monitoring data. Also, it is important to consider the safety of a sampler, by choosing a location that's safely accessible.

### **Frequency of Monitoring**

The frequency of monitoring refers to when data will be collected and how often this will be done. The frequency depends on how critical the parameter is, and how variable it is. The season should also be taken into account, such as rainfall and wind intensity and directions. Highly variable parameters need to be monitored more frequently.

### **Sampling Sites**

Sampling sites refer to the locations where the data is gathered. Sites should be chosen wisely so the data collected from them are considered a representative of the whole population. For air pollution, the sampling site is called airsheds and are identified by their similarity in climate, weather, meteorology, and topology. All these four factors affect the interchange or diffusion of pollutants in the atmosphere. Alternatively, a set of airsheds can also be identified from areas that share common interests or face similar development vision, challenges, and problems. Further, the number of airsheds can be increased or decreased depending on the need for additional data. Sometimes, the airsheds and number of airsheds, and its services can get very big. In such case, a governing board is created to effectively manage the airsheds and ensure its operations.

Sampling sites for water pollution is practically the same to that of airsheds. Samples need to be taken in at least three points – upstream, downstream and at the point where the effluent discharges to the water body (or the mixing zone).

Noise, on the other hand, differs largely from that of air and water since noise is greatly affected by the physical obstructions. Common locations for noise monitoring are indoors, and outdoors where human dwellings are mostly found, and taken at a height of adults.

### **Box 6. Planning for Sampling Event**

A sampling event involves observations, collection, field testing and measurements of elements which are being monitored. The basic steps for planning a sampling event are as follows:

- Review the monitoring plan, including sampling sites, number of samples to be collected, and sampling methods to be used. Remember that the most important aspect of sampling to ensure that the sample collected is considered as a representative of the whole population
- Obtain appropriate type and size of sample containers
- Schedule the monitoring event, including the transport of the samples back to the laboratory. The aim is to have all samples preserved and delivered to the laboratory as quickly as possible.
- Check all equipment to be used, test if operational and calibrated.
- Fill out as much paperwork as practical before sampling such as preparation of labels

## **Important Points to Remember**

- Mining Monitoring needs to be well-planned for it to be specific, targeted, and cost-effective. This helps prepare involved parties and avoid wasting human and financial resources.
- The scientific method is a systematic approach that starts with identifying a problem, down to experimentation and drawing conclusions and entails a multi-factorial approach to a particular problem.



## Chapter 6. Field Monitoring

This chapter will introduce readers to sample collection and field testing procedures to be considered in order to carry an organized field monitoring. This will include protocols on sample identification and storage,

### Learning Objectives of this Chapter

- Learn about sampling protocols and sampling storage and understand what to expect in during actual field monitoring
- Learn to conduct water, air, and soil quality monitoring activity from collecting samples to reporting findings

- Sample Collection and Field Testing Procedures
- Sample Identification and Storage
- Water Quality Monitoring
  - Collection of Water Samples
  - Field Testing
  - Recording of Field Observations and Results
  - Pretreatment of Samples
  - Reporting
  - Parameters Measured
  - Instrumentation
- How to conduct air quality monitoring?
- How to conduct soil quality monitoring?

## Field Testing Procedures

### 1. Field Observations

During sampling, observations of field conditions that could assist in the interpretation of monitoring data are to be recorded. This can provide useful information about the sample which can help identify the source of the pollutants. Example is that a recent rain on the area could have increased the solids content of the water. Activities in the vicinity should be taken note of. For example, an industrial activity nearby may be the cause of abnormalities from the baseline data.

### 2. Field Measurements

There are analytes that degrade easily right after being sampled, so it is important for them to be tested in the field. Examples of which are pH, temperature, conductivity, dissolved oxygen and conductivity. Measuring meters for these parameters should be calibrated before use. Calibration of all meters should be routinely recorded on a recording sheet which includes the date of calibration, calibration reading and the person who calibrated the meter.

### 3. Sample collection

As stated earlier, samples need to be the representative of the body of water from which they were taken. If the integrity of the sample is compromised, the information gathered from the analysis could be misleading. Listed below are activities that affect the integrity of the sample.

- Contamination. Contamination occurs when a foreign substance is introduced to the sample. This will cause the sample to have characteristics that are not found in situ. This can occur from sample gathering all the way to the final analysis.
- Physical changes. Changes in the physical characteristic of the sample may affect its integrity. Examples of which are:
  - Temperature. Especially for water samples, water temperature varies all year round. A change in temperature can alter the chemical properties of a wide range of many parameters.
  - Volatilization. It is the loss of dissolved compounds by evaporation. It is controlled by the vapor pressure of the solute or solvent. Most susceptible to volatilization are volatile organic compounds (VOC) such as chlorinated hydrocarbons.
  - Sorption. It is the attraction of dissolved compounds to the surface of solids particles, sampling equipment and containers. This may cause in the alteration of the measured concentrations of dissolved ions, heavy metal content and organic compounds.

- Chemical changes
  - Precipitation. It is the formation of solids by the reaction of dissolved compounds. It can cause changes in the temperature, pH, chemical concentration and the presence of seed particles for further processes. For example, during transport, a water sample loses carbon dioxide, resulting in a change in pH causing precipitation of metals such as iron.
  - Oxidation. It is the introduction of oxygen into the sample, which increases dissolved oxygen content and changes in pH. This can lead to a decrease in the concentration of calcium and magnesium ions, and heavy metals.
- Biological processes. Biological activity in a sample may affect both its physical and chemical characteristics. Parameters such as nitrite and nitrate can be affected by bacterial activity, i.e. denitrification. Biological activity may change the amount of dissolved oxygen, the pH and/or redox. Factors influencing the biological activity of a sample may in turn be influenced by temperature, available oxygen, pH and exposure to UV light.

The collection, equipment and preservation methods used for sampling should be chosen to minimize the impacts of the above-mentioned factors. To minimize and to quantify the impact of these processes on sample integrity, quality control protocols and procedures must be developed and implemented at all stages of monitoring. Other considerations for sampling include:

- Organics have a tendency to adsorb to plastic (including polyethylene, polypropylene and polycarbonate). Therefore, sampling equipment such as buckets and sampling rods should be made of stainless steel. Glass sample containers are preferred.
- When sampling for metal analytes the use of metal equipment, and some glasses such as soda glass should be avoided. Rubber can also cause contamination when sampling for trace concentrations. Plastic equipment should be used when possible when analyzing for metals.
- When sampling for analytes that are the major constituents of glass (eg sodium, potassium, boron and silicon), glass equipment and containers should be avoided.

## Sample Identification and Storage Protocols

1. **Labelling and identification.** Samples should be properly labelled at all times. Without this, all samples may look alike. Labels must specify a clear and unique code that can be cross-referenced to the monitoring location and time of sampling on the sampling recode sheet. Labels should contain important information such as:

- Date and time of sampling
- Location and name of sampling site
- Name of sampler
- Container pretreatment and preservations added
- Other pertinent observations that may affect the method or result of the analysis

1. **Transport.** During transport, it is important to ensure that the samples are not significantly altered in condition that could compromise the results. The key aspect for effective transport are:

- Ensure samples are appropriately packed to avoid breakage and cross-contamination
- Reduce sample degradation through appropriate preservation
- Ensure time between sampling and analyzing does not exceed holding time
- Sample containers should be sealed, carefully packed with an appropriate packing material, chilled or frozen (as required) and transported in an appropriate cooler (esky) or fridge. It is sometimes necessary to take further action to prevent cross contamination, either between samples or from ice, during transport. This could include placing sample containers in snap-lock bags or airtight, plastic tubes with screw caps before transport.

1. **Storage.** Storage and preservation are important to minimize any changes as discussed earlier of the sample. Some preservation techniques used are:

- Refrigeration  
Keeping samples between 1 and 4 deg. Celsius will preserve the majority of physical, chemical and biological characteristics in the short term (less than 24 hours), enough time for the transport of the samples from the field to the laboratory. If employed in sample transport, ice bricks are preferred over loose ice/
- Freezing  
Done at temperatures less than -20 deg. Celsius and generally employed if samples cannot be transported to the laboratory within 24 hours.
- Chemical addition

### **Data Analysis**

This is discussed in full in the Chapter for Monitoring Data Interpretation.

### **Reporting**

Simple statistical methods should be applied such as replication of samples, determination of mean, and standard deviation. This is to ensure the soundness of the data and also to check for any outliers. Also, presentation of data is recommended to be in figures and tables, this is easier and simpler to understand. The results will then be compared to the baseline data and to the standards of Department of Environmental Resources (DENR) namely the Philippine Clean Air Act and Water Quality Guidelines and General Effluent Standards of 2016.

### **Record Keeping**

Good planning and record keeping is imperative. The sampling plan, or concise sampling schedule and map should provide all the required information such as location of monitoring points, the number and type of samples that need to be collected and container types. Records of observations and actions can be critical for future reference. A camera is also recommended to be brought during monitoring because it can show where the sample was taken and illustrate observations recorded on the field data sheet. The weather conditions need to be noted also.

### **Occupational health, safety and welfare**

There are many hazards to be aware of when working in any field environment. It is advisable that a safety plan should be developed to address risks and may include such things as:

- Risk assessment and hazard identification and control measures
- Actions to be undertaken to remove, reduce or control risk
- Emergency procedures to be performed if such hazard occurs
- Information on the location of the nearest medical facility

## How to conduct water quality monitoring?

### Collection of Water Samples

Water samples are collected in such a way that the container excludes air bubbles. This is done by immersing the container in the water body and putting the cap on underwater.

Good containers are amber glasses of sufficient size to accommodate the needed sample volume. Plastic containers may also be used. In both cases, the container must be thoroughly washed first with detergent and washed finally by 5% nitric acid ( $\text{HNO}_3$ ), and then dried. In case amber containers are not available, transparent or translucent containers may also be used with provision of aluminum foil wrapping to exclude light and consequently photocatalytic reactions.

In case that the sample needs a significant time for transfer, it is best to store the samples in a dark and cooled container around  $5^\circ\text{C}$  in temperature. The cool temperature inhibits the action of bacteria that can alter the contents of the sample.

Labels should be attached on the containers and should contain the following information: sampling point location, time of sampling, and a sample ID. If a GPS is available, it is recommended to take note of the specific location. Ensure that the labels are wet-proof and will not be detached from the container.

### Field Testing

Some measurements on mine water should represent, as closely as possible, the properties of the water body at the time of sampling. This may be because the properties to be measured might change during transport, or it may be because measuring those properties onsite would be much easier as compared with measuring them in the laboratory.

Field notes should be taken while the monitoring team is present in the area. The details that can be taken note of are the clarity and color of the river, weather at the time of testing, natural disasters, as well as other interesting or notable observations. As a general rule, it is better to write more field notes than none at all.

Data forms should serve as a guide to the acquisition of field data. It is therefore recommended to measure what you can on the field, rather than relying solely on laboratory analysis. The monitoring personnel may wish to re-sample if he/she thinks there has been an error in the

procedure. The data forms used should also note the chain-of-custody of the samples collected and the data gathered from field tests to ensure that the data are not tampered with.

### **Recording of Field Observations and Results**

All data gathered from a field work or analysis must always be written in a laboratory notebook that will also serve as the logbook. This is a durable notebook that is specifically designated for the data acquired for each test. There is no single way of arranging a laboratory notebook but most of the time, the following data must be present but additional information may also be added:

- Date and time of activity
- Persons involved in the activity
- Objectives of the activity
- Observations
- Data gathered

It is important that the data must be written using oil-based ink to protect it from possible erasure by water splashes from the field or lab faucet. Erasures are not avoidable and must be corrected by running a single strikethrough on the erroneous data, countersigning just above it, and then writing the new data just after the strikethrough. This serves a good monitoring of errors and way of tracing it back when viewed by another person not involved in the activity.

### **Pretreatment of Samples**

In cases wherein on-site testing is impossible or impractical, there is no other option but to conduct laboratory analysis of samples taken from the site. However, the requirement to preserve the original condition of any sample taken from the water body to be tested remains. Thus, it is of utmost importance to properly treat the samples and deliver them directly to the laboratory so as to prevent contamination and in turn, avoid faulty data.

The first thing to consider here is the sampling methodology: the way the samples are obtained from the source. For example, heavy metals, cyanide, and suspended solids are directly obtained from the identified sources. Samples for BOD and COD are obtained and from the source with minimal inclusion of air cavities, and disturbance of air-water interface. Such technique is performed by slowly immersing the narrow-mouthed sample bottle in to the source. The immersion should be slow enough to allow laminar flow of the water to the container and at the same time avoid bubbling to disturbance of the air-water interface layer which promotes further dissolution of

## Empowered Communities

oxygen in the sample. Samples for oil and grease analysis are to be collected at the specified depth of the water which depends on the type of oil or grease to be analyzed.

Sampling time and duration must also be considered. Air and water pollutants are generally high in concentration during and may persist for extended period of time. Noise pollution on the other hand is evident only during operation hours but limited noise can also be observed due to operation of maintaining equipment and facilities.

In every analysis, the true value of the pollution is best approximated by employing multiple trials. A trial is defined to be the repetition of the process starting from the sampling down to actual measurement. A replicate is the measurement of the values sought and is done on the same sample. A replicate differs from a trial in a sense that a replicate eliminates some sources of indeterminate errors incurred in the trial due to sampling.

Generally, samples should be stored in a cold, dry place (e.g. an ice box) upon transport to the laboratory so as to minimize biological and chemical activity of the sample. The samples should be contained in the appropriate container. The type of container to be used depends on which test the sample will be used. Ideally, the containers should provide the following:

- cool temperature and sterile environment to inhibit biological activities
- dark or low lighting conditions to avoid photocatalytic reactions
- chemically clean environment to avoid contamination and indeterminate chemical reactions
- airtight seal to prevent atmospheric oxidation of chemical species, inhibit biological activities, or prevent the escape of moisture from the sample.

Such provisions for samples containers can be achieved through various processes. Sterilization can be done by autoclave apparatus or can be manually done by antiseptic treatment by chemicals, UV irradiation, or simple boiling water treatment. The choice of method depends on the type of container and preference of the analyst. For example, antiseptic chemical treatment works fast but may bring chemical contamination due to generally high adsorption capacity of organic polymers. On the other hand, UV irradiation may damage plastic containers. Boiling water may break glass containers or melt plastics unless rendered heat-resistant. Dark conditions can be achieved using amber bottles or wrapping the containers with aluminum foil. Chemical decontamination is commonly applied on plastic containers and is achieved by washing the container with dilute nitric acid followed by distilled water. Air-tight environment are commonly used in water analyses specifically in dissolved oxygen analyses. A common screw cap is usually

airtight. Air is excluded from the container by partially overflowing the container with sample water and then capping or capping the filled container under the sample water.

Samples should always be labeled. Not labeling the samples may cause confusion, erroneous data, and at worst sample switching. Each sample label should show (1) the site where the sample was taken, (2) the date and time of collection, (3) sample type, and (4) preservation technique done and preservatives added to the sample. Other comments pertinent to the sample can be written in a separate form or log book.

Procedures for pre-treatment and transport of samples differ for every monitoring method. Please refer to the specific monitoring method on the proper treatment of samples for transport.

Sometimes, origin? of the sample gives an issue of alteration. Such cases can be resolved by making a document for chain of custody (COC). The COC documents the transfer of the sample and shows the name of the persons or institutions that handled the sample. It also shows the date and duration the people or institutions had custody of the sample. This very useful to track the movement of the samples.

Experimental procedures that cannot be done on the field will be performed in an off-site laboratory setting. Factors contributing to this would be time, equipment and personnel constraints, and possibility of contamination in the field, amongst others. As mentioned in the preparation of a monitoring plan, it is therefore advisable to prepare the laboratory before or during sample collection for convenience and seamless transition.

### **Reporting**

To ensure the validity of data gathered from each test, it is strongly suggested to conduct at least three trials per pollutant measured. The measurements gathered should then be averaged to get a final value. As an aside, the use of spreadsheet software is highly recommended in this step of the process for quick, accurate, and convenient production of data. Data forms will serve as guides in baseline statistical analysis. Further statistical analysis such as analysis of variance (ANOVA), among other statistical methods, can also be done and can be outsourced to those who know how to perform them. However, for the purposes of this monitoring handbook, simple averaging of data can suffice.

The final values for each test should then be tabulated beside the date and time of sampling to see the behavior of that specific value over time. For a more visual approach, these values can be graphed in a Parameter vs. Time graph.

Once the final values have been measured and tabulated, these can then be counter-checked with the maximum values provided by Philippine laws to see whether the pollution levels in the area exceed regulation values. A table showing the maximum values per pollutant is shown in Chapter 7 for easier viewing. Further guides as to how the final values can be interpreted are included in the chapters for specific monitoring methods. Most standards listed here are adapted from Administrative Orders issued by DENR namely the Philippine Clean Air Act and Water Quality Guidelines and General Effluent Standards of 2016. For noise standards, the Department of Labor and Employment standards can be used.

