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CNSOPB | CANADA-NOVA SCOTIA OFFSHORE PETROLEUM BOARD

CANADA-NEWFOUNDLAND and LABRADOR OFFSHORE PETROLEUM BOARD

Offshore Waste Treatment Guidelines

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Foreword

The National Energy Board, the Canada-Newfoundland and Labrador Offshore Petroleum Board, and the Canada-Nova Scotia Offshore Petroleum Board have prepared these guidelines to aid operators in the management of waste material associated with petroleum drilling and production operations in offshore areas regulated by the Boards. These guidelines were prepared jointly by the three Boards with the assistance of a working group comprised of government, industry and public representatives (see Appendix A).

The Boards may develop or adopt guidelines, standards and recommended practices to support and complement the regulations they enforce. In all cases, the intent of the Boards is to provide additional information and guidance to operators so that they may better understand the expectations of the Boards regarding responsiveness to, and compliance with, the regulatory requirements. Section 1.2 of these guidelines provides a description of the relevant portions of the regulatory regime applicable to Canada's offshore oil and gas operations.

The authority to issue guidelines and interpretation notes with respect to regulations is specified by subsection 5.3 (1) of the *Canada Oil and Gas Operations Act*, sub-section 156(1) of the *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act,* and sub-section 151.1 of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Act* (the *Acts*).

In many instances, these guidelines identify a particular means or method toward achieving regulatory compliance. These means or methods may be based on a number of criteria, including:

- the mandatory requirements of the *Regulations*;
- the experience of the Boards in how compliance may be achieved; or
- industry best practice.

It is important to note that guidelines are not statutory instruments, and means and methods described in these guidelines are examples. It is not mandatory for an operator to follow the means or methods described in these guidelines. The onus is on the operator to achieve compliance with the applicable regulations, and to be able to demonstrate to the appropriate Board the adequacy and efficacy of the methods employed to achieve compliance.

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Acronyms

CALA	Canadian Association for Laboratory Accreditation
CEAA	*Canadian Environmental Assessment Act*
COGOA	*Canada Oil and Gas Operations Act*
CNAAIA[1]	*Canada-Newfoundland Atlantic Accord Implementation Act*
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
CNSOPB	Canada-Nova Scotia Offshore Petroleum Board
CNSOPRAIA[1]	*Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act*
EPP	Environmental Protection Plan
ISO	International Organization for Standardization
NEB	National Energy Board
NORM	Naturally Occurring Radioactive Material
OWTG	Offshore Waste Treatment Guidelines
SCC	Standards Council of Canada

[1] Where the acronyms CNAAIA or CNSOPRAIA are used in this document they may be interpreted to include both the federal and provincial versions of the legislation. Section 1.2 of these guidelines provides a description of the relevant portions of the regulatory regime applicable to Canada's offshore oil and gas operations.

Definitions

Selected definitions are excerpted here from the *Acts* and/or *Regulations* for convenience. Section 1.2 of these guidelines provides a description of the relevant portions of the regulatory regime applicable to Canada's offshore oil and gas operations. Where definitions are from an international standard or similar document an appropriate reference is provided.

Accord Acts	means the *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act* and *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation (Nova Scotia) Act*, *Canada-Newfoundland Atlantic Accord Implementation Act* and the *Canada-Newfoundland and Labrador Atlantic Accord Implementation (Newfoundland and Labrador) Act*
Acts	means the *Accord Acts* and the *Canada Oil and Gas Operations Act*
authorization[2]	means an authorization issued by a Board under paragraph 5(1)(*b*) of COGOA, 142(1)(*b*) of CNSOPRAIA, and 138(1)(*b*) of CNAAIA
Board	means the National Energy Board, Canada-Newfoundland and Labrador Offshore Petroleum Board or the Canada-Nova Scotia Offshore Petroleum Board, as the case may be
CO_2	means carbon dioxide, a chemical compound composed of two oxygen atoms covalently bonded to a single carbon atom
CO_2 equivalent[3]	means a unit of measure of the mass of an emitted non-CO_2 greenhouse gas or gaseous mixture as if it were CO_2, based on the relative global warming potential of the gas or gaseous mixture compared to the global warming potential of CO_2
development plan	means the development plan that is approved by a Board pursuant to paragraph 5.1(4) of COGOA, 143(4) of the *CNSOPRAIA*, or 139(4) of the CNAAIA

