Guidelines for Designing and Implementing Aquatic Effects Monitoring Programs for Development Projects in the Northwest Territories

Recommended Procedures for Evaluating, Compiling, Analyzing, Interpreting, and Reporting Data and Information Collected under Aquatic Effects Monitoring Programs

AEMP Technical Guidance Document
Volume 6

Indian and Northern Affairs Canada
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List of Acronyms

AEMP	-	Aquatic Effects Monitoring Program
CCME	-	Canadian Council of Ministers of the Environment
CEAA	-	Canadian Environmental Assessment Act
DQO	-	data quality objective
EEM	-	Environmental Effects Monitoring
EQG	-	environmental quality guideline
EQO	-	environmental quality objective
FSP	-	field sampling plan
GIS	-	geographic information system
GLWB	-	Gwich'in Land and Water Board
HSP	-	health and safety plan
INAC	-	Indian and Northern Affairs Canada
K_{oc}	-	organic carbon partition coefficient
K_{ow}	-	octanol water partition coefficient
LWB	-	the Land and Water Board
MRP	-	Management Response Plan
MVEIRB	-	Mackenzie Valley Environmental Impact Review Board
MVLWB	-	Mackenzie Valley Land and Water Board
MVRMA	-	Mackenzie Valley Resource Management Act
NWTWA	-	Northwest Territories Water Act
NWTWB	-	Northwest Territories Water Board
NWT	-	Northwest Territories
QAPP	-	quality assurance project plan
QA/QC	-	quality assurance/quality control
SLWB	-	Sahtu Land and Water Board
TK	-	Traditional Knowledge
USEPA	-	U.S. Environmental Protection Agency
VEC	-	valued ecosystem component
WLWB	-	We'eezhii Land and Water Board
WQG	-	water quality guideline
WQO	-	water quality objective

1.0 Introduction

Evaluation, compilation, analysis, interpretation and reporting of data and information represents the seventh step in the Aquatic Effects Monitoring Program (AEMP) development and implementation process. More specifically, this step involves evaluating the data and information generated under the AEMP to determine if they meet the data quality objectives (DQOs) that were established previously (See Technical Guidance Document Volume 3 for further information). Data that are deemed to be acceptable for assessing project-related effects are then compiled in database format to facilitate dissemination and subsequent data analyses. Then, the AEMP data are analysed and interpreted in accordance with the AEMP Analysis Plan. Finally, the results of the AEMP are disseminated to the responsible regulatory board for distribution to Aboriginal governments/organizations and other interested parties using a variety of reporting approaches. Each of these activities are briefly described in the following sections of this Technical Guidance Document. While this discussion is explicitly focussed on data and information generated under the AEMP, the principles are equally relevant to baseline data or data collected during mine closure and reclamation. It is also important to note that both Traditional Knowledge (TK)-based and western science-based approaches can be used to generate data and information under the AEMP.

2.0 Data Evaluation

Data evaluation represents a key step in the overall quality assurance process. The DQOs that were established early in the monitoring program development process define data requirements for supporting water management decisions. These DQOs need to be incorporated into the project Quality Assurance Project Plan (QAPP) and the associated procedures/protocols to ensure that the DQOs are met. Importantly, the QAPP includes performance criteria for measurement data that provide a systematic and scientifically-defensible basis for evaluating data quality. The procedures that are to be used for reviewing, verifying, and validating data are also specified in the project QAPP. Implementation of a well-designed quality assurance program maximizes the usability of the resultant data.

Establishment of appropriate performance criteria provides an objective and consistent basis for evaluating the measurement data generated in the AEMP. Such performance criteria are frequently established for five variables, including accuracy, precision, completeness, representativeness, and method sensitivity. As part of the QAPP development process, performance criteria are usually established for all five of these variables. In this way, the attributes of the resultant data can be evaluated to determine if they meet the needs for assessing environmental conditions in the study area. In addition, any issues related to sample holding times, instrument calibration, and related factors are considered in the verification and validation of project data. Appendix 1 provides further information on the procedures of evaluating the accuracy, precision, completeness, representativeness, and sensitivity of AEMP data.