### **Parameters Measured**

In identifying the necessary parameters to be measured in waters impacted by mine-related activities, the Department of Environment and Natural Resources (DENR) has issued the Department Administrative Order (DAO) 2016-08, also known as the Water Quality Guidelines and General Effluent Standards of 2016. The said DAO is in accordance with Sections 19e and 19f of the Republic Act 9275, otherwise known as the Philippine Clean Water Act of 2004. The DAO was crafted with the main objectives of classifying waters, setting the standards for water quality, and identifying specific parameters needed for water quality monitoring based on the industry/ies that affect certain bodies of water.

Apart from DAO 2016-08, this manual also adopts parameters identified by the US Geological Survey (USGS), US Environmental Protection Agency (US EPA), Canadian Council of Ministers of the Environment (CCME), and the Victoria EPA (Australia) that are important to be monitored in mine-impacted areas.

For mining of metals and precious metals, the following parameters are listed on Section 7.1 of DAO 2016-08, USGS, US EPA, and AU EPA: pH, Temperature, Total Dissolved Solids, Total Suspended Solids, Turbidity, Salinity, Conductivity, Dissolved Oxygen, and Oxidation-Reduction Potential, and Selected Metals, Heavy Metals, and Anions (Phosphates, Nitrates, Sulfates, and Cyanides).

**Box 7. List of Water Quality Parameters Commonly Measured**

- **pH** refers to the acidity of the water, or its capacity to donate a proton (H<sup>+</sup>) ion. In copper/gold mines, the pH of water is usually low (acidic) due to the presence of sulfide minerals that react with surface and groundwater, hence leading in the formation of sulfuric acid.
- **Temperature** is the measure of amount of increase or decrease of heat in the water. It is measured in Degrees Centigrade (°C)
- **Total Dissolved Solids and Total Suspended Solids** refer to the amount of solid-phase materials/elements present in the water. The word “dissolved” refers to small amounts of salts and organic matter present in solution with the water, while “suspended” refers to solids that can be filtered using a 0.45mm filtration system. Often, TSS is correlated to the amount of siltation in water systems. The sum of TSS and TDS is called Total Solids (TS)
- **Turbidity** refers to the amount of light that can pass through the water. It is measured in nephelometric turbidity unit (ntu), which is a qualitative measure of how much light can penetrate in the water. Generally, waters that have high TSS and TDS also have high Turbidity readings; however, turbidity may vary across waters with different colors.
- **Salinity** refers to the amount of total dissolved salt compounds in water, specifically metal-chloride compounds as MgCl<sub>2</sub>, NaCl, CaCl<sub>2</sub>, KCl etc.
- **Conductivity** is the measure of a material’s capacity to allow current flow. It is directly proportional to the water’s salinity and amount of total dissolved solids. Highly conductive waters usually imply presence either of dissolved salts or dissolved metals.
- **Dissolved Oxygen** refers to the amount of oxygen gas (O<sub>2</sub>) present in the water, and usually indicative of a water’s taste and amount of bacterial activity. Stream waters typically have higher DO content than groundwater and other forms of stagnant waters. DO in mine-impacted streams are comparably lower than those unaffected by any activities.
- **Oxidation-Reduction Potential (ORP)** is the capability of water to either release or accept electrons during a reaction. A solution with a high positive ORP means it has a greater ability to oxidize a solution than a negative ORP. Usually, a negative ORP indicates a reductive solution, one with higher amount of metals or sulfides.
- **Metals and Heavy Metals** are elements characterized by their lustrous appearance, ductility and malleability, positive ionic charge, and ability to conduct electricity. The terms “metals” and “heavy metals” are used based on the crustal abundance (abundance on the Earth’s surface) and density of these elements. Both of these are important resources that are

explored and exploited; however, high concentrations of these materials in soil and water pose adverse effects both in human health and the environment.

Metals are more abundant on the Earth's surface and are characteristically less dense than heavy metals. These include Iron (Fe), Nickel (Ni), Magnesium (Mg), Calcium (Ca), Sodium (Na), Potassium (K), Aluminum (Al). Heavy metals on the other hand, are lesser common and usually occur as traces on the Earth's surface. They are characteristically denser, and small increases in the amount of heavy metals usually cause toxicity for living organisms. Heavy metals include Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Lead (Pb), Thallium (Tl), Platinum (Pt), Palladium (Pd), Zinc (Zn) and Copper (Cu)

- **Anions** are negatively-charged particles or compounds and are non-metallic. In mine-impacted areas, the most common anions analyzed in the laboratory are Sulfates, Nitrates, Phosphates, and Cyanides.
- **Sulfates** are compounds consisting of the elements Sulfur and Oxygen, and are naturally-occurring in rocks and sulfide minerals. Reaction of sulfate with water yields Sulfuric acid, a common pollutant in stream waters.
- **Nitrates** are compounds that consist of the elements Nitrogen and Oxygen. They are commonly a by-product of biological decomposition and indicative of high amounts of organic waste in water. Although often chemically unreactive, they are usually associated with bacterial activity in water, which converts nitrates into ammonia.
- **Phosphates** are compounds made up of phosphorus and oxygen, which, like nitrates, are common by-product of biological decomposition and soil degradation. Increased amounts of phosphates and nitrates in water promote bacterial activity, and causes deoxygenation.
- **Cyanides** are a group of compounds primarily composed of Carbon and Nitrogen +/- Sodium, Sulfur that are used mainly for extracting gold. Cyanide poisoning has been linked to cardiac and neural disorders, if not sudden casualty.

### Instrumentation

Analysis of chemical parameters involves the use of traditional methods such as manual and analytical chemistry methods, but recent technologies and instrumentation for water quality monitoring allow faster, more efficient, and comparatively more accurate results than traditional methods. The development of portable instruments and spectrophotometers in particular, has significantly made water quality analyses easier by reducing the need for transportation of many samples and expediting analyses in laboratories.

Some of the chemical properties of water may be measured in-situ (on-site) and is more preferred because of the rapid and accurate execution and results that can be gathered. Analyses of metals and anions, however, require stricter sampling protocols and preservation, and analyses should be done in the laboratory by licensed chemists or authorize personnel.

Portable multimeters are hand-held instruments that could measure more than one parameter simultaneously. Spectrophotometers or Spectrometers are laboratory instruments that uses various forms of light and reagents for analyses of metals and anions. Several types and brands of multimeters and spectrometers exist in the market and offer different types of parameters measured, detection limit, and accuracy. In choosing the right instruments, determining the purpose and which parameters are primarily important, while a fair consideration should also be made for the detection limit, accuracy, and instrument price.



Figure 9. Instruments for In-situ Analyses. Hach © Portable TSS Meter for Turbidity, TSS, and Sludge Blanket (Top left); Hach © HQ40D Multimeter for pH, mV, temperature, Conductivity, TDS, salinity, resistivity, dissolved oxygen, ORP (bottom left); and the Hach © Pocket Pro Plus for pH, Conductivity, Salinity, TDS, and Temperature.

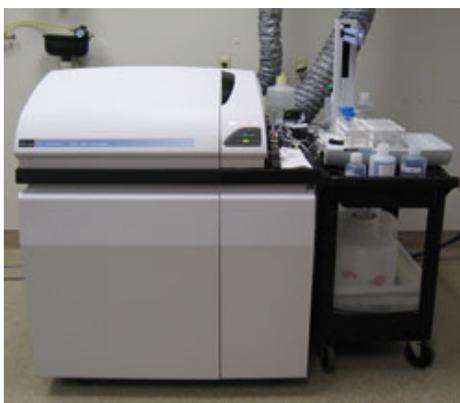


Figure 10: The Inductively Coupled Plasma – Mass Spectrometer, a high-precision spectrometer that can detect concentrations of certain substances up to parts per trillionth (ppt) or 1/1,000,000,000,000 of a substance.

## How to conduct air quality monitoring?

Common parameters to quantitatively describe the extent of air pollution are the **Total Suspended Particulates (TSP) and PM<sub>10</sub>**. TSP is defined as the total mass of particulates dispersed in a specific volume of air while PM<sub>10</sub> is defined as the amount of particulates with diameter of at most 10 µm. The Department of Energy and Natural Resources (DENR) assigned a daily average of 230 µg/m<sup>3</sup> for TSP and daily average of 150 µg/m<sup>3</sup> for PM<sub>10</sub> for an ambient air. These values serve as standard references for a clean air. Any values higher may pose respiratory diseases. Particulates with diameter less than 2.5 µm, hence PM<sub>2.5</sub>, are also monitored under DAO 2013-13 and must be lower than 50 µg/m<sup>3</sup> on daily average or 25 µg/m<sup>3</sup> on annual average

Ambient monitoring is necessary to evaluate the compliance of mining companies with the said standards. Additional parameters such as Volatile Organic Compounds (VOCs), carbon monoxide, nitrous oxides (NO<sub>x</sub>), sulfur oxides (SO<sub>x</sub>), lead and others may be required depending on the specificity of their operation.

Monitoring TSP and PM<sub>10</sub> can be done with the use of commercially available dust meters. These dust meters are sensitive to airborne dust particles, fumes, mists, and aerosols and can detect particulate sizes from 0-10 µm. Depending on the sensitivity, and mode of detection, brand, and model, prices range from Php 1,500 to Php 100,000. Most models rely on the detection of laser beam after it passes through or scattered by the particulates. Ambient air is drawn in the sampling air inlet of the equipment which is void of any stray light. The air then passes through a low power laser beam. Opposite the laser beam lies a photodiode that detects the intensity of light that managed to pass despite the interference of particulate matters. The photodiode produces an electrical signal which is then related to the amount of particulates present. (Sensidyne 1996) Generally, higher intensity of light detected translates to lower particulates present. Such equipment can be easily made with the help of local experts and even students of instrumentation physics, and electronics engineering. Determination of PM<sub>10</sub> is also done using the same dust meter. Short time exposure to dust particulates may trigger irritation and allergies while prolonged exposure may lead to silicosis and deterioration of alveolar tissues.

Portable and handheld gas meters are the easiest way to monitor gas concentrations. These gas detectors are also available in the market at costs starting at Php 1,500 to Php 30,000 per gas detector. Hybrid detectors, capable of detecting more than one gas at time is also available but at a higher price. Unlike, the dust meter, the principle of operation of gas detectors is not simple, not

easily replicable, and involves solid state chemical reactions. Permissible values of these gases, along with its hazards at higher concentrations, are summarized in Chapter 7.

The method of determining concentration of heavy metals, in the form particulates, in the atmosphere is via atomic absorption spectroscopy or atomic emission spectroscopy where the atoms are heated and allowed to emit their characteristic color of flame. The intensity of the color is then directly related to the amount of the metal atoms in the sample. In this method, air particulates are collected in filters and trapped until there is sufficient and workable amount. Determination is gravimetric in nature and requires extraction process of the heavy metal. Cold-vapor atomic fluorescence spectrometry (CVAFS) is utilized in determining elemental mercury in the atmosphere. Mercury is first extracted in air by two steps of amalgamation. The first steps involves is an extractive amalgamation in a gold-coated trap in order to extract mercury in considerable amount. The mercury is then desorbed and reamalgamated in another gold-coated trap, this time to have a pure stream of mercury. The stream of mercury is then allowed to hit with ultraviolet light and the glow of the atoms is translated as concentration of mercury.

Since sophisticated equipment and a higher level of knowledge in chemistry is needed, analysis of heavy metals is not easily executable without the guidance of the chemical technicians, analysts, and chemists. However, just like TSP, PM10, and gaseous pollutants, and mercury only can be easily monitored by portable handheld gas sensors.

Most of these pollutants are measured in a short term and long term basis. For short term, the averaging usually lasts for 1 hour to 24 hours while long term applies for 1 year.

### How to conduct soil quality monitoring?

The most common properties of soil measured are the **pH, organic matter content, and salinity** usually because these properties directly affect the ability of plants to grow. This follows that when these parameters are within allowable range, agriculture is not possible consequently food, thus the quality of living is not at par.

Soil sample are collected based from locations identified to be affected by pollution. In most cases, the samples have to be transported to the laboratory for analysis. On such case, the sample container must be designed to be air and watertight, dark, and cool. Absence of air inhibits microbial growth while absence of light avoids photocatalytic reactions. Cool temperature also helps in preserving the sample by slowing bacterial and fungal activities. Watertight containers must be used to avoid the leakage of moisture or liquid water naturally found in the soil sample. Again, the containers must be properly cleaned using a detergent, washed with 5% nitric acid, and then dried.

Soil pH is commonly measured using a pH meter. A saturated aqueous solution is prepared by mixing known amount of water and soil sample. The mixture is allowed to establish an equilibrium before finally measuring the pH. In some cases, pH paper may also be used but the soil color must be considered as this can interfere in the detection of color in the comparator chart. Same technique of sample preparation is also utilized in measuring the salinity. Since the salinity is defined as the amount of salt present in a sample, this parameter is easily measured using a conductivity meter instead of a pH meter.

The organic matter content, on the other hand, greatly differs from the first two analyses. This analysis is based on a gravimetric technique where the masses of the samples are obtained before and after the analysis. A sample of pre-weighed soil is heated 110 °C to remove the moisture. The mass difference between the pre-weighed soil and dry soil is then the moisture content. In order to get the organic content, the dry sample is heated further to 300-700°C depending on the need of the analysis. At this temperatures, the organic matters are assumed to degrade thermally and leave the soil sample as carbon dioxide and water vapor. The difference between the mass of dry soil and soil heated in higher temperature is then the organic matter content.

Properties of soil are not that variable unlike in water and air since the diffusion of mass in solids is very much slower. The frequency of soil monitoring relatively lower than air and water monitoring. Usually, the parameters are taken every 3 months.

## Interpretation of Results

Results whether taken directly from the field or measured in the laboratory should be compared with existing applicable standards. If a parameter exceeds the standards, it should be monitored more frequently. If succeeding measurements show exceedance, appropriate measures in the treatment process needs to be taken. Not meeting the air, water or noise standards can be penalized.

## Important Points to Remember

- Monitoring requires strict procedures and sampling protocols to ensure tests are credible and accurate. Instruments are also preferred for simpler sampling and testing and also for better accuracy of the results.
- Measuring levels of pollution requires looking at very specific parameters and their thresholds to know if they are beyond standards set by the government. The following are the most commonly measured parameter:
  - Water: pH, Temperature, Total Dissolved Solids, Total Suspended Solids, Turbidity, Salinity, Conductivity, Dissolved Oxygen, and Oxidation-Reduction Potential, and Selected Metals, Heavy Metals, and Anions (Phosphates, Nitrates, Sulfates, and Cyanides)
  - Air: Total Suspended Particulates (TSP) and PM<sub>10</sub>; additionally: Volatile Organic Compounds (VOCs), carbon monoxide, nitrous oxides (NO<sub>x</sub>), sulfur oxides (SO<sub>x</sub>), lead
  - Soil: pH, organic matter content, and salinity



## Chapter 7 Mining Monitoring Examples

This chapter will introduce readers to three commonly experienced pollution problem in mining sites. It will give an overview of step-by-step procedures that may be undertaken as discussed in previous chapters. By the end of this chapter, readers will be able to understand the actual practice and application of mining monitoring in very specific situations.

### Learning Objectives of this Chapter

- Learn about sampling protocols and sampling storage procedures for monitoring for siltation in streams and rivers, acid mine drainage and metal contamination, and soil quality assessment
- Apply previously discussed methods in very specific cases of pollution in mining operations

#### Parts of this Chapter

- Problem: Siltation in Streams and Rivers
- Problem: Acid Mine Drainage and Metal Contamination
- Problem: Soil Quality Assessment

## **PROBLEM: SILTATION IN STREAMS AND RIVERS**

Siltation levels in river systems are a particular concern in mining areas where there is direct dumping of mine waste materials (rocks removed prior to ore recovery that have no significant economic value) or where siltation control facilities such as drainage canals, siltation dams and ponds discharge waste waters. While riverbed siltation is a natural phenomenon, it may be enhanced and aggravated by anthropogenic causes such as mining, agricultural, industrial, and other land conversion activities.

Enhanced erosion and transport of sediments from upstream sources often cause adverse effects in rivers such as increase in water turbidity, perishing of aquatic organisms, and elevation of the stream bed which in extreme cases, may lead to easier flooding in nearby communities. In addition, sediments that contain high amounts of heavy metals and sulfides may also be transported and may grossly affect water quality by increasing the acidity and toxicity which may consequently result in poisoning and long-term damaging effects to humans and the ecosystem.

It is hence the purpose of this manual to point out, as close as possible, the sources of sedimentation in mine-impacted areas for monitoring and eventually construction of sediment-impounding facilities.

1. **HYPOTHESIS:** Mining activities at upstream places possibly cause sediment disturbance, and consequently, siltation occurs downstream.
2. **OBJECTIVES:** Determine all possible sources of siltation, segregate which are possibly from mine sites, from agricultural and residential areas, and natural sources.

In identifying the ideal monitoring sites, the first step is to identify the drainage systems that are potentially impacted by mine operations. This can be done through a Global Information Systems (GIS) – based approach, by generating an updated drainage systems map and locating streams where water and sediments may potentially exit from a mining tenement. The GIS approach is done

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through processing of digital elevation models (DEM's) in GIS software such as ArcGIS, QGIS, MapInfo, etc., to produce a map that shows the drainage systems and drainage divides within a selected area. The generated map is then overlaid on other software such as Google Earth and compared with existing published topographic (elevation) maps from the National Mapping and Resource Information Authority (NAMRIA).