[2] Excerpted from Section 1.(1) of the *Regulations*

[3] Environment Canada (2010), *Greenhouse Gas Emissions Reporting: Technical Guidance on Reporting Greenhouse Gas Emissions - Reporting of 2009 Emissions Data*, Greenhouse Gas Division, Environment Canada, Gatineau QC

enhanced mineral oil based mud (EMOBM)	means a drilling fluid in which the continuous phase is a highly-purified petroleum distillate which should have a total polycyclic aromatic hydrocarbon concentration of less than 10 mg/kg, be relatively non-toxic in marine environments and have the potential to biodegrade under aerobic conditions
natural environment[2]	means the physical and biological environment
oil based mud (OBM)	means a drilling fluid in which the continuous phase is a product obtained from petroleum distillation (e.g., diesel oil or mineral oil)
operator[2]	means a person that holds an operating licence under paragraph 5.1(*a*) of COGOA, 142.(1) of CNSOPRAIA, 138(1)(*a*) of CNAAIA, and an authorization
pollution[2]	means the introduction into the natural environment of any substance or form of energy outside the limits applicable to the activity that is subject to an authorization, including spills
Regulations	means the *Canada Oil and Gas Drilling and Production Regulations*, *Newfoundland Offshore Petroleum Drilling and Production Regulations*, and/or *Nova Scotia Offshore Petroleum Drilling and Production Regulations,* as the case may be
synthetic based mud (SBM)	means a drilling fluid in which the continuous phase is composed of one or more fluids produced by the reaction of specific purified chemical feedstock, rather than through physical separation processes such as fractionation, distillation and minor chemical reactions such as cracking and hydro processing, and which should have a total polycyclic aromatic hydrocarbon concentration of less than 10 mg/kg, be relatively non-toxic in marine environments and have the potential to biodegrade under aerobic conditions
waste material[2]	means any garbage, refuse, sewage or waste well fluids or any other useless material that is generated during drilling, well or production operations, including used or surplus drilling fluid and drill cuttings and produced water
water based mud (WBM)	means a drilling fluid whose continuous phase is composed of water to which various substances have been added

1 Introduction

The Offshore Waste Treatment Guidelines (OWTG), 2010 edition, outline recommended practices for the management of waste materials by operators of petroleum drilling and production operations in Canada's offshore areas. The waste materials discussed in these guidelines include effluents, emissions, and solid wastes normally associated with the operation of installations engaged in petroleum drilling and production activities.

These guidelines supersede the following documents:

- *Offshore Waste Treatment Guidelin*es (2002);
- *Offshore Waste Treatment Guidelin*es (September 1996);
- *Offshore Waste Treatment Guidelines* (Canada Oil and Gas Lands Administration and Canada-Newfoundland Offshore Petroleum Board, January 1989); and
- *Guidelines for the Use of Oil-Based Drilling Muds* (Canada Oil and Gas Lands Administration, November 1985).

In the preparation of these guidelines, the drafters reviewed the approaches of Canadian and international regulators regarding management of discharges of waste materials from installations operating in offshore environments. As well, the results of Canadian and international research into waste management approaches and technologies, environmental compliance requirements, and environmental effects monitoring programs were considered. This review was used to assess the adequacy of waste treatment technology, disposal procedures, and substance concentration targets for the protection of the offshore environment.

The Boards plan to initiate a formal review of these guidelines five years following their publication, to ensure that they continue to reflect significant gains in scientific and technical knowledge. An earlier review may be initiated should the results of environmental effects monitoring programs or research studies indicate a higher than anticipated risk to the environment from discharges of waste materials in accordance with the expectations described in these guidelines. An earlier review also may be considered at the written request of government, industry or the public.

1.1 Purpose and Scope of the Guidelines

The purpose of these guidelines is to aid operators in understanding the goals, objectives and requirements of the applicable acts and regulations, and to explain the expectations of the Boards regarding the management of waste material associated with drilling and production operations in areas under the Boards' jurisdictions. Section 1.2 of these guidelines provides a description of the relevant portions of the regulatory regime applicable to Canada's offshore oil and gas operations.

For an operator, the governing document with respect to management of discharges to the natural environment is the Environmental Protection Plan (EPP) submitted as part of the authorization application. Separate guidance has been published regarding the writing of an EPP[4]. The OWTG supplement the EPP guidelines, and the scope of the OWTG is limited to the management of waste material discharged from offshore drilling and production installations.

In addition, these guidelines do not consider the following:

- Performance targets related to the discharge of energy to the natural environment in the form of light, heat and noise from drilling and production installations. Where the environmental assessment for a proposed drilling or production operation has identified environmental hazards associated with one or more of these parameters, the operator should address their mitigation, including any associated limits on their discharge, in the EPP;
- Performance targets related to waste materials that are generated offshore but transported to shore for disposal; and
- Issues around substances described in these guidelines that are related to the health and safety of offshore workers. Operators are responsible to develop safety plans and to manage health and safety matters in relation to their authorized work or activity.

When, under exceptional circumstances, an operator plans to discharge waste material that has not been described in its EPP, it must contact the appropriate Board to vary the authorization to allow such a discharge. No substance should be discharged unless the appropriate Board has determined that the discharge is acceptable.