3.0 Data Compilation

Data compilation describes the activities associated with collating the information collected in the field and the data generated in laboratory analyses. This activity represents a key step in the overall aquatic effects monitoring process because it results in the compilation of data and information in a form suitable to support data analysis and interpretation. Although there are many ways of compiling monitoring data, geographic information system (GIS)-compatible relational databases have become the industry standard because they can interface with a variety of data analysis and data presentation programs. MS Access format is recommended because most data users have access to this software and it is sufficiently powerful to meet the needs of most data users. In addition, this database is compatible with most electronic data delivery systems, which reduces the need for manual entry. Because data are typically generated in multiple batches to support AEMPs, databases must be constantly updated and users apprised of the changes that have been made (i.e., using a version control and naming conventions). Periodic database auditing is also recommended to assure that the underlying data used in data analyses are correct and internally consistent. Guidance on data verification and validation is provided by Clark *et al.* (1996); USEPA (2001a); and, USEPA (1994; 1999; 2001b). Importantly, all of the raw data (i.e., benchsheets, electronic data deliverables, field notes) must be retained for the life of the project to ensure that electronic databases can be validated. The AEMP data should be delivered to the responsible regulatory board, Aboriginal governments/organizations, federal and territorial governments, and other interested parties in electronic format and in an annual AEMP data report.

4.0 Data Analysis and Interpretation

Planning for data analysis and interpretation should be initiated during problem formulation (through preparation of a preliminary AEMP Analysis Plan; see Technical Guidance Document Volume 2 for further information). The preliminary AEMP Analysis Plan should be refined during the development of DQOs for the AEMP (i.e., during the development of the analytical approach; see Technical Guidance Document Volume 3 for further information). The AEMP Analysis Plan is further refined during the design of the AEMP and documented in the AEMP Design document. It is important that the procedures described in the final AEMP Analysis Plan presented in the AEMP Design document be carefully followed during the data analysis and interpretation process. In some cases, it may be appropriate to conduct additional analyses to generate supplemental information from the data generated under the AEMP. In the case of TK, TK holders must be involved in the analysis and interpretation of the monitoring program results.

The data collected under the AEMP can be used in a number of ways. Whitfield (1988) classified the reasons for conducting monitoring into five main categories, including:

- ***Assessment of compliance with water quality objectives (i.e., status assessment)*** - The objective is to determine whether or not water quality guidelines (WQGs) or water quality objectives (WQOs) that have been established for a water body are being met;

- ***Trend assessment*** - The objective is to collect data that will facilitate the evaluation of temporal (short- and long-term) trends and spatial trends in environmental quality conditions;
- ***Estimation of mass transport*** - The objective is to determine the amount of material transported by a stream or river per unit time (i.e., which is termed the load);
- ***Environmental impact assessment*** - The objective is to evaluate the effects of one or more disturbance activities on water quality conditions. This type of assessment requires a design that facilitates differentiation among variations in environmental quality due to natural processes, sampling procedures, or human activities; and,
- ***General surveillance*** - The objective is to evaluate water quality conditions over a broad spatial area to provide an early warning of emerging problems.

AEMPs are typically designed to provide the data and information needed to support most or all of these activities. Accordingly, the procedures that are established for analyzing and interpreting data collected under the AEMP must clearly define the objectives that they are intended to support. While a great deal of literature is available that describes procedures for analyzing and interpreting environmental data, no attempt has been made here to identify or summarize the relevant guidance documents.

In general, it is recommended that the results of the analysis and interpretation be presented in an annual AEMP interpretive report and in a more detailed interpretive report every three years, or as required by the responsible regulatory board. These interpretive reports should describe any changes in the abiotic characteristics of the ecosystems that have occurred, any effects on aquatic receptors, aquatic-dependent wildlife, or human health that have been documented based in interpretation of individual lines-of-evidence (e.g., surface water chemistry, sediment chemistry, benthic invertebrate community structure, fish palatability) and integration of multiple lines-of-evidence (see Technical Guidance Volumes 2 and 3 for more information).

Any data gaps that are identified should be reported to the responsible regulatory board and to the members of the AEMP Working Group in the annual interpretive report. Identification of these data gaps generally provides the necessary and sufficient rational for refining the AEMP Design document and associated sampling and analysis plan to ensure that the data gaps are addressed in a timely manner.