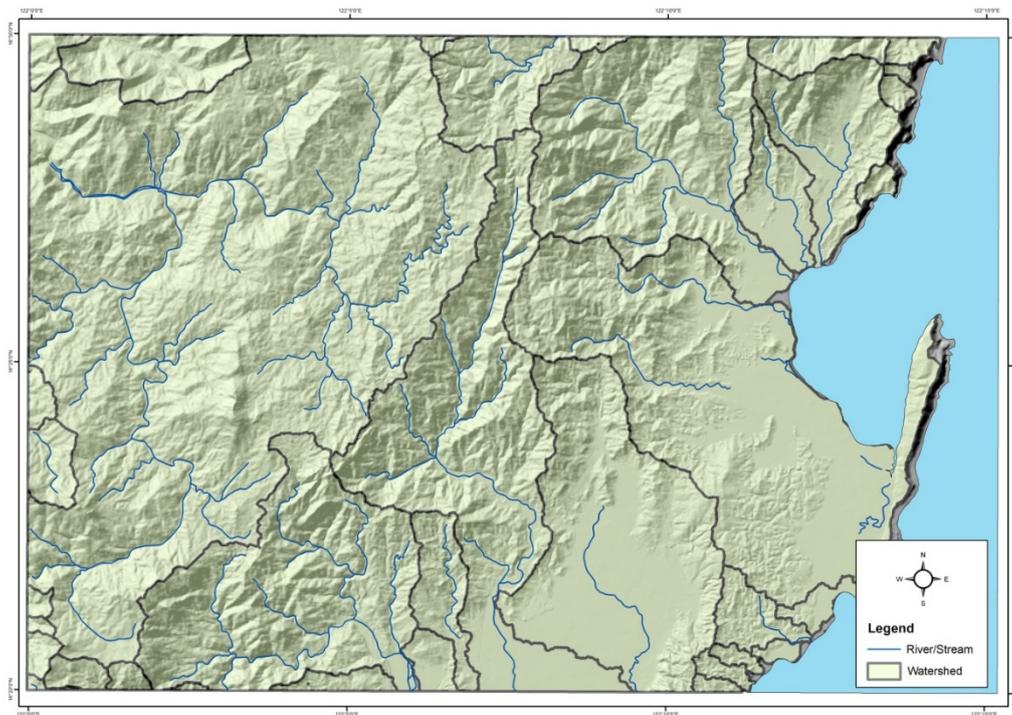


Figure 11: Sample Drainage Divide Map (Northern Aurora Province), showing major river systems (blue) and drainage divides (dark brown)

Drainage analysis is important to determine which areas water that carry the sediments will exit. Larger drainage basins have comparatively higher water volumes and may consequently be greater contributors of higher amounts of sediment downstream.

As watershed delineation relies solely on remote-sensed data and satellite imagery, this should be field-verified because some river systems are considerably more dynamic, so river patterns and drainage systems may change within a short span of time.

Ideal monitoring sites should be chosen before field verification. In siltation-impacted areas, an ideal monitoring site are sections of streams and tributaries where water and silt from mining tenements exit directly. This allows us to gauge how much sediments are directly coming from mining tenements.

Control sites should also be established during monitoring. These are tributaries which are unaffected by or away from any mining activity and will serve as baseline standards, or in other words, siltation from natural causes such as weathering and erosion of rocks.

Another important site for monitoring are the confluences of tributaries or channels, or where two or more small streams converge toward a larger stream body. These sites allow us to compare siltation levels as water exit from tenements and determine the dynamics of sediment transport. It is important to note, that while sediments are mobilized and transported from their sources, not all sediments reach the downstream areas of rivers. This is because particle settling may happen along the way, which may consequently result in lower amounts of sediment transported downstream.

Lastly, the most downstream sections of rivers (just before rivers exit to the sea) should also be monitored. The most downstream portion of the river is particularly important because it shall serve as the end-destination of sediments, and will allow us to compare how much sediments from source have actually been transported.

In addition to the aforementioned sites, other areas where monitoring may be done include agricultural, residential, and industrial areas. These could also be monitored to account for sedimentation other than from mining tenements or natural sources.

### 3. METHODOLOGY: Rainfall, Stream Flow, Sediment Flux Monitoring, and the Frequency of Monitoring

In selecting the ideal time for monitoring siltation, the activity should be divided into two phases: the first conducted during the dry season (ideally March – May) and the second during the rainy season (June – November).

Each phase should span at least two (2) months (or could be longer, depending on the consistency of weather, frequency of rainfall or occurrence of typhoons), consisting of non-stop, daily monitoring for the first thirty (30) days, and a weekly or every-other-day monitoring for the succeeding month. The said pattern is recommended to ensure that daily changes in weather is captured in the analyses.

Rainfall and streamflow are important parameters to be acquired for siltation analysis, as these reflect relationship of the potential changes in the volume of water (and consequently the amount of sediments transported) and rates of erosion and suspended matter.

Rainfall is measured in millimeters/day and is done using a rain gauge. Although there are no direct computations involving rainfall, the data is usually interpolated and correlated with the amount of Total Suspended Solids (TSS) and the Stream Discharge to derive a temporal (time) relationship between the amount of suspended solids and water volume and velocity during rainfall events.

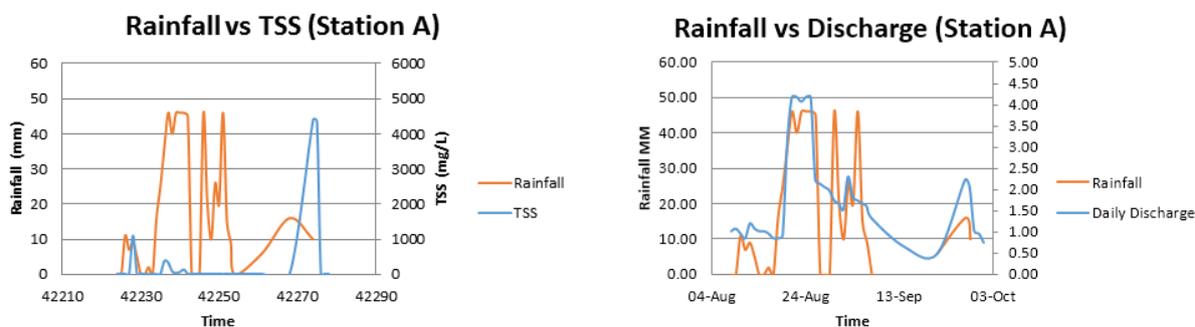


Figure 12: Sample interpolation of Rainfall, TSS, and Discharge data. High peaks both for TSS and Discharge are observed with peaks in rainfall.

Stream Flow on the other hand, is described in different ways (i.e. Flow velocity, Flow rate, Sediment Rating) and is directly involved in calculations for the Sediment Load. The flow velocity ( $u$ ) is a vector unit that describes how fast water is moving at a particular span of time and has a unit of meters/second. It can be measured using an automatic flow meter, or may be done manually by allowing an object (for example, a small twig) to move along with the water and measuring the amount of time it takes for the object to reach a particular point.

Flow rate or Discharge ( $Q$ ), on the other hand, describes the volume of water passing through a channel at a particular time and flow velocity ( $u$ ). Its unit is in cubic meters / second and is calculated as the product of the flow velocity and the cross-sectional area of the stream.

The Sediment Rating Curve relates the amount of suspended materials (TSS) with the flow rate / discharge. It is usually generated to predict and describe the amount of suspended materials given a particular discharge (or vice-versa). The sediment rating curve is specifically useful in predicting the possible amounts of suspended solids or discharge in events when sampling is not conducted. It is generated by plotting the TSS versus the Discharge and generating a best fit curve. The slope-intercept equation obtained from the best fit curve is then used to predict the discharge or the TSS by substituting  $x$  to the stage (water height).

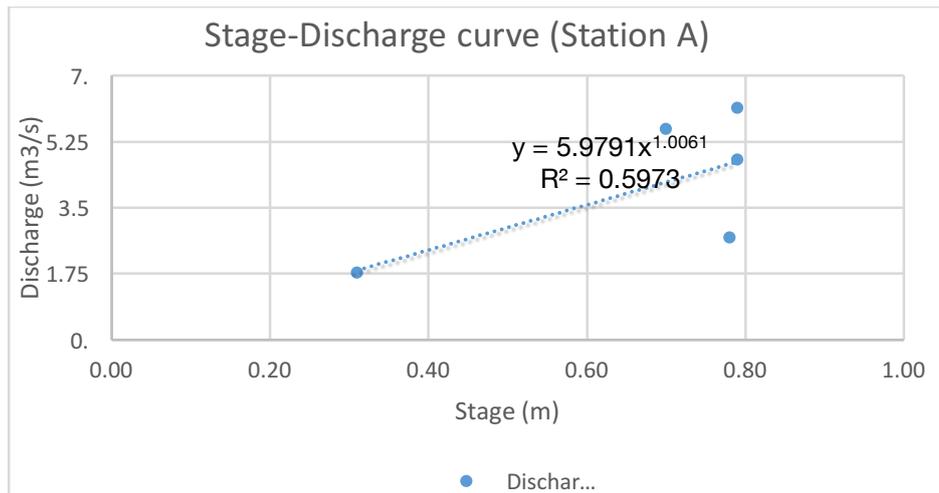


Figure 13: Sample Stage-Discharge Curve at a hypothetical Station A with only 4 discharge measurements. Since daily discharge is needed to calculate the sediment load, the Stage-Discharge Curve is generated to predict the discharge in other days when sampling was not conducted.

#### 4. EXECUTION: Monitoring Proper and Sampling Protocols

##### Measuring Rainfall and Stream Dimensions

In the analyses of how much water and sediments through streams (known as discharge and sediment load analysis), a factor to consider is the cross-sectional area of the stream. Calculating the cross-sectional area of a stream, however, is not straightforward because in reality, the morphology of the stream floor is irregular (which is why the formula length x width cannot be used directly). To calculate the cross-sectional area of a stream, horizontal and vertical measurements are first made. The horizontal measurement is done by measuring the length of the stream from left to right bank. Take note that a straight horizontal line (azimuth = 180°) should be maintained during measurement to avoid skewing.

Once the horizontal distance is measured, it will be divided into equal segments, where vertical measurements will be done. The vertical measurement is done by measuring the depth of stream perpendicular to the water surface. Take note that measuring the stream cross-section should be done every monitoring because the dimensions vary depending on the height of water (called stage).

The cross-sectional area can be obtained manually by dividing the section into right triangles, trapezoids, or rectangles and getting the individual areas then adding them up.

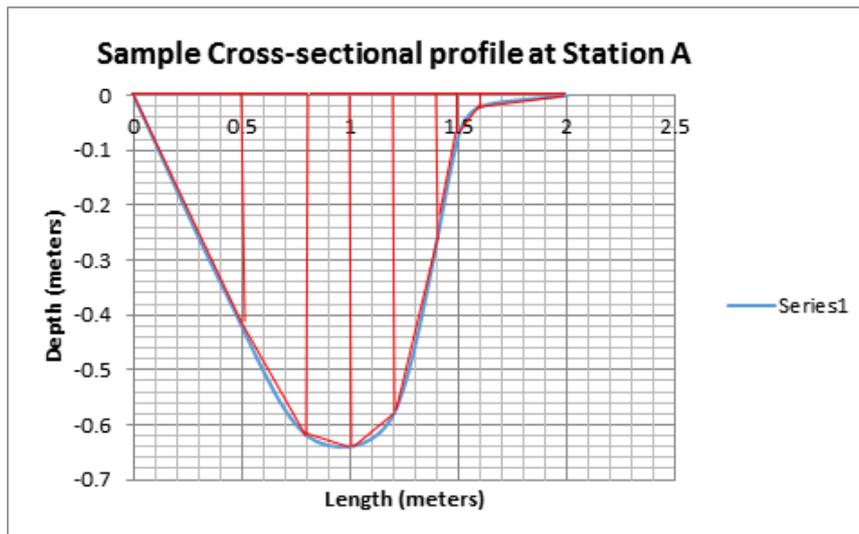


Figure 14: Hypothetical cross-sectional area of a stream, divided into trapezoids and triangles. The cross-sectional area is equal to the sum of the individual areas of each polygon

Rainfall measurement on the other hand, is done by obtaining the water level in either manual or automatic rain gauges in a 24-hour cycle. Rainfall data is recorded for data interpolation with stream discharge, and may be used in cases when stream discharge is not measured.



Figure 15: Manual (left) and Automated (right) rain gauges used to measure the amount of rainfall in an area. Manual rain gauges may be constructed from old plastic bottles, while automated rain gauges are coupled with a transmitter and a receiver which automatically record rainfall data in a 24-hour basis.

### Water Sampling for Analysis of Total Suspended Solids (TSS)

The Total Suspended Solids (TSS) refers to the concentration of solid materials in the water that can be filtered using a 0.45mm filtration system. Its unit is denoted in milligrams / liter (mg/L) or parts per

million (ppm) and is directly involved in the calculation for the amount of silt transported (Sediment Load).

Sampling for analysis of TSS utilizes polyethylene (PET) bottles usually in duplicates of 500-ml samples. The proper procedure for sampling should be done by rinsing the sample bottles thrice with the sample water and collection should be done simultaneously. For accurate results, sampling must be done with the containers facing opposite the direction of the flow of water (or facing upstream) and as much as possible, avoiding disturbance of the stream bed.

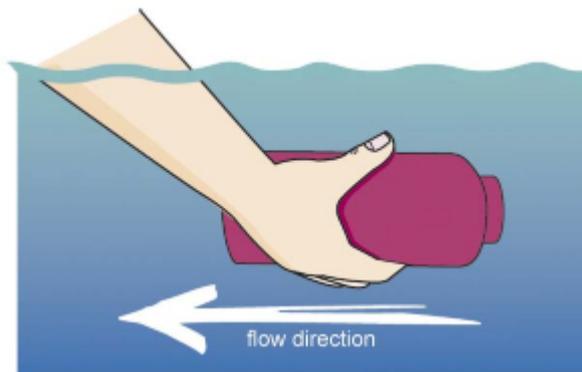


Figure 16: Technique for taking hand-held grab samples (Source: EMAN – N (2005))

On-site analysis of TSS is highly recommended using a portable TSS meter, but gravimetric methods may be done in the laboratory; however, not usually recommended because sediment load analysis requires numerous samples and gravimetric methods may be prone to human errors.

##### 5. DATA ACQUISITION AND RESULTS INTERPRETATION: Sediment Load Calculation

The Sediment Load describes the amount of suspended particulates in water that are transported within a particular time. Its unit is in weight / unit time, usually in tons or kilograms per day or month. In other words, the sediment load tells us how much sediments an area receives within a day or a month, and is the final parameter obtained in siltation monitoring studies.

The daily sediment load is obtained by multiplying the measured daily TSS (in mg/L) with the discharge ( $\text{m}^3/\text{sec}$ ). Note that the TSS and discharge have different units, so conversion must be done in order to obtain a final unit of kg/ day for the daily sediment load, so the TSS and Discharge are multiplied to 3600 and 24 (to convert seconds to day) and divided by 1000 (to convert mg to kg).

## Empowered Communities

The sum of the daily sediment load for 30 or 31 days (depending on the month) is called the monthly sediment load (kg/month), and should be the final unit declared in technical reports.

6. COMMUNICATING RESULTS AND FORMULATING SOLUTIONS: Results of a Sediment Flux Monitoring study should be relayed to the concerned communities, the mining companies, and government agencies for discussion of potential solutions.

Common remediation measures include desilting of streams, installation of sediment-impounding facilities such as additional dams and use of geotextiles, slope stabilization to reduce scouring of rocks and soils that further contribute to siltation, and even reintroduction of vegetation to support the slopes.

## **PROBLEM: ACID MINE DRAINAGE AND METAL CONTAMINATION**

1. **HYPOTHESIS:** Mine waste (non-economically viable rocks) from mine tenements that bear sulfides, metals, and heavy metals contaminate streams which result in stream health deterioration and acidification of waters.



Figure 17: Example of acid mine drainage and heavy-metal contamination in a stream. The bluish discoloration on the stream bed is due to the precipitation of copper.

2. **OBJECTIVES:** Determine the source of AMD and heavy metals, which elements and compounds are present and quantify the amount in stream waters.

The same pre-monitoring procedures will be done here. A GIS-based analyses and tracing of all possible sources of contaminants should be conducted to identify key sites for monitoring.

3. **METHODOLOGY:** Rainfall monitoring, Water sampling, and laboratory analyses
4. **EXECUTION:** Frequency of sampling and proper sampling and handling protocols

### Sampling Protocols and Preservation

Prior to field sampling, there are several things that must be kept in mind. Among these are the pre-field preparations which include selection and decontamination of ideal sampling containers, calibration of field equipment, and having a good knowledge on sampling protocols.

## Empowered Communities

Common sample containers used in water sampling are Polyethylene (PET), Polytetrafluoroethylene (PTFE), and glass/amber glass. Depending on which parameters will be analyzed, an appropriate container is deemed useful. For example, for trace organics (Carbon-based compounds), glass is preferred due to lesser adsorption and leaching; while for metals and anions, PET/PTFE is generally preferred.