[4] Canada Nova Scotia Offshore Petroleum Board and Canada Newfoundland and Labrador Offshore Petroleum Board (2009), *Environmental Protection Plan Guidelines*, published on their respective websites December 31, 2009, and available at http://www.cnlopb.nl.ca/pdfs/guidelines/env_pp_guide.pdf or http://www.cnsopb.ns.ca/sites/default/files/resource/Draft_Environmental_Protection_Guidelines_2009.pdf

1.2 Regulatory Framework

The regulatory framework applicable to oil and gas activities in each of Canada's offshore areas are broadly the same. In the Newfoundland and Labrador offshore area, such activities are administered by the Canada-Newfoundland and Labrador Offshore Petroleum Board under the *Accord Acts*.[5,6] In the Nova Scotia offshore area, oil and gas activities are administered by the Canada-Nova Scotia Offshore Petroleum Board under similar legislation.[7,8] The National Energy Board is responsible for the regulation of oil and gas operations in the rest of Canada's frontier lands.[9]

The Acts require that a person who proposes to carry out any work or activity related to oil or gas exploration or production on frontier lands must first obtain an authorization from the appropriate Board. In addition to the requirements of the *Acts* related to oil and gas activities on frontier lands, proposed offshore drilling or production activities must undergo environmental assessment pursuant to the *Canadian Environmental Assessment Act*[10]*,* the *Nunavut Land Claims Agreement*[11] the *Inuvialuit Final Agreement*[12]*,* and the *Labrador Inuit Land Claims Agreement*[13] as the case may be*,* before an authorization can be issued.

Drilling and Production Regulations[14,15,16], hereinafter referred to as the *Regulations*, have been promulgated under each Act. There are three federal versions of the *Regulations* (there are two provincial versions that are mirrors of their respective federal versions). References to the *Regulations* in this document have been reviewed and all sections referenced are the same in the three federal versions.

The *Regulations* require that, as part of its application for an authorization, an operator submit an EPP that includes elements related to discharges to the natural environment:

[5] *Canada-Newfoundland Atlantic Accord Implementation Act*, S.C. 1987, c. 3
[6] *Canada-Newfoundland and Labrador Atlantic Accord Implementation (Newfoundland and Labrador) Act*, R.S.N 1990, c. C-2.
[7] *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act*, S.C. 1988, c. 2
[8] *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation (Nova Scotia) Act*, S.N.S. 1987, c. 3
[9] *Canada Oil and Gas Operations Act*, R.S.C. 1987, c. O-7
[10] *Canadian Environmental Assessment Act*, S.C. 1992, c. 37
[11] *Nunavut Land Claims Agreement Act*, S.C. 1993, c. 29
[12] *Western Arctic (Inuvialuit) Claims Settlement Act*, S.C. 1984, c. 24
[13] *Labrador Inuit Land Claims Agreement Act*, 2005, c. 27
[14] *Canada Oil and Gas Drilling and Production Regulations*, SOR/2009-315
[15] *Newfoundland Offshore Petroleum Drilling and Production Regulati*ons, SOR/2009-316
[16] *Nova Scotia Offshore Petroleum Drilling and Production Regulations*, SOR/2009-317

> 9. The environmental protection plan shall set out the procedures, practices, resources and monitoring necessary to manage hazards to and protect the environment from the proposed work or activity and shall include…
>
> (*h*) a description of equipment and procedures for the treatment, handling and disposal of waste material;
>
> (*i*) a description of all discharge streams and limits for any discharge into the natural environment including any waste material;
>
> (*j*) a description of the system for monitoring compliance with the discharge limits identified in paragraph (i), including the sampling and analytical program to determine if those discharges are within the specified limits…

The operator's EPP is submitted in support of its application for an authorization. In addition to its other functions, the operator's EPP constitutes its plan to manage discharges, including discharges of waste material, to the natural environment during the conduct of the activities subject to the authorization. It is important to understand that, once a Board issues an authorization, conformance to the discharge limits described in the associated EPP is required and will constitute compliance regardless of the performance targets described in these guidelines.

In its review of an EPP, or additional documents submitted to meet the requirement for an EPP, the Board normally will consider the methods and performance targets described in these guidelines to evaluate whether or not the plan is adequate with respect to the management of discharges of waste material to the environment. However, guidelines are not statutory instruments and the operator may propose other appropriate measures to meet the goals of the *Regulations*.

1.3 Waste Minimization

Offshore operators are expected to take all reasonable measures to minimize the volumes of waste materials generated by their operations, and to minimize the quantity of substances of potential environmental concern contained within these waste materials. More explicitly, operators should make efforts to:

- Reduce amounts of waste material generated and discharged offshore;
- Reduce effluent volumes to the minimum required;
- Reduce the concentrations of substances of potential environmental concern in effluents through process management and effective treatment; and
- Reduce toxicity of effluent streams by practicing effective source control at the chemical selection phase.

With respect to source control and the selection of chemicals for use offshore, the *Offshore Chemical Selection Guidelines for Drilling and Production Activities*

on Frontier Lands[17] outline a process to achieve this objective.

Reporting requirements regarding efforts to minimize waste discharged to the natural environment are discussed in EPP guidance.

Where these guidelines include performance targets in respect of the concentration or volume of waste material in discharges, these are intended to express the minimum performance expectations of the Boards. In keeping with the spirit of waste minimization and the regulatory requirement for continual improvement outlined in subsections 5(2)(*b*) and 5(2)(*i*) of the *Regulations*, the Boards expect that operators will strive to minimize the concentrations and volumes of waste materials discharged to the environment, and will adopt best practices in waste management and treatment.