5.0 Aquatic Effects Monitoring Program Reporting

As described throughout this document, successful development and implementation of an AEMP necessitates effective involvement of Aboriginal governments/ organizations, federal and territorial governments, regulatory boards, and other interested parties in the process. These organizations will have a wide range of interests and concerns relative to the project and many organizations will have unique requirements relative to AEMP reporting. For this reason, project proponents are strongly encouraged to work with an AEMP Working Group to develop an AEMP that meets the needs and expectations of diverse parties during AEMP reporting. An AEMP communication plan could then be developed to describe the tools that will be used to communicate the results of the AEMP to participants in the process, establish the schedule for dissemination of information on the AEMP results, and identify the target audience for each tool. Some of the communication tools that should be prepared by project proponents, along with their potential frequency and whether or not they are likely to be subject to approval by the responsible regulatory board, are listed below:

Communication Tool	**Frequency**	**Approval Needed?**
Plain Language AEMP Design Report	Every 3 years	Yes
Detailed AEMP Design Report	Every 3 years	Yes
Field Sampling Plan	Updated annually	Yes
Quality Assurance Project Plan	Updated annually	Yes
TK Acquisition Plan	As needed	Possibly
AEMP Database (Web Page/FTP Site)	Updated periodically	No
Annual AEMP Data Report	Annual	Yes
Plain Language AEMP Annual Report	Annual	Yes

Detailed AEMP Annual Report	Annual	Yes
Community Workshop(s)	At least annually	No
Detailed AEMP Interpretive Report	Every 3 years	Yes

The responsible regulatory board will make the final decisions regarding the list of communication tools that are required, their frequency of preparation, and whether or not they are subject to regulatory approval. The authors of all of the documents prepared under the AEMP must be explicitly identified. It is important to recognize that reviewers are likely to provide a diverse array of comments, some of which may necessitate additional analysis of the data, reformatting of reports, and/or revision of conclusions by the proponent.

6.0 References Cited

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Appendix

Appendix 1 Performance Criteria for Measurement Data

A1.0 Introduction

Establishment of performance criteria for measurement data represents a key step in the data quality objectives (DQO) process. Such performance criteria provide a basis for objectively evaluating the data that are generated under the Aquatic Effects Monitoring Program (AEMP) and determining if they can be used to address the study objectives. The parameters that are typically used to evaluate data quality and/or usability include accuracy, precision, sensitivity, completeness, comparability, and representativeness. Each of these parameters are briefly described below. An example of performance criteria for metals is presented in Table A1-1.

A1.1 Accuracy

Accuracy is a measure of the bias of a system or measurement. It is the closeness of agreement between an observed value and an accepted or true value. For a specific project, accuracy of chemical analysis can be determined through the analysis of matrix spikes, certified reference materials, and/or method blanks. Matrix spikes are environmental samples into which known quantities of surrogates are added and their concentrations are subsequently measured. Information on the recovery of surrogate spikes is used directly to assess analytical accuracy. The standard/certified reference materials (SRMs/CRMs; typically obtained from National Institute of Standards and Technology and/or National Research Council) contain known concentrations of key chemicals of potential concern (e.g., polychlorinated biphenyls, polychlorinated dibenzo-*p*-dioxins/polychorinated dibenzofurans, pesticides, and metals). Analysis of such CRMs by the analytical laboratories can be used to evaluate analytical accuracy. Method blanks are used to measure contamination associated with processing and analysis of samples in the laboratory.

For toxicity tests, no true accuracy measurements are possible because of the lack of accepted values. Instead, acceptable accuracy levels are addressed during water quality measurements through: 1) the calibration of the instruments used; and, 2) establishment of acceptable ranges for target analytes. Test acceptability for organisms in the negative control (without the addition of the test chemical) are usually established based on the performance-based criteria outlined in USEPA (1994; 2000). Positive controls (i.e., reference toxicant tests) should be used to determine if the sensitivities of test organisms fall within normal ranges.

A1.2 Precision

Precision is a measure of mutual agreement among individual measurements of the same property, usually under similar conditions. For a specific project, measures of analytical precision can be determined by the analysis of laboratory duplicates and matrix-spike duplicates. Laboratory duplicates can be prepared by splitting environmental samples in the laboratory and carrying the sub-samples through the entire analytical process. Matrix-spike duplicates can be prepared by splitting matrix spike samples in the laboratory and carrying the sub-samples through the entire analytical process. Precision is expressed in terms of the relative percent difference (RPD) and calculated as follows:

$$RPD = \frac{|C_1 - C_2|}{(C_1 + C_2)/2} \times 100$$

where: C_1 = larger measured value; and,
C_2 = smaller measured value.