For Quality Assurance and Quality Control (QA/QC) purposes, sample Blanks are always a requirement. A sample blank is a container that serves as a baseline standard prior to sampling, for determining purity of chemical preservatives, contamination levels of the sample containers prior and during sampling, and for correcting random errors in contaminant concentration (Canada EPA, 2011). Trip blanks are prepared in the laboratory and are usually placed with the samples to determine contamination within the bottle or from volatile compounds that may have been incurred during sample transport. A field blank on the other hand, is used to determine contamination which may have been acquired during sampling or from the handling during the sampling process. Both are necessary before and during sample acquisition.

Decontamination of sample containers must also be conducted in the laboratory prior to sampling. A common methodology is washing the containers with acid, then rinsed with water and detergent, then finally subjected to an autoclave for sterilization; however, in the absence of an autoclave, acid and detergent washing may do, except if bacterial analyses will be conducted.

In the field, it is always a must that the samplers take precaution. This is why a set of Personal Protective Equipment (PPE) is a requirement. Common PPE include nitrile gloves, a protective eye gear, boots, and dust masks. The use of PPE not only protects the sampler from possible harmful or toxic substances, but also aids in the preservation of the integrity of the samples taken.

Depending on how the data will be statistically represented, two common methods of sampling are employed: Grab sampling or composite sampling. A grab sample is an individual and discrete sample which is time and place-specific. Grab sampling is particularly significant if a place is to be represented at one particular time and space. Composite sampling, on the other hand, is composed of several grab samples that are usually mixed together then a random amount of sample is taken for analyses. Composite sampling is significant in instances where the spatio-temporal distribution of contaminants is not homogenous. Composite sampling and analysis yields average contaminant distribution, and reduces the time and cost by reducing the amount

of samples needed for analysis; however, lacks information in variability and specificity because only average data is considered.

For physico-chemical parameters (pH, Temperature, Total Dissolved Solids, Total Suspended Solids, Turbidity, Salinity, Conductivity, Dissolved Oxygen, and Oxidation-Reduction Potential), analyses may be done in-situ (direct measurement in streamwaters) or in the laboratory. If samples are to be collected, a 500-ml polyethylene (PET) bottle shall be used as sample container. The sampling process, called “grab sampling,” involves washing of the containers with the streamwater sample thrice before acquisition, then submerging the container facing the upstream and upwind direction. Stream bed disturbance and presence of air bubbles in containers should be avoided, especially for analysis of Dissolved Oxygen. All samples are expected to have duplicates, and transported in ice bath (approx. 4°C) to slow down bacterial activity to preserve the samples.



Figure 18: A 500-ml Polyethylene (PET) bottle

For sampling of water for the analysis of metals and heavy metals (excluding Mercury), PET bottles may be used; however, a more preferred sample container would be a Polytetrafluoroethylene (PTFE) Bottle or more commonly known as a Teflon container. PTFE is more preferred because its linings react lesser with water and metals and is comparatively

thicker and opaque. The thickness and opacity of the linings of PTFE prevents possible leakage and effects of light on the state of metals in water.



Figure 19: A 500-ml Polytetrafluoroethylene (PTFE) bottle.

Sampling method is similar with the aforementioned, but preservation is different. Upon acquisition of the samples, concentrated Nitric Acid ( $\text{HNO}_3$ ) is added to the samples until a pH of 2.0 is achieved (measure with pH meter or pH paper). This process, called acidification, is done to keep the metals in solution with water and to prevent them from precipitating. For analysis of Ferrous Iron ( $\text{Fe}^{2+}$ ), concentrated Hydrochloric acid (HCl) is added instead of Nitric acid. The samples are then preserved in ice bath and transported for analysis in the laboratory. The maximum holding time of the samples is less than six (6) months after acquisition.

For Mercury, sampling procedure is similar with other metals and heavy metals, but containers are restricted to PTFE or acid-washed borosilicate glass. Preservation of water samples for Mercury analysis requires addition of 5ml of 12M HCl or Bromine Monochloride ( $\text{BrCl}$ ) for every 1 liter sample, or approximately 2.5ml for a 500-ml water sample. Upon addition of acid, the samples should be stored and transported in ice. Maximum holding time for samples is around 28 days.

For Nitrates, Sulfates, and Phosphates, either PET or PTFE may be used as sample container. Sampling method is also similar with the aforementioned. HCl may or may not be added to acidify the sample to pH 2.0, and must be transported in ice. Sample holding time, however, will vary. If the samples were not acidified, the maximum holding time is up to 48 hours, but may be extended to seven (7) days with addition of HCl.

Similar sampling protocols and containers are followed for sampling and analyses of Cyanides. Preservation is rather complicated, as interference of other compounds should be avoided in the analysis. The most common form of interference is from oxidants and sulfides, both of which are ubiquitous in Acid Mine Drainage (AMD). In such scenario, HCl is first added to the sample, then deionized or distilled water is added to neutralize sulfides. Finally, addition of 5.0M Sodium Hydroxide (NaOH) is done until pH reaches 12.0. Samples must be preserved and transported in ice. Holding time is up to fourteen (14) days.

#### 5. DATA ACQUISITION AND RESULTS INTERPRETATION: Water Quality Standards

In order to make sense of analyses of water samples to determine water quality, analytical results are compared to water quality standards. In the Philippines, the Department of Environment and Natural Resources determines the water quality standards based on its latest issuance of the Department Administrative Order (DAO) 2016-08.

It is important to note however, that water quality standards are not the same for all waters. In this case, it is important to first establish the classifications of water bodies based on DAO 2016-08. A list of water classification is on the next chapter. Water quality standards for different classes of waters are also found in the next chapter.

#### 6. COMMUNICATING RESULTS AND FORMULATING SOLUTIONS: Results of a Acid Mine Drainage Monitoring study should be relayed to the concerned communities, the mining companies, and government agencies for discussion of potential solutions.

Common remediation measures include acid neutralization in streams by introducing substances such as lime (which can be obtained from limestones or bivalve shells), antacids (magnesium, sodium, or aluminum-based antacids), use of coagulants to bind and precipitate metals, and even introduction of algae.

## PROBLEM: SOIL QUALITY ASSESSMENT

1. HYPOTHESIS: Heavy metal and acid contamination present in soil are possibly affecting plant growth and crop production
2. OBJECTIVES: Determine the source of AMD and metals, identify which elements and compounds are present and quantify the amount in soils
3. METHODOLOGY: Soil sampling and laboratory analyses, frequency of monitoring

Soil is another good proxy (apart from water) in environmental impact assessment. However, unlike water in streams, soil is relatively heterogeneous in composition, with varying amounts of rocks, trapped gases, and liquids (NJIT, 1994). Apart from compositional heterogeneity, soil layering also varies and thus contaminant distribution and transport are also largely variable. This makes representing soil contamination more ambiguous. In selecting an area for monitoring soil quality, it is thus important to have a clear context both of spatial and temporal distribution of contaminants before beginning with the actual monitoring. A good way is to begin with generating a map that shows the spatial distribution of impacted areas with respect to the duration of the contamination.

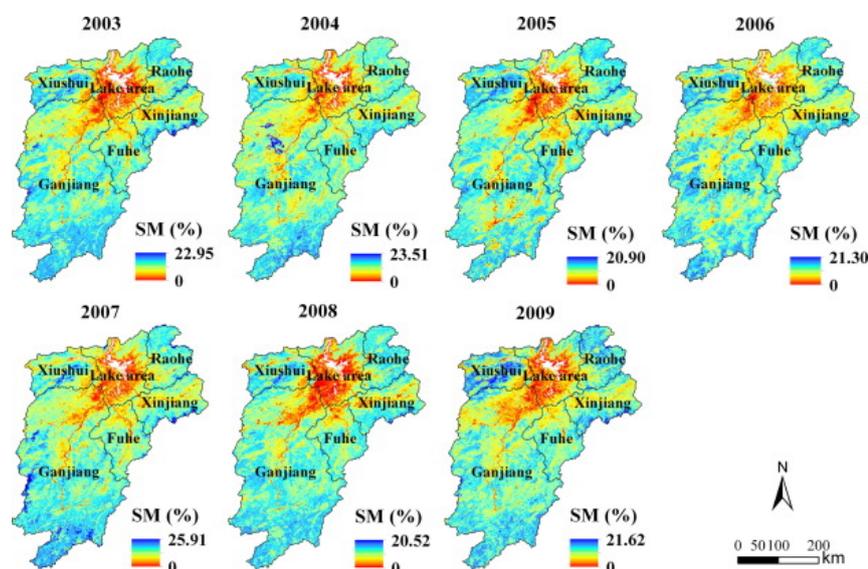


Figure 20: Spatiotemporal map of soil moisture at the Poyang Lake Basin in China from 2003 to 2009, showing the variations in soil moisture content in 7 years. Taken from Feng and Liu, 2015.

Also, because soil is not as dynamic as water, contamination may not be reflected in a short span of time (i.e. hourly or daily basis) and requires a particular period of time before contaminants settle and are significant in analyses. This is why soil quality monitoring should be done over a monthly, quarterly, semi-annual, or annual basis, depending on the rates of contamination while taking into consideration meteorologic factors such as weather, climate, and rainfall in an area.

Other factors also play a key role in determining contaminant transport and soil quality such as the type of soil, the land use, vegetation, and the physical properties of the soil (cohesion, porosity, hydraulic conductivity, etc.)

In order to understand soil quality, a “benchmark” soil is also analyzed in comparison and contrast with a target area. A benchmark soil is one that is adjacent to the area of study which is not impacted by any activities and shall serve as a baseline of standards both for physical and chemical properties. Ideally, a benchmark soil should be compositionally similar and belongs in the same environment as the target soil.

#### 4. EXECUTION: Proper sampling and handling protocols

Depending on the variables or contaminants to be analyzed, a unique method for soil and sediment sampling is employed. This document particularly follows standards for soil sampling protocols set by the US EPA – Georgia Science and Ecosystem Support Division (SESD) published in 2014 or the Standard Operating Procedures for Soil Sampling.

#### PRECAUTIONS

The sampler should always consider operational standards such as use of PPE’s during sampling. He/she should use a new pair of nitrile (non-powdered) gloves every time a new sample is to be collected to avoid contamination of samples, especially if the samples are to be analyzed for trace elements.

#### HANDLING AND STORING SAMPLES

If a sample is suspected to contain high amounts contaminants, it should be stored separate from samples with low concentrations of contaminants and away from control / benchmark samples. Take note that for the sequence of sampling, the sampler should always start taking specimens from areas with the least amount of contamination towards the area with the

greatest suspected amount of contamination – this is where a map of the spatial distribution of contamination is very important.

If homogenization of samples is to be done, ensure that the amount of samples taken from different sites that are to be mixed are approximately equal in volume so as to be statistically accurate in representing homogeneity. Take note that for analyses of Volatile Organic Compounds (VOCs), samples should not be homogenized.

For vertical soil sampling, make sure that the exposed surfaces are first scraped with the shovel to be used for sampling. The shovel should be stainless, plastic, or Teflon-coated, so as to prevent flaking of the surface and consequently contaminating the samples. An ordinary garden shovel made of steel is not advisable to be used.

To accurately and effectively represent soil contamination, both grab and composite sampling are employed. It is a common practice to obtain both grab and core samples for soil analyses. Core sampling utilizes tubes 3 to 8 centimeters in diameter drilled into the ground to obtain soil while minimizing the disturbance and preserving the layering. The drill is usually made of brass, stainless steel, plastic, or Teflon to prevent flaking in contact with the soil due to friction and thus minimizes contamination.

For manual sampling (use of shovel or a hand auger), vegetation such as roots and other plant debris should be removed before obtaining samples. Gravel, concrete, etc., should also be excluded from the samples. A 1 meter by 1 meter excavation may be done to expose the soil profile. The depth of measurement begins at the top of the soil horizon, after debris have been removed. Typical sampling procedure may be done in intervals of 6 inches, or where soil profiles have visible changes.

## What is a soil profile?

A soil profile consists of several **soil horizons**.

### O horizon

- humus on the ground surface.

### A horizon

- Top soil.
- Rich in organic matter. Typically dark color.
- Also called zone of **leaching**.

### B horizon

- Subsoil.
- Also called zone of accumulation.
- May contain soluble minerals such as calcite in arid climates (caliche).

### C horizon

- Weathered bedrock (rotten rock).
- Bedrock lies below the soil profile.

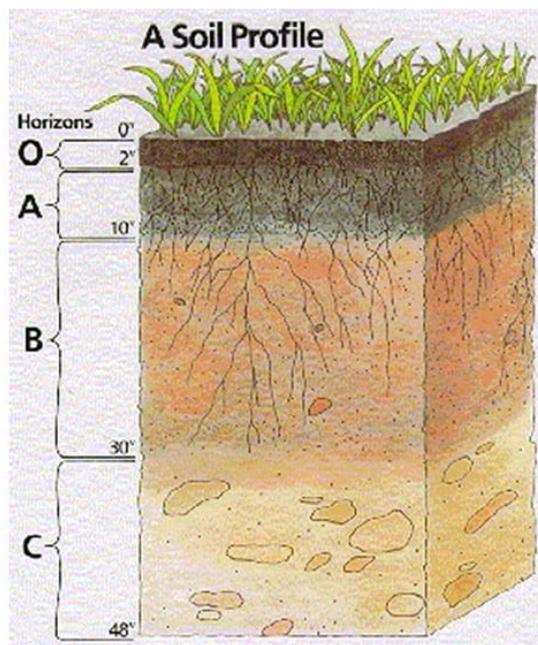


Figure 21: A sample soil profile. Sampling may be done where there is a visible change in soil layer, or every 6 inches interval below the ground. Image lifted from Google.

All soil samples should be placed in a ziplock plastic containers with proper sample labels and stored in a cool place to slow down microbial activities that may degrade soil and metals, thus altering the composition and concentration of contaminants.

## 5. DATA ACQUISITION AND RESULTS INTERPRETATION: Soil Quality Standards

For the purpose of this manual, the standards and soil classification from the US EPA Regional Screening Level (published May 2016) will be used. The same standards have also been adopted by the Australian, New Zealand, and Canadian EPA. Standards are also hereby divided into different soil classes, with two types identified, resident and industrial soils.

The US EPA defines resident soils as “activities for this receptor involve typical home making chores (cooking, cleaning and laundering) as well as outdoor activities. The resident is assumed to be exposed to contaminants via the following pathways: incidental ingestion of soil, dermal contact with soil, inhalation of volatiles and fugitive dust.” Industrial soils, on the

other hand, are not formally defined by the EPA. This manual however, will define industrial soils as those involved or utilized in the mining, manufacturing, and large-scale agricultural sectors.

As with water quality monitoring, the same analytes are hereby deemed important in soil quality monitoring in areas impacted by mining activities:

Table 29. Analyte as per US EPA Standards

| ANALYTE                      | US EPA STANDARDS       |                          |
|------------------------------|------------------------|--------------------------|
|                              | Resident Soils (mg/kg) | Industrial Soils (mg/kg) |
| Aluminum                     | 7.7 E+04               | 1.1 E+06                 |
| Arsenic                      | 6.8 E-01               | 3.0 E+00                 |
| Benzaldehyde                 | 1.7 E+02               | 8.2 E+02                 |
| Benzene                      | 1.2 E+00               | 5.1 E+00                 |
| Benzyl Chloride              | 1.1 E+00               | 4.8 E+00                 |
| Cadmium                      | 7.1 E+01               | 9.8 E+02                 |
| Carbon Tetrachloride         | 6.5 E-01               | 2.9 E+00                 |
| Chromium (III)               | 1.2 E+05               | 1.8 E+06                 |
| Chromium (VI),<br>Hexavalent | 3.0 E-01               | 6.3 E+00                 |
| Cobalt                       | 2.3 E+01               | 3.5 E+02                 |
| Copper                       | 3.1 E+03               | 4.7 E+04                 |
| Cyanide                      | 2.3 E+01               | 1.5 E+02                 |
| Thiocyanates                 | 1.6 E+01               | 2.3 E+02                 |
| Fluoride                     | 3.1 E+03               | 4.7 E+04                 |
| Iron                         | 5.5 E+04               | 8.2 E+05                 |
| Lead and Compounds           | 4.0 E+02               | 8.0 E+02                 |

|                            |          |          |
|----------------------------|----------|----------|
| Manganese                  | 1.8 E+03 | 2.6 E+04 |
| Mercuric Chloride          | 2.3 E+01 | 3.5 E+02 |
| Mercury                    | 1.1 E+01 | 4.6 E+01 |
| Nickel Hydroxide           | 8.2 E+02 | 1.1 E+04 |
| Nickel Oxide               | 8.4 E+02 | 1.2 E+04 |
| Nickel Soluble Salts       | 1.5 E+03 | 2.2 E+04 |
| Nitrates                   | 1.3 E+05 | 1.9 E+06 |
| Phosphates (Inorganic)     | 3.8 E+06 | 5.7 E+07 |
| Selenium                   | 3.9 E+02 | 5.8 E+03 |
| Sulfate (as Sulfuric Acid) | 1.4 E+06 | 6.0 E+06 |
| Tin                        | 4.7 E+04 | 7.0 E+05 |
| Toluene                    | 4.9 E+03 | 4.7 E+04 |
| Trichlorobenzene           | 2.4 E+01 | 1.1 E+02 |
| Vanadium and<br>Compounds  | 3.9 E+02 | 5.8 E+03 |
| Zinc and Compounds         | 2.3 E+04 | 3.5 E+05 |

6. COMMUNICATING RESULTS AND FORMULATING SOLUTIONS: Results of a Soil Quality Monitoring study should be relayed to the concerned communities, the mining companies, and government agencies for discussion of potential solutions.