1.4 Identification, Monitoring and Reporting of Discharges

1.4.1 Identification

In accordance with Paragraph 9(*i*) of the *Regulations,* an EPP must provide an inventory of all planned discharges to the natural environment and the limits, qualitative or quantitative, that the operator will apply to each discharge. Each discharge location should also be described.

Section 2 of these guidelines describes categories of waste material discharges that are typically associated with drilling and production operations, and the Boards' expectations concerning them. Operators should note that the listing in Section 2 is not intended to be exhaustive, and where discharges not described in Section 2 are contemplated, these discharges also should be described in the operator's EPP.

1.4.2 Routine Monitoring and Reporting

Paragraph 9(*j*) of the *Regulations* requires that an EPP include a system for monitoring compliance with discharge limits. Board expectations are provided throughout Section 2. Compliance monitoring programs should also provide, where practicable, for the measurement or the calculation of absolute quantities of oil and other contaminants contained in discharges.

[17] National Energy Board, Canada-Nova Scotia Offshore Petroleum Board and Canada-Newfoundland and Labrador Offshore Petroleum Board (2009), *Offshore Chemical Selection Guidelines For Drilling & Production Activities On Frontier Lands* , published on their respective websites April 2009, and available on their respective websites at https://www.cer-rec.gc.ca/bts/ctrg/gnthr/2010ffshrwstgd/index-eng.html, http://www.cnlopb.nl.ca/pdfs/guidelines/ocsg.pdf and http://www.cnsopb.ns.ca/sites/default/files/resource/chemicalguidelines

Where specific qualitative or quantitative discharge limits are identified in the EPP pursuant to Paragraph 9(*i*), the operator should report the results of its compliance monitoring program monthly to the Board. Electronic reporting is strongly encouraged.

1.4.3 Reporting of Exceedances

Reporting expectations for exceeding the limits described in the operator's EPP in CNSOPB and C-NLOPB jurisdictions are described in the *Guidelines for the Reporting and Investigation of Incidents*.[18] Operators should contact the NEB to discuss requirements in its jurisdiction.[19]

[18] Canada Nova Scotia Offshore Petroleum Board and Canada Newfoundland and Labrador Offshore Petroleum Board (2009), *Guideline for the Reporting and Investigation of Incidents* , published on their respective websites June 2009, and available at http://www.cnlopb.nl.ca/pdfs/guidelines/incrptgl.pdf and http://www.cnsopb.ns.ca/sites/default/files/resource/incrptgl.pdf

[19] Procedures for incident reporting in NEB jurisdiction are described in the *Canada Labor Code Part II*, *Oil and Gas Occupational Safety and Health Regulations* and in the *Canada Oil and Gas Operations Act* and associated regulations. The NEB is developing a specific incident reporting procedure.

2 Performance Expectations for Specific Discharges

This section of the guidelines describes performance targets for concentrations of waste material in discharges. In addition, potential treatment methods and methods for sampling and analysis of effluents have been described. Based on current knowledge and experience available to the Boards, waste material discharged at the concentrations and in the manner specified in these guidelines is not expected to cause significant adverse environmental effects in areas where offshore petroleum activities are anticipated to occur in the near future. In addition, the performance targets recommended in these guidelines for concentrations of specific waste materials in discharges are believed to be achievable using proven and practicable best practices in waste management and treatment.

Each drilling and production project is unique. The environmental assessment process performed during the pre-project phase of each such project should identify potential environmental sensitivities, while environmental effects monitoring programs are intended to monitor effects during development drilling or production operations. In areas where the environmental assessment process identifies increased environmental sensitivity, or where environmental effects monitoring detects indications of unanticipated adverse effects on the natural environment, it may be necessary to require modified approaches to waste disposal or more stringent performance targets with respect to waste material concentrations. The operator should address these issues in its EPP, and in so doing, may consider: modified sampling, analysis and reporting regimes; more advanced or unconventional waste treatment technologies; the relocation of discharge points; or the use of subsurface formations for waste disposal rather than disposal to the marine environment to prevent adverse effects.

2.1 Emissions to Air

The Boards regulate emissions to air from installations on Canada's frontier lands, including setting flare volume limits. However, it is not currently the intent of the Boards to duplicate, in these guidelines, regulatory processes undertaken by governments in respect of air emissions. These guidelines focus on the regulatory activities undertaken by the Boards regarding emissions to air.

2.1.1 Greenhouse Gases

Each operator of a production installation should, as part of its development application, provide an annualized estimate of the quantities of greenhouse gases (CO_2 or CO_2 equivalent) that will be emitted from its offshore installation(s), and a description of its strategy to control and reduce these emissions. In keeping with the philosophy of continual improvement and waste

minimization, each operator's EPP should include a provision to periodically review and update this strategy, and to report the results to the Board.

Each Board may set flare volume limits for offshore production installations under its respective jurisdiction. The Boards expect all operators to take steps to minimize flare gas volumes and operators are encouraged to develop flare management plans that strive for the minimization of gas flaring volumes.