A1.3 Sensitivity

Sensitivity is typically defined in terms of the detection limits that are achieved for analyses of chemicals of potential concern. The detection limit is the minimum concentration of a substance that can be measured and reported. Target detection limits should be established for each analyte during the DQOs process. At that time, Action Levels are determined for each analyte. Target detection limits should generally be a factor of ten lower than the lowest Action Level for each analyte. In that way, matrix interferences or other analytical difficulties will not likely compromise the use of the resultant data. Examples of target detection limits for the parameters of interest presented in Table A1.1 are based on the applicable methods.

A1.4 Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. Target completeness values are typically in the order of 95% for chemical analyses of water and sediment, and 90% for toxicity test ancillary measurements. Completeness is defined as follows for all measurements:

$$\%C = \frac{V}{n} \times 100$$

%C = percent completeness;
V = number of measurements judged valid; and,
n = total number of measurements necessary to achieve a specified statistical level of confidence in decision making.

A1.5 Comparability

Comparability expresses the confidence with which one data set can be compared to another. Comparability for a project is difficult to quantify, but is usually achieved through the use of consistent laboratory methods. Comparability of data generated under the AEMP to data generated for other projects within the study area should be discussed in AEMP data and interpretive reports. To the extent possible, project proponents operating within a geographic area should communicate and select comparable analytical methods. In this way, the resultant data can be used in regional cumulative effects assessments.

A1.6 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. Representativeness should be addressed primarily in the experimental design and through the selection of appropriate characterization procedures. Representativeness can also be ensured by the proper handling and storage of samples and analysis within the accepted holding times so that the material analyzed reflects the material collected as accurately as possible (USEPA 2000; ASTM 2008). Representativeness of data should be discussed in AEMP data and interpretive reports.

A1.7 References Cited

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Table A1.1. An example of chemicals of potential concern and associated performance criteria for measurement data for investigation of sediment quality conditions.

Media Type/Group/Substance	Target Detection Limit[1]	Analytical Method (suggested)	Preliminary Action Level	Target Accuracy (% Spike Recovery)	Target Accuracy (% Surrogate Recovery)	Target Accuracy (Reference Material Recovery)	Target Precision (Relative Percent Difference %)	Target Completeness	Lead Responsibility
Sediment									
Metals Target Compound List (mg/kg DW)									
Aluminum	2	EPA 6010B or 6020	NBA	75-125	NA	Within +/- 20% of 95% confidence interval for true value	20	95%	Analytical Lab
Antimony	0.05	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Arsenic	0.01	EPA 6010B or 6020	7.15	75-125	NA		20	95%	Analytical Lab
Barium	0.05	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Beryllium	0.01	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Cadmium	0.01	EPA 6010B or 6020	0.991	75-125	NA		20	95%	Analytical Lab
Calcium	10	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Chromium	0.05	EPA 6010B or 6020	20.2	75-125	NA		20	95%	Analytical Lab
Cobalt	0.01	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Copper	0.05	EPA 6010B or 6020	25.2	75-125	NA		20	95%	Analytical Lab
Iron	5	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Lead	0.05	EPA 6010B or 6020	35.3	75-125	NA		20	95%	Analytical Lab
Magnesium	1	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Mangenese	1	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Mercury (total)	0.02	EPA 7471A	0.158	75-125	NA		20	95%	Analytical Lab
Nickel	0.05	EPA 6010B or 6020	18.7	75-125	NA		20	95%	Analytical Lab
Potassium	5	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Selenium	0.05	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Silver	0.02	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Sodium	5	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Thallium	0.01	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Vanadium	0.05	EPA 6010B or 6020	NBA	75-125	NA		20	95%	Analytical Lab
Zinc	0.5	EPA 6010B or 6020	124	75-125	NA		20	95%	Analytical Lab
Simultaneously Extracted Metals (SEM; ng/g DW)									
Arsenic	50	Lab SOP, EPA 376.2, 200.8	NBA	80-120	NA	Within +/- 20% of 95% confidence interval for true value	20	95%	Analytical Lab
Cadmium	50	Lab SOP, EPA 376.2, 200.8	NBA	80-120	NA		20	95%	Analytical Lab
Copper	50	Lab SOP, EPA 376.2, 200.8	NBA	80-120	NA		20	95%	Analytical Lab
Nickel	50	Lab SOP, EPA 376.2, 200.8	NBA	80-120	NA		20	95%	Analytical Lab
Lead	50	Lab SOP, EPA 376.2, 200.8	NBA	80-120	NA		20	95%	Analytical Lab
Zinc	50	Lab SOP, EPA 376.2, 200.8	NBA	80-120	NA		20	95%	Analytical Lab