Common remediation measures include introduction of metal-degrading plants and bacteria, addition of fertilizers to boost plant growth, metal immobilization and leaching, etc.

## **Important Points to Remember**

- Specific situations require different analyses, parameters, and instrumentation. It is important to identify and characterize the problem to make sure that monitoring and interventions are relevant to the issue at hand.
- Remediation measures are important to learn to know what to do next should findings point to levels of pollution beyond the thresholds set by international and/or national standards.



## Chapter 8. Interpretation of Monitoring Data

This chapter will introduce readers to the various tables and standards in measuring data collected from water, air, and soil quality monitoring activities.

To interpret the data and values generated from the various field monitoring techniques previously discussed, this handbook adopts the standards provided for by domestic legal instruments and policies. For water quality, this handbook refers to standards embodied in DAO 2016-34. For air quality, standards used are derived from the Republic Act 8749 (Clean Air Act of 1999) and its Implementing Rules and Regulations (DAO 2000-81). However, for soil quality, there is no existing domestic legal framework on acceptable standards thus, this handbook uses the suggested standards developed by the Soil Quality organization headed by Dr. Michelle Wander of Agroecology and Sustainable Agriculture Program of University of Illinois.

### Learning Objectives of this Chapter

- Learn about data interpretation for water, air, and soil quality monitoring given specific parameters of interest
- Identify allowable range and thresholds for specific parameters

Parts of this Chapter:

- Water Quality Monitoring Data Interpretation
  - Body of Water Classification
  - Water Quality Thresholds and Ranges per Body of Water Classification
  - Physical Characteristics
  - Water Oxygenation
  - Solid Contents
  - Heavy Metals
  - Other Pollutants
- Air Quality Monitoring Data Interpretation
  - Particulate Content
- Soil Quality Monitoring Data Interpretation
  - Soil pH
  - Soil Salinity

### Water Quality Monitoring Data Interpretation

Data generated from monitoring activities are used to assess whether the receiving body of water is negatively impacted or cannot be used for its intended purpose.

To facilitate the classification of water and degree of pollution, this handbook adopts the classification system prescribed by the Department of Environment and Natural Resources (DENR) through its Administrative Order Nos. 34 and 35 series of 2016 (DAO 2016). The water classification for fresh bodies of water are as follows:

Table 30. Freshwater body classification and its intended use.

| Class | Intended Use   |
|-------|--|
| AA    | Public water supply class I<br>Intended primarily for waters having watersheds, which are uninhabited and/or otherwise declared as protected areas, and which require only approved disinfection to meet the latest Philippine National Standards for Drinking Water (PNSDW).  |
| A     | Public water supply class II<br>Intended as sources of water supply requiring the aids of treatment plants for processes like coagulation, sedimentation, filtration, and disinfection to meet the PNSDW   |
| B     | Recreational water class I<br>Intended for water primary contact recreation like in swimming pools   |
| C     | <ol style="list-style-type: none"> <li>1. Fishery water intended for propagation and growth of fish and other aquatic resources</li> <li>2. Recreational water class II – intended for boating, fishing, and other similar recreational activities</li> <li>3. Water for agriculture, irrigation, and livestock watering.</li> </ol> |
| D     | Navigable waters   |

Table 31. Coastal and marine water body classification and its intended use.

| Class | Intended Use  |
|-------|---|
| SA    | 1. Tourism zones (e.g. National marine parks and reserves and coral reef parks as mandated by the law)<br>2. Commercial purposes (e.g. Harvesting of shellfish)                                 |
| SB    | 1. Recreational water class I<br>Intended for water primary contact recreation like in swimming pools<br>2. Fishery water class I<br>Intended for spawning areas for Bangus and similar species |
| SC    | 1. Recreational water class II<br>Boating, etc.<br>2. Fishery water class II<br>Intended for commercial and sustenance fishing  |
| SD    | Industrial water supply class II<br>Intended for industrial applications (e.g. Cooling). And other waters that does not belong to the abovementioned classifications belong in this group       |

For water quality standards, the following tables (lifted from DAO 2016-08) show the effluent standards for different classes of waters.

Table 32. Water Quality Guidelines for Primary Parameters

| Parameter                                    | Unit      | Water Body Classification |         |         |         |         |         |         |         |         |
|--|-----------|---------------------------|---------|---------|---------|---------|---------|---------|---------|---------|
|  |           | AA                        | A       | B       | C       | D       | SA      | SB      | SC      | SD      |
| BOD  | mg/L      | 1                         | 3       | 5       | 7       | 15      | n/a     | n/a     | n/a     | n/a     |
| Chloride                                     | mg/L      | 250                       | 250     | 250     | 350     | 400     | n/a     | n/a     | n/a     | n/a     |
| Color  | TCU       | 5                         | 50      | 50      | 75      | 150     | 5       | 50      | 75      | 150     |
| Dissolved Oxygen <sup>(a)</sup><br>(Minimum) | mg/L      | 5                         | 5       | 5       | 5       | 2       | 6       | 6       | 5       | 2       |
| Fecal Coliform                               | MPN/100mL | <1.1                      | <1.1    | 100     | 200     | 400     | <1.1    | 100     | 200     | 400     |
| Nitrate as NO <sub>3</sub> -N                | mg/L      | 7                         | 7       | 7       | 7       | 15      | 10      | 10      | 10      | 15      |
| pH (Range)                                   |           | 6.5-8.5                   | 6.5-8.5 | 6.5-8.5 | 6.5-9.0 | 6.0-9.0 | 7.0-8.5 | 7.0-8.5 | 6.5-8.5 | 6.0-9.0 |
| Phosphate                                    | mg/L      | <0.003                    | 0.5     | 0.5     | 0.5     | 5       | 0.1     | 0.5     | 0.5     | 5       |
| Temperature <sup>(b)</sup>                   | °C        | 26-30                     | 26-30   | 26-30   | 25-31   | 25-32   | 26-30   | 26-30   | 25-31   | 25-32   |
| Total Suspended Solids                       | mg/L      | 25                        | 50      | 65      | 80      | 110     | 25      | 50      | 80      | 110     |

**Notes:**

MPN/100mL – Most Probable Number per 100 milliliter

n/a – Not Applicable

TCU – True Color Unit

(a) Samples shall be taken from 9:00 AM to 4:00 PM.

(b) The natural background temperature as determined by EMB shall prevail if the temperature is lower or higher than the WQG; provided that the maximum increase is only up to 10 percent and that it will not cause any risk to human health and the environment.

Table 33. Water Quality Guidelines for Secondary Parameters - Inorganics

| Parameter                     | Unit | Water Body Classification |      |      |      |      |      |      |      |      |
|-------------------------------|------|---------------------------|------|------|------|------|------|------|------|------|
|                               |      | AA                        | A    | B    | C    | D    | SA   | SB   | SC   | SD   |
| Ammonia as NH <sub>3</sub> -N | mg/L | 0.05                      | 0.05 | 0.05 | 0.05 | 0.75 | 0.04 | 0.05 | 0.05 | 0.75 |
| Boron                         | mg/L | 0.5                       | 0.5  | 0.5  | 0.75 | 3    | 0.5  | 0.5  | 5    | 20   |
| Fluoride                      | mg/L | 1                         | 1    | 1    | 1    | 2    | 1.5  | 1.5  | 1.5  | 3    |
| Selenium                      | mg/L | 0.01                      | 0.01 | 0.01 | 0.02 | 0.04 | 0.01 | 0.01 | 0.1  | 0.2  |
| Sulfate                       | mg/L | 250                       | 250  | 250  | 275  | 500  | 250  | 250  | 275  | 500  |

Table 34. Water Quality Guidelines for Secondary Parameters - Metals

| Parameter   | Unit | Water Body Classification |       |       |       |       |       |       |       |       |
|---|------|---------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
|   |      | AA                        | A     | B     | C     | D     | SA    | SB    | SC    | SD    |
| Arsenic   | mg/L | 0.01                      | 0.01  | 0.01  | 0.02  | 0.04  | 0.01  | 0.01  | 0.02  | 0.04  |
| Barium  | mg/L | 0.7                       | 0.7   | 0.7   | 3     | 4     | 0.1   | 0.7   | 1     | 4     |
| Cadmium   | mg/L | 0.003                     | 0.003 | 0.003 | 0.005 | 0.01  | 0.003 | 0.003 | 0.005 | 0.01  |
| Chromium as Hexavalent Chromium (Cr <sup>6+</sup> ) | mg/L | 0.01                      | 0.01  | 0.01  | 0.01  | 0.02  | 0.05  | 0.05  | 0.05  | 0.1   |
| Copper as Dissolved Copper                          | mg/L | 0.02                      | 0.02  | 0.02  | 0.02  | 0.04  | 0.02  | 0.02  | 0.02  | 0.04  |
| Iron  | mg/L | 1                         | 1     | 1     | 1.5   | 7.5   | 1.5   | 1.5   | 1.5   | 7.5   |
| Lead  | mg/L | 0.01                      | 0.01  | 0.01  | 0.05  | 0.1   | 0.01  | 0.01  | 0.05  | 0.1   |
| Manganese   | mg/L | 0.2                       | 0.2   | 0.2   | 0.2   | 2     | 0.4   | 0.4   | 0.4   | 4     |
| Mercury   | mg/L | 0.001                     | 0.001 | 0.001 | 0.002 | 0.004 | 0.001 | 0.001 | 0.002 | 0.004 |
| Nickel  | mg/L | 0.02                      | 0.02  | 0.04  | 0.2   | 1     | 0.02  | 0.04  | 0.06  | 0.3   |
| Zinc  | mg/L | 2                         | 2     | 2     | 2     | 4     | 0.04  | 0.05  | 0.8   | 1.5   |

Note:

(c) Unless otherwise specified, the above parameters are expressed as total metals.

Table 35. Water Quality Guidelines for Secondary Parameters - Organics

| Parameter                                      | Unit | Water Body Classification |        |        |      |     |        |        |      |     |
|--|------|---------------------------|--------|--------|------|-----|--------|--------|------|-----|
|  |      | AA                        | A      | B      | C    | D   | SA     | SB     | SC   | SD  |
| Benzo(a)pyrene                                 | µg/L | 0.7                       | 0.7    | 0.7    | 1.5  | 3   | 0.7    | 0.7    | 1.5  | 3   |
| BTEX   |      |                           |        |        |      |     |        |        |      |     |
| Benzene  | mg/L | 0.01                      | 0.01   | 0.01   | 0.05 | 0.5 | 0.01   | 0.01   | 0.05 | 0.5 |
| Toluene  | mg/L | 0.7                       | 0.7    | 1      | 4    | 5   | 1      | 1      | 4    | 5   |
| Ethylbenzene                                   | mg/L | 0.3                       | 0.3    | 0.3    | 1.5  | 2   | 0.2    | 0.2    | 1.5  | 2   |
| Xylenes  | mg/L | 0.5                       | 0.5    | 0.5    | 1.5  | 1.8 | 0.5    | 0.5    | 1.5  | 1.8 |
| Cyanide as Free Cyanide                        | mg/L | 0.07                      | 0.07   | 0.07   | 0.1  | 0.2 | 0.02   | 0.02   | 0.1  | 0.2 |
| Organophosphate as Malathion                   | µg/L | 1                         | 1      | 1      | 3    | 6   | 1      | 1      | 3    | 6   |
| Oil and Grease                                 | mg/L | <1                        | 1      | 1      | 2    | 5   | 1      | 2      | 3    | 5   |
| Polychlorinated Biphenyls <sup>(d)</sup>       | µg/L | <0.1                      | <0.1   | 0.2    | 0.5  | 1   | 0.3    | 0.3    | 0.5  | 1   |
| Phenol & Phenolic Substances <sup>(e)</sup>    | mg/L | <0.001                    | <0.001 | <0.001 | 0.05 | 0.5 | <0.001 | <0.001 | 0.05 | 0.5 |
| Surfactants (MBAS)                             | mg/L | <0.025                    | 0.2    | 0.3    | 1.5  | 3   | 0.3    | 0.3    | 1.5  | 3   |
| Trichloroethylene                              | mg/L | 0.07                      | 0.07   | 0.07   | 0.9  | 2   | 0.07   | 0.07   | 0.9  | 2   |
| Total Organochlorine Pesticides <sup>(f)</sup> | µg/L | n/a                       | n/a    | 50     | 50   | 50  | 50     | 50     | 50   | 50  |
| Aldrin   | µg/L | 0.03                      | 0.03   | n/a    | n/a  | n/a | n/a    | n/a    | n/a  | n/a |
| Chlordane                                      | µg/L | 0.2                       | 0.2    | n/a    | n/a  | n/a | n/a    | n/a    | n/a  | n/a |
| Dichlorodiphenyltrichloroethane (DDT)          | µg/L | 1                         | 1      | n/a    | n/a  | n/a | n/a    | n/a    | n/a  | n/a |
| Dieldrin                                       | µg/L | 0.03                      | 0.03   | n/a    | n/a  | n/a | n/a    | n/a    | n/a  | n/a |
| Endrin   | µg/L | 0.6                       | 0.6    | n/a    | n/a  | n/a | n/a    | n/a    | n/a  | n/a |
| Heptachlor                                     | µg/L | 0.03                      | 0.03   | n/a    | n/a  | n/a | n/a    | n/a    | n/a  | n/a |
| Lindane  | µg/L | 2                         | 2      | n/a    | n/a  | n/a | n/a    | n/a    | n/a  | n/a |
| Methoxychlor                                   | µg/L | 50                        | 50     | n/a    | n/a  | n/a | n/a    | n/a    | n/a  | n/a |
| Toxaphene                                      | µg/L | 4                         | 4      | n/a    | n/a  | n/a | n/a    | n/a    | n/a  | n/a |

In addition, for threshold standards which are not listed in DAO 2016-08 which include TDS, Salinity, and Conductivity, this manual will be adopting the standards used by the US EPA, Victoria EPA, and American Public Health Association (APHA). The upper limits are at 500 mg/L, 0.7 ppt, and

1000 $\mu$ S/cm for TDS, Salinity, and Conductivity, respectively. The concentration limits apply to an equivalent Class AA waters (drinking waters). Moreover, these limits may increase depending on the water classification applied. For example, for Classes B and C waters, Salinity limit may be increased to 1.0 ppt or even slightly higher as waters classified under these are for aquaculture or recreational purposes only.

Note that if element/compound concentrations far exceed the listed limits of concentration, then a body of water is considered polluted; however, for some elements and compounds, particularly heavy metals, even small increments in concentrations may mean toxicity in waters. It is therefore important to scale the amounts of these substances in water.

## **1. Physical Characteristics**

### 1.1 Color

Organic colors of water like hues of brown and its turbid forms generally originate from the disturbance of soil from a nearby source. A turbid river can be caused by rainwater which carries with it soil particles from upstream. Human activities like dredging of the mud can also contribute to this kind of color. Discoloration of the water due to disturbance of the soil is temporary. The color usually reverts back in a few days' time as the suspended particles resettle down but may persist if the disturbance continues. Other contributors are organic decaying matters like poultry wastes. Green color may also occur due to algae and aquatic plants.

Artificial colors in the water like hues of red, blue, yellow and many inorganic colors do not occur naturally and are mostly due to pollutants. Among them are dyes and chemicals. Red and orange discoloration can also occur naturally due to red tides caused by growth of red algae called dinoflagellates. Blue luminescence observed particularly at night when water is agitated is also caused by dinoflagellates. Black color is basically the most polluted.

Severe discoloration of water via chemical pollutants requires a large-scale water treatment process and may range from filtration to coagulation and flocculation. Mild discoloration can be mitigated by adding adsorbents like coconut husks, dried leaves, or zeolites. Photocatalytic materials like Titania may also be used but is more costly. . . These photocatalytic materials attracts the colored pollutants to its surface and oxidizes them to produce carbon dioxide. In using the said adsorbents, it is also important to consider the recovery of the materials in order to lessen additional pollutants in the water. Bleaching may also help but may also cause chemical pollution.

### 1.2 Temperature

Water temperature can be affected by both natural and man-made factors. The temperature is most of the time, dependent on the weather. Cooler weather generally lowers the water temperature. Time of the day is also a factor. Water bodies are warmer at night as the water absorbs heat throughout the day and releases it slowly after sunset. Another natural factor for variations in temperature of water is active volcanism in nearby waters. This phenomenon transfers heat from the underlying magma to the water causing it to warm up. Depth of water also affects as cooler water tends to sink and warm water rises to the surface. Biological factors may also affect water temperature but primarily happens on waters rich in organic materials. Decomposition of organic matters by bacteria and fungi releases metabolic heat significant enough to raise the temperature up to 60 °C.