The Government of Canada has established a national system for quantifying and reporting greenhouse gases, and Environment Canada maintains a Greenhouse Gas Emissions Reporting Program. For operators that must report their greenhouse gas emissions to this program, reference to this information will suffice to meet the reporting requirements of the Boards.

2.1.2 Other Emissions to Air

Environment Canada administers regulations concerning various chemical substances and classes of substances under the *Canadian Environmental Protection Act*.[20] The Government of Canada has identified reporting requirements for a number of substances that may be emitted to the air from industrial operations, and has nominated other substances as priorities for emissions reduction at a national level. The management of emissions to air in relation to these priorities is beyond the scope of this guidance and operators should consult with Environment Canada in respect of these emissions.

2.2 Produced Water

Produced water includes formation water, injection water and process water that is extracted along with oil and gas during petroleum production. In addition, a portion of the chemicals added during processing of reservoir fluids may partition to the produced water. At most offshore production installations, this water is separated from the petroleum process stream and, after treatment, is discharged to the marine environment or disposed of in a subsurface formation.

2.2.1 Treatment and Monitoring

As part of its development application, each operator of a production installation should examine and report upon the technical requirements for treatment of produced water to meet discharge requirements. As well, the operator should consider the technical and economic feasibility of alternatives to conventional marine discharge of produced water. Operators should consider proven and practicable best practices in produced water management and treatment, to reduce oil-in-water concentrations to as low as practicable, or to reduce or

[20] *Canadian Environmental Protection Act*, 1999, S.C. 1999 c. 33

eliminate produced water discharges to sea. Operators are encouraged to regularly compare their respective performances against appropriate international benchmarks as part of their continual improvement programs.

The performance target for produced water to be discharged to sea from a production installation is as follows:

- **a 30-day volume weighted average oil-in-water concentration in discharged produced water should not exceed 30 mg/L, and**
- **a 24-hour average oil-in-water concentration in discharged produced water, as calculated at least twice per day, should not exceed 44 mg/L.**

Existing operators of production installations should be able to meet this performance target within one year of the publication of these guidelines.

As a minimum, the discharge of produced water should be sampled and analyzed every 12 hours, and the 30-day and 24-hour averages calculated, but the operator may elect to sample and analyze more frequently. Where an operator collects and analyzes samples from the produced water discharge more frequently, it may use samples collected at regular intervals (i.e. every 6 hours, 4 hours etc.), or all of the samples collected during the previous 24-hour period to calculate the average discharge concentration using a methodology that gives appropriate weight to each sample (see Appendix B).

Operators are encouraged to evaluate the potential utility of in-line automated analyzers to provide oil-in-water analyses, or to provide trending information to aid in treatment system management.

The methods for sampling and analysis of oil in produced water should be in accordance with *Standard Methods for the Examination of Water and Wastewater*, 20th Edition (or as amended or updated), 5520 Oil and Grease, 5520 C Partition-Infrared Method and 5520 F Hydrocarbons.[21] All samples of produced water, the analysis of which is intended to support compliance monitoring, should be collected at a point that is upstream of the discharge location and downstream of the last treatment unit. The sampling port should be designed to facilitate collection of a representative sample.

The results of the sampling and analysis program, including the individual sample values, the 24-hour performance metric, the 30-day volume-weighted average, and the total volume of produced water discharged, for each day of discharge, should be reported to the Board monthly.

[21] American Public Health Association, American Water Works Association & Water Environment Federation (1998), *Standard Methods for the Examination of Water and Wastewater,* 20th Edition (as amended or updated), available from APHA, 800 I Street, NW Washington, DC 20001

Where fluids such as ethylene glycol, methanol or other substances have been added to prevent hydrate and/or ice formation, and are discharged as part of produced water, the volume discharged and average concentration should be reported as part of the monthly produced water reporting.

2.2.2 Produced Water Characterization

The operator should describe, as part of its EPP, the program by which it monitors the chemical and potentially biologically relevant characteristics of its produced water, and how this changes over time. Chemical characterization, to the greatest degree practicable, may draw upon sampling programs conducted for reservoir monitoring purposes. Other program initiatives may include toxicity testing on a regular basis, detailed component and/or fate modeling studies, participation in relevant research activities directly relating to produced water discharge at the production installation, or a combination of these. The results of this program should be reported to the Board at least annually.

2.3 Drilling Muds

Drilling muds are fluids that are circulated in oil and gas wells to clean and condition the hole, to lubricate the drill bit and to counterbalance formation pressure. These muds consist of a “continuous phase” which forms the base fluid and in which the various other mud components are suspended or dissolved. Depending on the nature of the well to be drilled and the technical requirements, wells may be drilled using one mud system from top to bottom, or may require modifications to the mud formulation or mud type as the well progresses.

All substances that make up drilling muds are screened through the chemical management system developed by the operator in consideration of the *Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands.*[22] These chemical selection and management systems are intended to be used as source control to manage the toxicity of chemicals used offshore. Acceptability of mud ingredients under this screening should not be construed as permissibility to discharge them, or the mud formulation of which they are constituents.