Man-made factors that can affect the water temperature mostly come from machinery. Heating of machines need an immediate cooling to achieve spontaneous operation. Water is the most common coolant used to suppress overheating of the machine. Water used for this purposes are sometimes released directly in to the water bodies resulting in increase in temperature.

For the organisms thriving in water, temperature is important for the metabolic activity. Most organisms can live on temperature range of 0 °C to 40 °C. Their metabolic activity doubles for every 10 °C increase in temperature. However, temperatures exceeding 40 °C kill these organisms.

### 1.3 Acidity

Natural waters tend to be slightly acidic due to equilibrium between carbon dioxide, bicarbonate, and carbonate established when carbon dioxide is dissolved in water. This equilibrium produces low acidic pH value of at least 4.5 especially at night due to respiratory processes of plants. The pH gradually increases to at most 8.5 during daytime as carbon dioxide is consumed by photosynthetic processes.

Generally, pH values lower than 2.0 and higher than 12.0 present a problem to the ecology. Although certain types of bacteria can survive in extreme levels of pH, most flora and fauna are found to thrive in pH 6.9 to 9.0. Acidic water can be made basic by adding calcium carbonate from limestone, ashes from burned biomass, and caustic chemicals at regulated amounts. Table 36 below shows the pH range of water and its implications

Table 36. Implications of different pH levels of water on aquatic lives.

| pH level | Nature            | Implications  |
|----------|-------------------|---|
| 0        | Highly acidic     | Detrimental condition   |
| 1        |                   |   |
| 2        |                   |   |
| 3        | Acidic            | Only adaptive species can live.<br>Can cause physiological stress to most organisms |
| 4        |                   |   |
| 5        | Slightly acidic   | Optimum pH for aquatic life, and water consumption                                  |
| 6        |                   |   |
| 7        | Neutral           |   |
| 8        | Slightly alkaline |   |
| 9        |                   |   |
| 10       | Alkaline          |   |
| 11       |                   |   |
| 12       | Highly alkaline   | Detrimental condition   |
| 13       |                   |   |
| 14       |                   |   |

## 2. Water Oxygenation

### 2.1 Dissolved Oxygen

Adequate concentrations of dissolved oxygen are necessary for the life of 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. The level of dissolved oxygen in natural bodies of water should generally be high because oxygen is needed by the aerobic organisms for their metabolic activity. DO is typically expressed in units of parts per million (ppm) or milligrams per liter (mg/L). That is to say that certain

## Empowered Communities

mass of oxygen gas is dissolved in a liter of water. Values range from 0 to well above 10. Values falling within this range correspond to various conditions summarized in the following table.

Table 37. Dissolved oxygen concentration values and corresponding implications to aquatic lives.

| DO, ppm | Implications  |
|---------|---|
| 0       | <ul style="list-style-type: none"> <li>• Anoxic water</li> <li>• Extremely detrimental for aerobic organisms</li> <li>• Algae and anaerobic organism may overtake the water and give off unpleasant odor</li> </ul> |
| 1       |   |
| 2       |   |
| 3       | <ul style="list-style-type: none"> <li>• Tolerable DO concentration for a short period of time</li> <li>• Stressful condition for aerobic lives.</li> </ul>   |
| 4       |   |
| 5       |   |
| 6       | <ul style="list-style-type: none"> <li>• Condition is good for spawning and reproduction of aquatic animals</li> </ul>  |
| 7       | <ul style="list-style-type: none"> <li>• Ideal condition of spawning and growth of aerobic organisms</li> </ul>   |
| 8       |   |
| 9       |   |
| 10      | <ul style="list-style-type: none"> <li>• Supports abundant aerobic population</li> <li>• May lead to gas bubble disease and physical transformation of dissolved oxygen to gaseous oxygen.</li> </ul>               |

Anoxic water is the result of too much organic matters in the water. Decomposers have used up most of the dissolved oxygen leading to low concentrations. The by-products of the decomposition process gives the foul smell of the water and a dense discoloration. Those by products are also rich in nutrients for algae so bloom is expected to follow.

Low DO can be countered by introducing aquatic photosynthetic plants in the water. These plants will be giving off oxygen that will be dissolved in the water. However, the discoloration of the water should be taken in to account since colored water will not allow the sunlight to reach the plants under the water. Physical disturbance of the water surface by wind and waves can also increase the DO levels. Aeration can also be done using mechanical pumps similar to what is done in aquariums.

DAO 2016-34 accepts DO values of 7 ppm for class AA water. On the other hand, a DO value of 4 ppm are approved for industrial, agriculture and irrigation purposes and are classified under class D.

## 2.2 Biochemical Oxygen Demand

Microorganisms such as bacteria and fungi are the organisms responsible for the decomposition of organic matter in water. This decomposition is integrated in their metabolic process in order to continue thriving. The decomposition process also requires oxygen as most bacteria and fungi are aerobic. When the decompositions starts, the microorganisms obtain the necessary oxygen form the DO in water thereby reducing the quality of the water. Further, it makes sense that higher BOD values will consume more DO and lead to highly polluted water. Just like DO, the BOD is reported in ppm or mg/L. Table 38 shows the relative quality of the water as BOD level increases.

Table 38. Biological oxygen demand of water and corresponding water quality.

| BOD level, ppm | Water Quality   |
|----------------|---|
| 0              | <ul style="list-style-type: none"> <li>• Excellent water quality</li> <li>• Practically free of microorganisms</li> <li>• Fit for drinking</li> </ul>   |
| 1              | <ul style="list-style-type: none"> <li>• Good water quality</li> </ul>  |
| 2              | <ul style="list-style-type: none"> <li>• Some microorganisms are present</li> <li>• Suitable for bathing, household, and recreational use</li> </ul>  |
| 3              | <ul style="list-style-type: none"> <li>• Moderately clean water</li> <li>• Suitable for industrial use such as in boiler waters, and coolants</li> <li>• Suitable for use agriculture such in carp and tilapia fish ponds, and irrigation.</li> </ul> |
| 4              |   |
| 5              |   |
| 6              | <ul style="list-style-type: none"> <li>• Polluted water</li> <li>• Organic matter and bacteria are present in the water</li> <li>• Used only to conserve the ecology</li> </ul>   |
| 7              |   |
| 8              |   |
| 9              |   |

## Empowered Communities

|                 |  |
|-----------------|--|
| Greater than 10 | <ul style="list-style-type: none"> <li>• Extremely polluted water</li> <li>• Primarily made up of effluents from poultry farms, and sewage waters.</li> <li>• Recommended for immediate wastewater treatment before any use</li> </ul> |
|-----------------|--|

BOD levels are controlled through biological wastewater treatment plants such as activated sludge systems where the wastewater is aerated for the microorganisms to thrive and decompose the organic matter.

Typical wastewaters coming from poultry and sewage are expected to have at most 250 to 350 ppm of BOD. However, DAO 2016-35 requires that BOD value of the effluent be at 20-150 ppm to have it released in the surrounding body of water.

Table 39. Biological oxygen demand of water and corresponding water quality.

| BOD level, ppm | Water Quality   |
|----------------|---|
| 0              | <ul style="list-style-type: none"> <li>• Excellent water quality</li> <li>• Practically free of microorganisms</li> <li>• Fit for drinking</li> </ul>   |
| 1              | <ul style="list-style-type: none"> <li>• Good water quality</li> <li>• Some microorganisms are present</li> <li>• Suitable for bathing, household, and recreational use</li> </ul>  |
| 2              |   |
| 3              | <ul style="list-style-type: none"> <li>• Moderately clean water</li> <li>• Suitable for industrial use such as in boiler waters, and coolants</li> <li>• Suitable for use agriculture such in carp and tilapia fish ponds, and irrigation.</li> </ul> |
| 4              |   |
| 5              |   |
| 6              | <ul style="list-style-type: none"> <li>• Polluted water</li> <li>• Organic matter and bacteria are present in the water</li> <li>• Used only to conserve the ecology</li> </ul>   |
| 7              |   |
| 8              |   |
| 9              |   |

|                 |  |
|-----------------|--|
| Greater than 10 | <ul style="list-style-type: none"> <li>• Extremely polluted water</li> <li>• Primarily made up of effluents from poultry farms, and sewage waters.</li> <li>• Recommended for immediate wastewater treatment before any use</li> </ul> |
|-----------------|--|

### 2.3 Chemical Oxygen Demand

As discussed in previous chapters, different chemical species that require oxygen contribute to the chemical oxygen demand. As such, the chemical process of oxidation decreases the amount of oxygen dissolved in water and works simultaneously with aerobic organisms to further diminish it. Like DO and BOD, COD is reported in ppm or mg/L. Table 40 shows the class of water when certain COD value is achieved according to DAO 2016-35.

Table 40. Chemical oxygen demand of water and corresponding effluent water quality.

| COD level, ppm | Effluent Water Quality                 |
|----------------|--|
| Less than 60   | Freshwater quality.                    |
| 60             | Class A and Class B Effluent           |
| 100            | Class C Effluent                       |
| 200            | Class D Effluent                       |
| 300            | Effluent for discharge in coastal area |

Lower COD values are better. COD can be removed through coagulation, advanced oxidation processes or adsorption.

## 3. Solid Contents

### 1. Settleable Solids

Settleable solids are practically any solid that can settle at the bottom of a water sample if left undisturbed. Those solids include sand, gravel, metal chunks and other dense materials that can settle on its own. This parameter is mostly used to describe effluents. Freshwaters are expected to have very little value for this parameter. DAO 2016-35 requires at most 0.5 mg of solids per liter of effluent for it to be allowed for discharge in surrounding water body. High values for settleable solids can be mitigated by utilization of settling ponds that stores the effluent undisturbed for a period of

time until the solids have settled. Alternatively, filtration beds can also remove settleable solids smaller than the pore size of the filter.

**2. Total Suspended Particles**

Total suspended particles (TSP) differs from settleable solids by their sizes. After filtration of the water to remove settleable solids, all other solids that managed to pass are small enough to be affected by gravitational force and thus remain suspended in the water and do not settle at the bottom. These solids are 1 micrometer to 1 nanometer in size. Particles with this size are colloidal in nature and make the water appear cloudy. Although some of it can settle at a much slower rate and longer time, mitigation is hard and requires professionals and sophisticated equipment. Avoiding the agitation of water may help but up to minimal extent. It is removed through the coagulation process.

The TSP parameter can be used to describe both freshwater, and effluents inland and by the coast. Values of TSP needed for each class of water is summarized in Table 41.

Table 41. Total suspended solids for classes of freshwater and effluents.

| TSP,<br>ppm | Class of Water or Effluent |                    |                     |
|-------------|----------------------------|--------------------|---------------------|
|             | Freshwater                 | Effluent           |                     |
| 25          | Class AA                   | Inland<br>effluent | Coastal<br>effluent |
| 50          | Class A                    |                    |                     |
| 65          | Class B                    |                    |                     |
| 80          | Class C                    |                    |                     |
| 90          | Class D                    |                    |                     |
| 110         |                            |                    |                     |
| 150         | Not allowed                | Not<br>allowed     |                     |
| 260         |                            |                    |                     |

**3. Total Dissolved Solids**

Soluble salts like sodium chloride in seawater, and ammonium nitrates in fertilizers are the solids that contribute to the value of total dissolved solids (TDS). The main concern about these solids is that they can be easily absorbed by the body because of their very small effective size nearing that

of the atoms. Osmosis can happen on all cells if there is an imbalance of salt concentrations inside and outside the cells body. If concentrations of this solids inside the cell of living organism is higher than the concentration outside the cell, the cell may take in water to balance the concentration resulting to bloated cells and sometimes so bloated that it ruptures. On the other hand, if concentration is higher outside, the cell will be releasing out its water and will result to withered cell. Both bloated and withered cell conditions are fatal to the organism. In addition, dissolved salts also contribute to the taste of the water.. Reducing TDS is a task better left to the hands of wastewater treatment facility since treatment uses sophisticated filtration systems, reverse osmosis, and distillation. Values of TDS for freshwater and effluents are summarized in the following table.

Table 42. Total dissolved solids for classes of freshwater and effluents.

| TDS, ppm       | Class of Water or Effluent               |                 |                  |
|----------------|--|-----------------|------------------|
|                | Freshwater                               | Effluent        |                  |
| 50             | Class AA                                 | Inland effluent | Coastal effluent |
| 70             |  |                 |                  |
| 90             |  |                 |                  |
| 500            | Class A<br>Class B<br>Class C<br>Class D | Not allowed     |                  |
| 1000           |  |                 |                  |
| 2000           |  |                 |                  |
| More than 2000 |  |                 | Not allowed      |

**4. Heavy Metals**

The heavy metal parameter can be thought of as an extended TDS. Soluble salts of heavy metals are dissolved in water producing ions of heavy metals. Although salts, the common ions measured in TDS are safe to a relatively high value, concentrations of heavy metals are lethal due to its bioaccumulation where the metal ions bind with tissues, alter the functions, and remain there forever. Table 43 condenses the minimum concentration of heavy metal ions in various waters and effluents.

Table 43. Maximum allowable heavy metal content of freshwaters and effluents.

| Heavy metal | Maximum allowable concentration, ppm |                 |                  |
|-------------|--------------------------------------|-----------------|------------------|
|             | Freshwater                           | Inland Effluent | Coastal Effluent |
| Arsenic     | 0.05                                 | 0.10 - 0.50     | 0.50 - 1.00      |
| Cadmium     | 0.01                                 | 0.02 - 0.05     | 0.10 - 0.50      |
| Chromium    | 0.05                                 | 0.05 - 0.20     | 0.20 - 1.00      |
| Copper      | 0.05                                 | -               | -                |
| Lead        | 0.05                                 | 0.10 - 0.50     | 0.50 - 1.00      |
| Mercury     | 0.002                                | 0.005           | 0.01 - 0.05      |

High concentrations of any metal is extremely toxic. Mitigating high heavy metal content of water can be done by adsorption techniques.

### 5. Other Pollutants

Other water pollutants tackled in this handbook consists of cyanide, and oil and grease. DAO 2016-08 requires cyanide concentration of 0.07 ppm for a class AA freshwater and 0.20 ppm for a class D freshwater. Concentrations for marine water has a wider range of 0.02 ppm to 0.20 ppm for class A and class D marine water respectively. Although cyanide can occur naturally, it is not usual for it to end up in large amount in water. Any water sample containing high cyanide content is deemed contaminated by cyanide pollution.

For oil and grease content of a water sample, DENR requires that all freshwater and marine water has less than 5 ppm of oil and grease content. It also limits the value to 15 ppm for effluents.

## Air Quality Monitoring Data Interpretation

### 1. Particulate Content

Air quality in the Philippines is protected by a law as provided for in Republic Act 8749 (Clean Air Act of 1999 and its Implementing Rules and Regulations (DAO 2000-81). Under its provisions, for an ambient air, various pollutants must have defined concentration for a specific duration..

Table 44 summarizes the maximum allowable concentration of pollutants in air based on DAO 2000-81. Any value higher than the values stipulated indicates polluted air.

Table 44. Philippine ambient air quality guideline values.

| Pollutants       | Short time   |                   | Long Time                    |                |
|------------------|--|-------------------|------------------------------|----------------|
|                  | Concentration  | Averaging time    | Concentration                | Averaging time |
| TSP              | 230 $\mu\text{g}/\text{m}^3$                           | 24 hours          | 90 $\mu\text{g}/\text{m}^3$  | 1 year         |
| PM <sub>10</sub> | 150 $\mu\text{g}/\text{m}^3$                           | 24 hours          | 60 $\mu\text{g}/\text{m}^3$  | 1 year         |
| Sulfur dioxide   | 180 $\mu\text{g}/\text{m}^3$                           | 24 hours          | 80 $\mu\text{g}/\text{m}^3$  | 1 year         |
| Nitrogen dioxide | 150 $\mu\text{g}/\text{m}^3$                           | 24 hours          | 0                            | -              |
| Carbon monoxide  | 35 $\text{mg}/\text{m}^3$<br>10 $\text{mg}/\text{m}^3$ | 1 hour<br>8 hours | 0                            | -              |
| Lead             | 1.5 $\mu\text{g}/\text{m}^3$                           | 3 months          | 1.0 $\mu\text{g}/\text{m}^3$ | 1 year         |

The concentration indicated in table 44 is an average of all the data taken within the averaging time. For example, the concentration of the TSP may be 260  $\mu\text{g}/\text{m}^3$  at one specific hour of the day, but all the other samples are at a steady 100  $\mu\text{g}/\text{m}^3$  during the remaining time of the day, the TSP concentration is still allowed since the average for 24 hours does not exceed 230  $\mu\text{g}/\text{m}^3$ .

Spike of pollutant concentration in the air in short time periods are tackled in a separate guidelines issued by DENR. Table 45 shows the ambient air standards for pollutants from industrial sources.