Where it is technically reasonable, water based mud (WBM) should be used in the drilling of wells and well sections. Spent and excess WBM may be discharged onsite from offshore installations without treatment. Plans to discharge WBM should be described in the operator’s EPP. Operators should develop management approaches for the use of WBM that reduce the need for the bulk disposal of these materials.

Where there is technical justification (e.g., requirements for enhanced lubricity or for gas hydrate mitigation), operators may use synthetic based mud (SBM) or

[22] NEB *et al.* 2009

enhanced mineral oil based mud (EMOBM) in the drilling of wells and well sections. Other than residual base fluid retained on cuttings as described in the operator's EPP (see Section 2.4 of these guidelines), no whole SBM or EMOBM base fluid, or any whole mud containing these constituents as a base fluid, should be discharged to the sea.

From an environmental perspective, oil based mud (OBM) is the least desirable base fluid, although it may possess technical advantages in relation to particularly technically challenging well sections. The use of OBM will be approved only in exceptional circumstances. Under no circumstances should oil base fluid or whole mud containing oil base fluid be discharged to the sea.

2.4 Drilling Solids

Drilling solids or cuttings are particles that are generated by drilling into subsurface geological formations and are carried to the surface with drilling muds.

Drilling solids associated with the use of WBM may be discharged to the marine environment without treatment.

Each operator that plans to use SBM or EMOBM in development drilling should, as part of its development application, examine and report upon the technical feasibility and economic reasonability of re-injecting the associated drilling solids into subsurface formations at its drill site(s). For a drilling program where an operator has demonstrated that re-injection of drilling solids associated with the use of SBM or EMOBM is not technically feasible or economically reasonable, the operator's EPP should describe the manner in which drilling solids will be managed and discharged to the marine environment. The operator should manage drilling solids in a manner which achieves the lowest concentration of drilling fluid retained on cuttings using proven and practicable best practices. This may include technological approaches to cuttings treatment on the installation, strategies for mud management at the installation, and transfer of materials to onshore facilities for further treatment.

At the time of writing of these guidelines, proven and practicable best available technologies and practices in waste management and treatment are believed to be capable of achieving a concentration of 6.9 g/100 g or less oil on wet solids.

The performance target for "synthetic-on-cuttings" or "enhanced mineral oil-on-cuttings" concentration is as follows:

- **the 48-hour mass weighted average of retained "synthetic-on-cuttings" or "enhanced mineral oil-on-cuttings" discharged to sea should not exceed 6.9 g/100 g oil on wet solids.**

Drilling solids associated with the use of OBM should not be discharged to the marine environment. The Boards take the view that cuttings associated with OBM should be re-injected downhole, or collected and transported to shore and disposed of in a manner acceptable to local authorities.

The concentration of non-aqueous base fluid (SBM or EMOBM) retained on discharged drilling solids from all sources should be measured every 12 hours in accordance with *Procedure for Field Testing Oil Based Drilling Muds*[23]*,* and a mass-weighted rolling 48-hour average calculated in units of grams of oil per 100 grams wet solids.

Time series of both raw and averaged data should be reported. The operator's sampling and analysis program should provide for more frequent sampling and analysis during periods of operations not considered to be within normal operating practice.

2.5 Storage Displacement Water

Storage displacement water is water that is pumped into and out of oil storage chambers on certain types of production installations during oil production and offloading operations.

The performance target for storage displacement water is as follows:

- **storage displacement water that is to be discharged to sea should have a residual oil concentration that does not exceed 15 mg/L.**

Where discharge is continuous, the discharge should be sampled for oil-in-water at least every 12 hours. Where batch discharge is contemplated, the operator should devise a methodology for sampling of the water to be discharged, such that the samples are representative of the oil-in-water concentrations in the discharge.

The methods for sampling and analysis of oil in water should be in accordance with *Standard Methods for the Examination of Water and Wastewater*, 20th Edition (or as amended or updated), 5520 Oil and Grease, 5520 C Partition-Infrared Method and 5520 F Hydrocarbons[24].

[23] American Petroleum Institute (1991), *Procedure for Field Testing Oil Based Drilling Muds*, API Recommended Practice RP 13B-2, Appendix B (as amended or updated), available from API Publications, IHS, 15 Inverness Way East, c/o Retail Sales, Englewood, CO 80112-5776
[24] APHA *et al.* 1998

2.6 Bilge Water

Bilge water is typically composed of seawater that may seep or flow into an offshore installation from various points in the structure, and may also be contaminated with oil and other substances from machinery spaces. The performance target for bilge water is as follows:

The performance target for bilge water is as follows:

- **bilge water that is to be discharged to sea should be treated such that the residual oil concentration does not exceed 15 mg/L.**

Where an oil-water separator is in place on an installation and that device meets the requirements of Transport Canada regarding the discharge of bilge water from a vessel, the operator may discharge bilge water through that device in conformance with the oil concentration limits set out in the *Regulations for the Prevention of Pollution from Ships and for Dangerous Chemicals* (SOR/2007-86), regarding discharge of water from machinery space bilges. These requirements are generally consistent with the requirements of the *International Convention for the Prevention of Marine Pollution from Ships, 1973 as modified by the Protocol of 1978 relating thereto (MARPOL 73/78), as amended*.[25]