Table 45. Philippine ambient air quality standards for pollutants from industrial sources.

| Pollutants                 | Concentration                         | Averaging time, mins |
|----------------------------|---------------------------------------|----------------------|
| Ammonia                    | 200 µg/m <sup>3</sup>                 | 30                   |
| Carbon disulphide          | 30 µg/m <sup>3</sup>                  | 30                   |
| Chlorine and its compounds | 100 µg/m <sup>3</sup>                 | 5                    |
| Formaldehyde/formalin      | 50 µg/m <sup>3</sup>                  | 30                   |
| Hydrogen chloride          | 200 µg/m <sup>3</sup>                 | 30                   |
| Hydrogen sulphide          | 100 µg/m <sup>3</sup>                 | 30                   |
| Lead                       | 20 µg/m <sup>3</sup>                  | 30                   |
| Nitrogen dioxide           | 375 µg/m <sup>3</sup>                 | 30                   |
|                            | 260 µg/m <sup>3</sup>                 | 60                   |
| Phenol                     | 100 µg/m <sup>3</sup>                 | 30                   |
| Sulfur dioxide             | 470 µg/m <sup>3</sup>                 | 30                   |
|                            | 340 µg/m <sup>3</sup>                 | 60                   |
| TSP                        | 300 µg/m <sup>3</sup>                 | 60                   |
| PM <sub>10</sub>           | 200 µg/m <sup>3</sup>                 | 60                   |
| Antimony                   | 0.02 mg/m <sup>3</sup>                | 30                   |
| Arsenic                    | 0.02 mg/m <sup>3</sup>                | 30                   |
| Cadmium                    | 0.01 mg/m <sup>3</sup>                | 30                   |
| Asbestos                   | 2 million particulates/m <sup>3</sup> | 30                   |
| Sulfuric acid              | 0.3 mg/m <sup>3</sup>                 | 30                   |
| Nitric acid                | 0.4 mg/m <sup>3</sup>                 | 30                   |

## Soil Quality Monitoring Data Interpretation

### 1. Soil pH

The pH of saturated water extracts of soil, known as soil pH, affects various properties and processes. Low pH tend to dissolve most vital metal nutrients and make it available for the soil while high pH transform metal ions to insoluble ones making absorption impossible. Bacteria are well suited to acidic soil while fungi can work at a wider range of pH. Good pH is needed for bacteria to speed up the decomposition process of organic materials and make it available for absorption by the plants. Most plants prefer growing in slightly basic soil. Presently, no law regulates the quality of soil in the Philippines. The Soil Quality organization headed by Dr. Michelle Wander of Agroecology and Sustainable Agriculture Program of University of Illinois suggests an optimum soil pH for growing plants and microorganisms. These levels and their implications are illustrated in Table 46.

Table 46. Implications of different pH levels of soil on plants and microorganisms.

| pH level | Nature            | Implications   |
|----------|-------------------|--|
| 0        | Highly acidic     | Detrimental condition  |
| 1        |                   |  |
| 2        |                   |  |
| 3        | Acidic            | Only adaptive species can live.<br>Can cause physiological stress to most organisms            |
| 4        |                   |  |
| 5        | Slightly acidic   | Optimum condition for growth of fungi  |
| 6        |                   |  |
| 7        | Neutral           | Optimum pH for plants and microorganisms like blue-green bacteria, actinomycetes, and protozoa |
| 8        | Slightly alkaline |  |
| 9        | alkaline          | Only adaptive species can live.<br>Can cause physiological stress to plants                    |
| 10       | Alkaline          |  |
| 11       |                   |  |
| 12       | Highly alkaline   | Detrimental condition  |
| 13       |                   |  |
| 14       |                   |  |

Soil pH are mostly made acidic by the same factors that cause acidity of water. If alarming decline in pH is evident, the soil can be made basic by addition of lime, egg shells, or baking soda. If pH is rising, applying ammonium-based fertilizers, urea, saw dusts, or rice husks can counter the problem. Adding organic matter can increase the buffering capacity of the soil that is to increase its resistance to change pH.

### 2. Soil salinity

In essence, soil salinity can be thought of as TDS applied to soil since the term salinity generally applies to how much ions are present. Soils become saline when there is an overuse of water with high TDS value and application of excessive fertilizers. Seawater can also cause soil salinity in instances where sea water seep in underground far enough to affect the inland soil. High soil salinity can be easily spotted. Formation of white crusts in soil surface, poor drainage, black powdery residues, gray-colored soil, yellow spots or discolorations on the leaves, and leaf tip burns are all symptoms of saline soil. Sonon and colleagues in the Agricultural and Environmental Services Laboratories in University of Georgia adopted the guidelines in table 47 for interpreting salinity of soil.

Table 47. Implications of different concentration of dissolved salts in soil

| Salinity, ppm  | Nature           | Implications  |
|----------------|------------------|---|
| 0 - 96         | Very low         | Deficiency of nutrients for plants  |
| 97 - 320       | Low              | Satisfactory of soil is high in organic matter                              |
| 321 - 800      | Medium           | Satisfactory for established plants   |
| 801 - 1120     | High             | Best condition for established plants<br>Too high for seedlings or cuttings |
| 1121 - 1280    | Very high        | Plants wither or become pale in color                                       |
| More than 1280 | Excessively high | Plants severely dwarfed, or die   |

In case of extremely high salinity, the soil can be reclaimed by leaching process which is done by irrigating the soil to a certain depth. Generally, flooding the soil with 6, 12, and 24 inches of water removes 50%, 80%, and 90% of the salt content of the soil.

## Important Points to Remember

- Specific parameters require different data interpretation. It is not enough that samples are collected and tested. Interpretation of the data collected is of value to ensure that allowable thresholds and ranges for all parameters are well-monitored and public health and safety are accounted for.
- For water quality, this handbook refers to standards embodied in DAO 2016-34. For air quality, standards used are derived from the Republic Act 8749 (Clean Air Act of 1999) and its Implementing Rules and Regulations (DAO 2000-81). However, for soil quality, there is no existing domestic legal framework on acceptable standards thus, this handbook uses the suggested standards developed by the Soil Quality organization headed by Dr. Michelle Wander of Agroecology and Sustainable Agriculture Program of University of Illinois.

## ENDNOTES

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<sup>1</sup> <http://newsinfo.inquirer.net/516883/china-firm-uses-shore-as-waste-pond>

<sup>2</sup> DENR CDAO 2010-21, Section 3

<sup>3</sup> DENR CDAO 2010-21, Section 173.

<sup>4</sup> An AEPEP or “Annual Environmental Protection and Enhancement Program” refers to a yearly environmental management work plan based on the approved environmental protection and enhancement strategy.

<sup>5</sup> DENR CDAO 2010-21, Section 181

<sup>6</sup> DAO 003-15 (IRR of R. A. No. 7076).

<sup>7</sup> DENR CDAO 2010-21, Section 194-195.

<sup>8</sup> DENR CDAO 2010-21, Section 196.

<sup>9</sup> DENR CDAO 2010-21, Section 183.

<sup>10</sup> DENR CDAO 2010-21, Section 182.

<sup>11</sup> An FMRDF or a Final Mine Rehabilitation and Decommissioning Fund shall be established by each operating Contractor/Permit Holder to ensure that the full cost of the approved FMR/DP is accrued before the end of the operating life of the mine. The FMRDF shall be deposited as a trust fund in a Government depository bank and shall be used solely for the implementation of the approved FMR/DP

<sup>12</sup> DENR CDAO 2010-21, Section 183

<sup>13</sup> Ibid.

<sup>14</sup> Cognizant of the need to ensure just and timely compensation for damages and progressive and sustainable rehabilitation for any adverse effect a mining operation or activity may cause, the Department through the Bureau shall institutionalize an environmental guarantee fund mechanism to be known collectively as the CLRF.

The CLRF shall be in the form of the MRF, the MWT Fees and the Final Mine Rehabilitation and Decommissioning Fund and shall be administered by the CLRF Steering Committee.

<sup>15</sup> DENR CDAO 2010-21, Section 186.

<sup>16</sup> The EIS or the The EIS System is concerned primarily with assessing the direct and indirect impacts of a project on the biophysical and human environment and ensuring that these impacts are addressed by appropriate environmental protection and enhancement measures. The EIS System aids proponents in incorporating environmental considerations in planning their projects as well as in determining the environment's impact on their project.

<sup>17</sup> DAO 2003-30, Section 1.

<sup>18</sup> DAO 2003-30, Section 4.

<sup>19</sup> DAO 2003-30, Section 9.

<sup>20</sup> The EMP or the Environmental Management Plan/Program section in the EIS that details the prevention, mitigation, compensation, contingency and monitoring measures to enhance positive impacts and minimize negative impacts and risks of a proposed project or undertaking. For operating projects, the EMP can also be derived from an EMS

<sup>21</sup> DAO 1996-37.

<sup>22</sup> IEE or the Initial Environmental Examination Report is a document similar to an EIS, but with reduced details and depth of assessment and discussion.

<sup>23</sup> The PENRO or CENRO refers to the Provincial Environment and Natural Resources Officer or Community Environment and Natural Resources Officer of the Department of Environment and Natural Resources (DENR) is responsible for the implementation of DENR policies, programs, project and activities and the enforcement of ENR laws and regulations in the community level.

<sup>24</sup> DAO 1996-37, Section 10.

<sup>25</sup> DAO 1996-37, Section 12.

<sup>26</sup> An SMR or the self-monitoring system is part of the compliance monitoring system of the DENR. The SMR has two basic objectives:

- It allows firms or establishments to demonstrate their compliance with environmental regulations (e.g. P.D. 984, P.D. 1586, R.A. 6969, R.A. 8743); and,
- It allows EMB to confirm or validate that firms or establishments comply with environmental regulations or requirements and it also provides for the mechanism needed to standardized SMR requirement as provided in DAO 2003-14.

<sup>27</sup> The EIA or Environmental Impact Assessment is a the compliance monitoring system of the DENRting the likely impacts of a project (including cumulative impacts) on the environment during construction, commissioning, operation and abandonment. It also includes designing appropriate preventive, mitigating and enhancement measures addressing these consequences to protect the environment and the community' s welfare".

<sup>28</sup> DAO 2015-02.

<sup>29</sup> DAO 2015-02, Section 6.

<sup>30</sup> DENR CDAO 2010-21, Section 185.

<sup>31</sup> DAO 2015-02.

<sup>32</sup> R. A. No. 7076, Section 24.

<sup>33</sup> DAO 003-15 (IRR of R. A. No. 7076).

<sup>34</sup> DAO 003-15 (IRR of R. A. No. 7076).

<sup>35</sup> DAO 003-15 (IRR of R. A. No. 7076).

<sup>36</sup> DAO 003-15 (IRR of R. A. No. 7076).

<sup>37</sup> DAO 003-15 (IRR of R. A. No. 7076).

<sup>38</sup> DAO 003-15 (IRR of R. A. No. 7076).

<sup>39</sup> DAO 003-15 (IRR of R. A. No. 7076).

<sup>40</sup> DAO 003-15 (IRR of R. A. No. 7076).

<sup>41</sup> DAO 003-15 (IRR of R. A. No. 7076).

<sup>42</sup> DAO 003-15 (IRR of R. A. No. 7076).

<sup>43</sup> DENR CDAO 2010-21, Section 70 and 102.

<sup>44</sup> DENR MC 1997-05.

<sup>45</sup> DAO 003-15.

<sup>46</sup> DENR MC 1997-05.

<sup>47</sup> WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, Preface.

<sup>48</sup> WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p7.

<sup>49</sup> Ambient (outdoor) Air Quality and Health, Fact sheet N°313, Updated March 2014

<sup>53</sup> WHO Air quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p9.

<sup>54</sup> WHO Air quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p10.

<sup>55</sup> WHO Air quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p10.

<sup>56</sup> WHO Air quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p12.

<sup>57</sup> WHO Air quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p11.

<sup>58</sup> WHO Air quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p14.

<sup>59</sup> WHO Air quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p15.

<sup>60</sup> WHO Air quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p16.

<sup>61</sup> WHO Air quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p17.

<sup>62</sup> WHO Air quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p18.

<sup>63</sup> WHO Air quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide Global Update 2005 Summary of risk assessment, 2006, p18.

<sup>64</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p2.

<sup>65</sup> These numerical guideline values are best accessed and understood from the Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011 directly.

<sup>66</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, Preface.

<sup>67</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p4.

<sup>68</sup> The Application of the Guidelines and the Supporting Information are best taken directly from the Guidelines itself and will not be presented in this chapter.

<sup>69</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p35.

<sup>70</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p36.

<sup>71</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p39.

<sup>72</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p47.

<sup>74</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p48.

<sup>75</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p49.

<sup>76</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p54.

<sup>77</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p55.

<sup>78</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p57.

<sup>79</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p50.

<sup>80</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p51.

<sup>81</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p51.

<sup>82</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p52.

<sup>83</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p52.

<sup>84</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p62. Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p52.

<sup>85</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p 62.

<sup>86</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p 65.

<sup>87</sup> Supporting Programmes are those that ensure drinking-water safety but do not directly affect drinking-water quality and are therefore not control measures.

<sup>88</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p 76.

<sup>89</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p 76.

<sup>90</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p 9.

<sup>91</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p 9.

<sup>92</sup> Guidelines for Drinking-Water Quality, 4<sup>th</sup> Edition, 2011, p 9.

<sup>93</sup> Ambient air quality guideline values refers to the concentration of air over specified periods classified as short-term and/or long-term which are intended to serve as goals or objectives for the protection of health and/or public welfare. These values shall be used for air quality management purposes such as determining time trends, evaluating stages of deterioration or enhancement of the air quality. In general, used as a basis for taking positive action in preventing, controlling, or abating health impacts from air pollution (Source: RA 8749 IRR).

<sup>94</sup> Normal Cubic Meter (NCM) means the volume of dry gas which occupies a cubic meter measured at twenty five degrees Celsius (25o) at an absolute pressure equivalent to seven hundred sixty (760) mm Hg (Source: RA 8749 IRR).

<sup>95</sup> Sulfur dioxide (SO<sub>2</sub>) is a colorless gas with a pungent smell at low concentrations. Fossil fuel combustion, power plants and other industrial facilities are the main sources of SO<sub>2</sub> in the atmosphere. In the atmosphere, it can undergo chemical reactions (oxidation) creating sulfur trioxide, particulate sulfates and sulphuric acid which can lead to acid rain. Exposure to SO<sub>2</sub> can have adverse respiratory effects and heart diseases. (Source: NASQSR 2012-2013)

<sup>96</sup> Particulate Matter or Suspended Particulates means any material, other than uncombined water, which exists in a finely divided form as a liquid or solid (Source: RA 8749 IRR).

<sup>97</sup> Total Suspended Particulates (TSP) refers to all atmospheric particles in the atmosphere with diameters equal to or less than 100 micrometers. These relatively 'coarse' particles are mainly related to soiling and dust nuisance. On the other hand, particulates with diameters less than 10 micrometers are called Particulate Matter (PM) and are of greater health concern as they can penetrate deep into the lungs. PM with diameters less than 10 micrometers are specifically called PM<sub>10</sub> while PM with diameters less than 2.5 micrometers are called PM<sub>2.5</sub>. (Source: NASQSR 2012-2013).

<sup>98</sup> APPENDIX B TO PART 50—REFERENCE METHOD FOR THE DETERMINATION OF SUSPENDED PARTICULATE MATTER IN THE ATMOSPHERE (HIGH-VOLUME METHOD): This method provides a measurement of the mass concentration of total suspended particulate matter (TSP) in ambient air for determining compliance with the primary and secondary national ambient air quality standards for particulate matter as specified in § 50.6 and § 50.7 of this chapter. The measurement process is nondestructive, and the size of the sample collected is usually adequate for subsequent chemical analysis. (Source: <https://www.law.cornell.edu/cfr/text/40/part-50/appendix-B>)

<sup>99</sup> APPENDIX J TO PART 50—REFERENCE METHOD FOR THE DETERMINATION OF PARTICULATE MATTER AS PM<sub>10</sub> IN THE ATMOSPHERE: This method provides for the measurement of the mass concentration of particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers (PM<sub>10</sub>) in ambient air over a 24-hour period for purposes of determining attainment and maintenance of the primary and secondary national ambient air quality standards for particulate matter specified in §50.6 of this chapter. The measurement process is nondestructive, and the PM<sub>10</sub> sample can be subjected to subsequent physical or chemical analyses. (Source: <http://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol2/pdf/CFR-2011-title40-vol2-part50-appJ.pdf>)

<sup>100</sup> APPENDIX A-1 TO PART 50—REFERENCE MEASUREMENT PRINCIPLE AND CALIBRATION PROCEDURE FOR THE MEASUREMENT OF SULFUR DIOXIDE IN THE ATMOSPHERE (ULTRAVIOLET FLUORESCENCE METHOD): This ultraviolet fluorescence (UVF) method provides a measurement of the concentration of sulfur dioxide (SO<sub>2</sub>) in ambient air for determining compliance with the national primary and secondary ambient air quality standards for sulfur oxides (sulfur dioxide) as specified in § 50.4, § 50.5, and § 50.17 of this chapter. The method is applicable to the measurement of ambient SO<sub>2</sub> concentrations using continuous (real-time) sampling. (Source: <https://www.law.cornell.edu/cfr/text/40/part-50/appendix-A-1>)

<sup>101</sup> APPENDIX F TO PART 50—MEASUREMENT PRINCIPLE AND CALIBRATION PROCEDURE FOR THE MEASUREMENT OF NITROGEN DIOXIDE IN THE ATMOSPHERE (GAS PHASE CHEMILUMINESCENCE): Atmospheric concentrations of nitrogen dioxide (NO<sub>2</sub>) are measured indirectly by photometrically measuring the light intensity, at wavelengths greater than 600 nanometers, resulting from the chemiluminescent reaction of nitric oxide (NO) with ozone (O<sub>3</sub>). (1,2,3) NO<sub>2</sub> is first quantitatively reduced to NO(4,5,6) by means of a converter. NO, which commonly exists in ambient air together with NO<sub>2</sub>, passes through the converter unchanged causing a resultant total NO<sub>x</sub> concentration equal to NO + NO<sub>2</sub>. A sample of the input air is also measured without having passed through the converter. This latter NO measurement is subtracted from the former measurement (NO + NO<sub>2</sub>) to yield the final NO<sub>2</sub> measurement. The NO and NO + NO<sub>2</sub> measurements may be made concurrently

with dual systems, or cyclically with the same system provided the cycle time does not exceed 1 minute.