Where the equipment described above is not used, the operator should devise a methodology for sampling of the bilge water to be discharged such that the samples are representative of the oil-in-water concentrations in the discharge. The sampling and analysis should be conducted in accordance with *Standard Methods for the Examination of Water and Wastewater*, 20th Edition (or as amended or updated), 5520 Oil and Grease, 5520 C Partition-Infrared Method and 5520 F Hydrocarbons.[26]

2.7 Ballast Water

Ballast water is water used to maintain the stability of an offshore facility. In typical practice, ballast water is segregated from ship's bilge and should not be contaminated with oil. Where ballast water is segregated and no contamination with oil is suspected, ballast water may be discharged without treatment or monitoring.

[25] International Maritime Organization (IMO), the *International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78)* and any amendments, whenever made, to Protocol I, the Annexes or Appendices to that Convention, available from the IMO Publishing Service, 4 Albert Embankment, London SE1 7SR, United Kingdom

[26] APHA *et al.* 1998

The performance target for ballast water is as follows:

- **ballast water that is to be discharged to sea, if it is known or suspected to be contaminated with oil, should be treated such that the residual oil concentration does not exceed 15 mg/L.**

Where oil contamination is known or suspected to exist, the operator should devise a methodology for sampling of the water to be discharged such that the samples are representative of the oil-in-water concentrations in the discharge.

The methodology for sampling and analysis of oil in water should be in accordance with *Standard Methods for the Examination of Water and Wastewater*, 20th Edition (or as amended or updated), 5520 Oil and Grease, 5520 C Partition-Infrared Method and 5520 F Hydrocarbons.[27]

2.8 Deck Drainage

Deck drainage is water that reaches the deck of offshore installations through precipitation, sea spray, or from routine operations such as washdown and fire drills.

The performance target for deck drainage is as follows:

- **deck drainage that is to be discharged to sea, if there is potential for it to be contaminated with oil, should be collected and treated such that the residual oil concentration does not exceed 15 mg/L.**

Where discharge is continuous, the discharge should be sampled for oil-in-water concentration at least every 12 hours. Where batch discharge is contemplated, the operator should devise a methodology for sampling of the water to be discharged such that the samples are representative of the oil-in-water concentrations in the discharge.

The methods for sampling and analysis of oil in water should be in accordance with *Standard Methods for the Examination of Water and Wastewater*, 20th Edition (or as amended or updated), 5520 Oil and Grease, 5520 C Partition-Infrared Method and 5520 F Hydrocarbons.[28]

Any systems used to collect deck drainage should be separated from drip pans placed under machinery. Waste materials and fluids from drip pans should be returned to the process, recovered and recycled, or transferred to shore and disposed of in a manner approved by local regulatory authorities.

[27] APHA *et al.* 1998
[28] APHA *et al.* 1998

2.9 Produced Sand

Produced sand originates from geological formations and is separated from formation fluids during oil and gas production. It may also contain scale particles that are generated during the processing of those fluids.

Operators of production installations should monitor and report the volume of produced sand that is being recovered during production operations.

Acceptability of the discharge of produced sand will depend on the concentration of oil in the produced sand and its aromatic content. In all cases, the sand should be treated to reduce oil concentrations to the lowest level practicable.

2.10 Well Treatment Fluids

Well treatment fluids are fluids used in, or generated from, operations such as well workovers, well stimulation, well completion and formation fracturing.

The performance targets for well treatment fluids are as follows:

- **on a production installation, well treatment fluids may be recovered and directed to the produced water treatment system, if feasible, and then treated as a component of produced water; or**
- **where it is not feasible to discharge well treatment fluids through a produced water treatment system, well treatment fluids should be collected and treated such that the residual oil concentration does not exceed 30 mg/L before being discharged to sea.**

Where well treatment fluids are not being discharged with produced water, the operator should devise a methodology for sampling of the fluid to be discharged such that the samples are representative of the oil-in-water concentrations in the discharge.

The methods for sampling and analysis of oil in water should be in accordance with *Standard Methods for the Examination of Water and Wastewater*, 20th Edition (or as amended or updated), 5520 Oil and Grease, 5520 C Partition-Infrared Method and 5520 F Hydrocarbons.[29]

Results of sample analyses should be reported to the Board.

Well treatment fluids containing diesel oil or other highly aromatic oils should not be used unless they are recovered at site and recycled, or are transferred to shore and disposed of in a manner approved by local regulatory authorities.

[29] APHA *et al.* 1998

Strongly acidic fluids recovered from well treatment operations should be treated with neutralizing agents to a pH of at least 5.0 prior to discharge.

2.11 Cooling Water

Cooling water is seawater that has been pumped from the sea onto an installation and passed through heat exchangers to remove heat from processes on the installation before being returned to the sea.