(Source: <https://www.law.cornell.edu/cfr/text/40/part-50/appendix-F>)

<sup>102</sup> APPENDIX D TO PART 50—MEASUREMENT PRINCIPLE AND CALIBRATION PROCEDURE FOR THE MEASUREMENT OF OZONE IN THE ATMOSPHERE

### Measurement Principle

1. Ambient air and ethylene are delivered simultaneously to a mixing zone where the ozone in the air reacts with the ethylene to emit light, which is detected by a photomultiplier tube. The resulting photocurrent is amplified and is either read directly or displayed on a recorder.
2. An analyzer based on this principle will be considered as a reference method only if it has been designated as a reference method in accordance with part chapter and calibrated as follows:

### Calibration Procedure

1. Principle. The calibration procedure is based on the photometric assay of ozone (O<sub>3</sub>) concentrations in a dynamic flow system. The concentration of O<sub>3</sub> in an absorption cell is determined from a measurement of the amount of 254 nm light absorbed by the sample. This determination requires knowledge of (1) the absorption coefficient ( $\alpha$ ) of O<sub>3</sub> at 254 nm, (2) the optical path length ( $l$ ) through the sample, (3) the transmittance of the sample at a wavelength of 254 nm, and (4) the temperature ( $T$ ) and pressure ( $P$ ) of the sample. The transmittance is defined as the ratio  $I/I_0$ , where  $I$  is the intensity of light which passes through the cell and is sensed by the detector when the cell contains an O<sub>3</sub> sample, and  $I_0$  is the intensity of light which passes through the cell and is sensed by the detector when the cell contains zero air. It is assumed that all conditions of the system, except for the contents of the absorption cell, are identical during measurement of  $I$  and  $I_0$ . The quantities defined above are related by the Beer-Lambert absorption law, where:

$\alpha$  = absorption coefficient of O<sub>3</sub> at 254 nm = 308 ± 4 atm – 1 cm<sup>-1</sup> at 0 °C and 760 torr. <sup>3(1 2 3 4 5 6 7)</sup>

$c$  = O<sub>3</sub> concentration in atmospheres

$l$  = optical path length in cm

In practice, a stable O<sub>3</sub> generator is used to produce O<sub>3</sub> concentrations over the required range.

Each O<sub>3</sub> concentration is determined from the measurement of the transmittance ( $I/I_0$ ) of the sample at 254 nm with a photometer of path length  $l$  and calculated from the equation,

The calculated O<sub>3</sub> concentrations must be corrected for O<sub>3</sub> losses which may occur in the photometer and for the temperature and pressure of the sample.

2. Applicability. This procedure is applicable to the calibration of ambient air O<sub>3</sub> analyzers, either directly or by means of a transfer standard certified by this procedure. Transfer standards must meet the requirements and specifications set forth in Reference 8.

(<https://www.law.cornell.edu/cfr/text/40/part-50/appendix-D>)

<sup>103</sup> APPENDIX C TO PART 50—MEASUREMENT PRINCIPLE AND CALIBRATION PROCEDURE FOR THE MEASUREMENT OF CARBON MONOXIDE IN THE ATMOSPHERE (NON-DISPERSIVE INFRARED PHOTOMETRY): This non-dispersive infrared photometry (NDIR) Federal Reference Method (FRM) provides measurements of the concentration of carbon monoxide (CO) in ambient air for determining compliance with the primary and secondary National Ambient Air Quality Standards (NAAQS) for CO as specified in § 50.8 of this chapter. The method is applicable to continuous sampling and measurement of ambient CO concentrations suitable for determining 1-hour or longer average measurements. The method may also provide measurements of shorter averaging times, subject to specific analyzer performance limitations. Additional CO monitoring quality assurance procedures and guidance are provided in part 58, appendix A, of this chapter and in reference 1 of this appendix C.

(Source: <https://www.law.cornell.edu/cfr/text/40/part-50/appendix-C>)

<sup>104</sup> US EPA 40 CFR, Part 50, APPENDIX G: The proposed FRM uses the ambient air sample collection procedures of the high-volume TSP method (40 CFR part 50, Appendix B) and the analytical procedure for the measurement of Pb based on ICP-MS. Two extraction methods are proposed: one using heated

ultrasonic and one using heated block digestion. The proposed extraction methods and ICP-MS analysis method have been tested and found acceptable for extraction of Pb from glass fiber, Teflon®, or quartz filter media (Rice 2013). The proposed method will replace the existing FRM specified in 40 CFR part 50, Appendix G. Although the existing FRM in Appendix G is adequate, the proposed FRM offers advantages over the current FRM by providing improved sensitivity or detection limits, precision, sample throughput, and extraction efficiency. (<http://www3.epa.gov/airquality/lead/pdfs/20130125fr.pdf>)

<sup>105</sup> <https://www.law.cornell.edu/cfr/text/40/part-53>

<sup>106</sup> RA 8749 IRR, Rule VII National Air Quality, Section 1.

<sup>107</sup> RA 8749 IRR, Part III Maintenance of Attainment Areas, Rule VIII Attainment Areas- General, Section 1.

<sup>108</sup> RA 8749 IRR, Part III Maintenance of Attainment Areas, Rule VIII Attainment Areas- General, Section 4.

<sup>109</sup> Ambient air quality standard means the concentration of an air pollutant which, in order to protect public health and/or public welfare, shall not be exceeded in the breathing zone, at any time. Standards are enforceable and must be complied with by the owner or person in-charge of an industrial operation, process or trade (Source: RA 8749 IRR).

<sup>110</sup> RA 8749 IRR, Rule X New / Modified Sources in Attainment Areas, Section 1.

<sup>111</sup> RA 8749 IRR Rule X New / Modified Sources in Attainment Areas, Section 3.

<sup>112</sup> PERFORMANCE SPECIFICATION 3 -- SPECIFICATIONS AND TEST PROCEDURES FOR O<sub>2</sub> AND CO<sub>2</sub> CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES: This specification is to be used for evaluating acceptability of O<sub>2</sub> and CO<sub>2</sub> continuous emission monitoring systems (CEM's) at the time of or soon after installation and whenever specified in an applicable subpart of the regulations. The specification applies to O<sub>2</sub> or CO<sub>2</sub> monitors that are not included under Performance Specification 2 (PS 2). This specification is not designed to evaluate the installed CEMS performance over an extended period of time, nor does it identify specific calibration techniques and other auxiliary procedures to assess the CEMS performance. The source owner or operator, however, is responsible to calibrate, maintain, and operate the CEMS properly. To evaluate the CEMS performance, the Administrator may require, under Section 114 of the Act, the operator to conduct CEMS performance evaluations in addition to the initial test.

Reference method (RM) tests and calibration drift tests are conducted to determine conformance of the CEMS with the specification. (Source: [http://www.deq.state.or.us/aq/forms/sourcetest/appendix\\_b.pdf](http://www.deq.state.or.us/aq/forms/sourcetest/appendix_b.pdf))

<sup>113</sup> Opacity means the amount of light obscured by particle pollution in the atmosphere (Source: RA 8749 IRR).

<sup>114</sup> NASQR 2012-2013.

<sup>115</sup> RA 8749, Part VII Pollution from Stationary Sources, Rule XXV Stationary Sources- General, Section 1.

<sup>116</sup> Ringelmann Chart means the chart described in the U.S. Bureau of Mines, Information Circular No. 8333 and No. 7718, and used for measuring smoke opacity (Source: RA 8749 IRR).

<sup>117</sup> RA 8749, Part VII Pollution from Stationary Sources, Rule XXV Stationary Sources- General, Section 2.

<sup>118</sup> RA 8749, Part VII Pollution from Stationary Sources, Rule XXV Stationary Sources- General, Section 3.

<sup>119</sup> RA 8749, Rule XXVI Source Specific Ambient Air Quality Standards, Section 1.

<sup>120</sup> RA 8749, Annex A.

<sup>121</sup> Water Quality Monitoring Manual Volume I: Manual on Ambient Water Quality Monitoring, Preface.

<sup>122</sup> Water Quality Monitoring Manual Volume 1: Ambient Water Quality Monitoring (EMB-DENR, 2008).

<sup>123</sup> Ibid.

<sup>124</sup> In general, this refers to current best beneficial use that is expected to last, at least, for the next 10 to 20 years. In special cases when dictated by political, economic, social, public health, Environmental and other considerations, certain waters may be classified according to the intended or future beneficial use (Source: DENR AO 34-1990).

<sup>125</sup> "Coastal Water" means an open body of water along the country's coastline starting from the shoreline (MLLW) and extending outward up to the 200- meter isobath or three-kilometer distance, whichever is farther (Source: DENR AO 35-1990).

<sup>127</sup> "BOD" means a measure of the approximate quantity of dissolved oxygen that will be required by bacteria to stabilize organic matter in wastewater or surface water. It is a semi-quantitative measure of the wastewater organics that are oxidizable by bacteria. It is also a standard test in assessing wastewater strength. (Source: DAO 35-1990)

<sup>128</sup>

1. Except as otherwise indicated, the numerical limits in Table 9 and 12 is yearly average values. Values enclosed in parentheses are maximum values;
2. For irrigation purposes, SAR should have a minimum value of 8 and a maximum value not to exceed 18. Boron should not exceed 0.75 mg/L;
3. No abnormal discoloration from unnatural causes;
4. The allowable temperature increase over the average ambient temperature for each month. This rise shall be based on the average of the maximum daily temperature readings recorded at the site but upstream of the mixing zone over a period of one (1) month;
5. Sampling taken between 9:00 AM and 4:00 PM;
6. Not more than 30% increase;
7. Not more than 30 mg/L increase;
8. Not more than 60 mg/L increase;
9. Do not apply if natural background is higher in concentration. The latter will prevail will be used as baseline;
10. Applicable only to lakes or reservoirs, and similarly impounded water;
11. When applied to lakes or reservoirs, the Phosphate as P concentration should not exceed an average of 0.05 mg/L nor a maximum of 0.1 mg/L;
12. Not present in concentrations to affect fish flavor/taste;
13. These values refer to the geometric mean of the most probable number of coliformorganism during a 3-month period and that the limit indicated shall not be exceeded in 20 percent of the samples taken during the same period;
14. For spawning areas for Chanoschanos and other similar species;
15. Limit is in terms of dissolved copper;
16. "nil"- Extremely low concentration and not detectable by existing equipment;
17. "---" - Means the standard of these substances are not considered necessary for the present time, considering the stage of the country's development and DENR capabilities, equipment and resources; and
18. "Nr"- Means No Recommendation made (Source: DAO 34-1990)

<sup>129</sup> Limiting values of organophosphates and organochlorines may in the meantime serve as guidelines in the interim period pending the procurement and availability of necessary laboratory equipment. For Barium, Cobalt, Fluoride, Iron, Lithium, Manganese, Nickel, Selenium, Silver and Vanadium, the 1978 NPCC Rules and Regulations, Section 69 may be considered. (Source: DAO 34-1990)

<sup>130</sup> Limiting values of organophosphates and organochlorines may in the meantime serve as guidelines in the interim period pending the procurement and availability of necessary laboratory equipment. For Barium,

Cobalt, Fluoride, Iron, Lithium, Manganese, Nickel, Selenium, Silver and Vanadium, the 1978 NPCC Rules and Regulations, Section 69 may be considered (Source: DAO 34-1990).

<sup>131</sup> "NPI" means New/Proposed Industry or wastewater treatment plants to be constructed.

<sup>132</sup> "OEI" means Old or Existing Industry.

<sup>133</sup> The effluent standards for heavy metals and toxic substances in Table 5 are applicable to all establishments, regardless of volume (Source: EMB MC 2012-01).

<sup>134</sup> "Inland Water" means an interior body of water or watercourse such as lakes, reservoirs, rivers, streams, creeks, etc., that has beneficial usage other than public water supply or primary contact recreation. Tidal affected rivers or streams are considered inland waters for purposes of these regulations.

<sup>135</sup> For tables 22 and 23, the following notes are applicable:

1. In cases where the background level of Total Dissolved Solids (TDS) in freshwater rivers, lakes, reservoirs and similar bodies of water is higher than the Water Quality Criteria, the discharge should not increase the level of TDS in the receiving body of water by more than ten percent of the background level;
2. The COD limits in Tables 22 and 23 generally apply to domestic wastewater treatment plant effluent. For industrial discharges, the effluent standards for COD should be on a case to case basis considering the COD – BOD ratio after treatment. In the interim period that this ratio is not yet established by each discharger, the BOD requirements shall be enforced;
3. There are no effluent standards for chloride except for industries using brine and discharging into inland waters, in which case the chloride content should not exceed 500 mg/L; and
4. The effluent standards apply to industrial manufacturing plants and municipal treatment plants discharging more than thirty (30) cubic meters per day. (Source: DAO 35-1990)
5. Establishments are required to comply with the effluent standards in Table 22 and 23, except those discharging 30 or less than 30 m<sup>3</sup>/ day (Source: EMB MC 2012-001)
6. However, Tables 22 and 23 will apply regardless if any of the following conditions are present:
  - a. If the quality of the RBW has consistently exceeded the WQ criteria for Class D and Class SD for inland and marine waters, respectively, for at least six months preceding the date in question;
  - b. If the industrial establishment is within the catchment basin of a lake or a water body proclaimed by the DENR for rehabilitation under the Rivers Revival program such as Pasig River, Tullahan-Tenejeros River etc.;
  - c. If the discharge is considered strong wastewater or that which has BOD in the raw wastewater of at least 3,000 mg/L;
  - d. If the discharge causes consistent deterioration of the receiving body of water with respect to its classification for at least one month singly or in combination with other dischargers within the catchment; and
  - e. If the RBW is declared by the DENR as non-suitable for any amount of discharge (Source: EMB MC 2012-001)

<sup>136</sup> Notes for Table 24:

1. Use either the numerical limit or percentage removal whichever is lower (or whichever is more strict);
2. Starting January 1, 1995, the applicable effluent requirements for old or existing industries are indicated in Table 25; and
3. For parameters other than BOD, Tables 22 and 23 both under Section 5 shall apply. (Source: DAO 35-1990)

<sup>137</sup> Notes for Table 25:

1. Use either numerical limits or percentage removal whichever is lower (or whichever is stricter).
2. For parameters other than BOD, Tables 22 and 23 shall apply (Source: DAO 35-1990).

<sup>138</sup> DAO 35-1990, Section 7.

<sup>139</sup> DAO 35-1990, Section 8.

<sup>140</sup> "Effluent" is a general term denoting any wastewater, partially or completely treated, or in its natural state, flowing out of a manufacturing plant, industrial plant or treatment plant (Source: DAO 35-1990).

<sup>141</sup>

Sajona, F. D., & Domingo, E. G. (2011). Philippine Mineral Exploration Perspective. Mining Philippines. Manila.

<sup>142</sup>

Sajona, F. D., & Domingo, E. G. (2011). Philippine Mineral Exploration Perspective. Mining Philippines. Manila.

<sup>143</sup> Mines & Geosciences Bureau. "Mining Industry Statistics." 2015. Mines & Geosciences Bureau. "Philippine Metallic Production." 2015.

<sup>144</sup> Hartman, Howard L, and Jan M Mutmanský. Introductory Mining Engineering. John Wiley & Sons, Inc., n.d.

1. <sup>145</sup> Hartman, Howard L, and Jan M Mutmanský. Introductory Mining Engineering. John Wiley & Sons, Inc., n.d.

<sup>146</sup> Hentschel, Thomas, Felix Hruschka, and Michael Priester. Global Report on Artisanal & Small-Scale Mining. International Institute for Environment and Development, World Business Council for Sustainable Development, 2002.

2. <sup>147</sup> Carbonell, C. (2015, January 29). The Philippines Leads the World in Nickel Production. Retrieved August 27, 2016, from <https://www.ceicdata.com>

<sup>148</sup> Arpacioğlu, C. B., and C. Er. "Estimation of Fugitive Dust Impacts of Open-Pit Mines on Local Air Quality - A Case Study: Bellavista Gold Mine, Costa Rica." 18th International Mining Congress and Exhibition of Turkey. Ankara, 2003.

<sup>149</sup> Blacksmith Institute. Artisanal Gold Mining - Central Kalimantan. 2016.

<http://www.blacksmithinstitute.org/projects/display/165> (accessed February 28, 2016)