To prevent biofouling and corrosion of piping and mechanical systems on the installation, it is typical to add biocide to the cooling water prior to circulating it through the installation. Although chlorination is typically used, other biocides may be chosen by the operator for control of corrosion and biological activity as required. All biocides should be screened through the chemical management system developed by the operator in consideration of the *Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands.*[30]

The operator shall identify, in its EPP, any biocide that may be discharged in cooling water and the concentrations to be discharged to the sea.

2.12 Desalination Brine

Desalination brine recovered from the production of potable water may be discharged without treatment.

2.13 Sewage and Food Wastes

Sewage and food wastes must be macerated before discharge. In some circumstances, the Board may require additional treatment. In cases where an installation chemically disinfects sewage prior to discharge, the operator shall describe any biocide that may be discharged in sewage and the concentrations to be discharged to the sea.

The performance target for sewage and food wastes is as follows:

- **sewage and food wastes should be reduced through maceration to a particle size of 6 millimetres or less prior to discharge to sea.**

2.14 Testing of Fire Control Systems

Water for testing fire control systems may be discharged without treatment.

[30] NEB *et al.* 2009

Where chemical fire suppressant agents are added to water, the operator should describe the chemicals and amounts to be discharged in its EPP.

Prior to conducting scheduled testing of fire suppression systems, and where fire suppression chemicals are expected to be discharged to sea, the operator should notify the appropriate Board when this discharge is expected to occur.

Oil should not be discharged to sea in conjunction with testing of fire suppression systems. Any such discharge of oil must be reported and responded to as a spill in accordance with the operator's contingency plans.

2.15 Operational Discharges from Subsea Systems

A variety of non-petroleum fluids are used in association with the operation of subsea equipment, including but not limited to, production risers, wellheads, blowout preventers, subsea pipelines and flowlines, and associated control systems. The uses of these fluids may include: as a hydraulic medium; for pressure testing of components; as antifreeze to prevent ice formation; and for purging of lines. Typical examples of these fluids include (Mono)Ethylene Glycol and Methanol. These fluids may be used neat, or they may be part of a mixture of water and additives that provide the specific properties required to perform the functions required.

The toxicity of these fluids is managed through the chemical management system developed by the operator in consideration of the *Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands*[31], and, as far as possible, the operator is expected to select the lowest toxicity alternative and to minimize the amount discharged.

Typically, a number of non-petroleum fluids are discharged continually as part of the operation of valves and other subsea controls. In the EPP submitted as part of an application for authorization, operators should describe the fluids of this type that are required for operation of subsea systems and that will be discharged to sea. The EPP should also contain estimates the volumes to be discharged or the discharge rate, and the frequency of reporting.

2.16 Discharges Associated with Installation and Maintenance of Subsea Systems

During installation of subsea systems, subsea maintenance activities, and connection of new equipment to existing systems, there may be discharges to the environment that include ethylene glycol, methanol, water, brine, residual petroleum, and other residues. These discharges are typically limited in volume and occur when submerged systems are opened to the natural environment

[31] NEB *et al.* 2009

subsea. Chemicals to be discharged should be screened through the operator's chemical management system.

Planned batch discharges from subsea systems should be described in the operator's EPP. Where operators have not described a necessary discharge in the EPP, they should contact the appropriate Board to vary the authorization to allow such a discharge. The volumes of chemicals discharged in association with subsea work should be reported through the normal process for reporting chemical usage.

Operators should take all reasonable precautions to reduce to a minimum the amount of residual hydrocarbons in subsea equipment that is to be opened to the natural environment subsea. For planned discharges, the amount of residual petroleum should be estimated in the EPP, if possible. Otherwise, operators must contact the appropriate Board to vary the authorization to allow such a discharge.

The estimated volume of residual petroleum that is actually discharged should be reported to the Board. Where a subsea discharge of residual petroleum causes a surface expression (slick or sheen), the surface expression should be reported and managed in a manner consistent with the operator's spill contingency plan.

2.17 Naturally Occurring Radioactive Material

Operators should report the occurrence or probability of occurrence of naturally occurring radioactive material (NORM) to the appropriate Board as early as possible in order to initiate discussion on available disposal options. General guidance on the management of NORM is provided in *Canadian Guidelines for the Management of Naturally Occurring Radioactive materials (NORM).*[32]

[32] Health Canada (2000), *Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM)*, available from the Minister of Public Works and Government Services Canada, Ottawa, Catalogue number H46-1/30-2000E

3 Mixing Of Waste Discharges

Any proposal relating to the mixing of waste material discharge streams should be prepared and presented to the Board for consideration as early as possible in the design stage of a project, and should specifically identify the points of waste discharge. Mixing of waste should not be carried out as a means of dilution in order to meet specified waste concentrations. Where there are justifiable technological, engineering or environmental reasons for mixing, these may be considered by the Board. In most cases, the sampling points for the purposes of compliance monitoring of waste concentrations cited in these guidelines will be upstream of the mixing point.

4 Location of Discharges

The locations on offshore installations for the discharge of waste materials should be specified in the EPP and will be reviewed by the Board on a case-by-case basis. Typically, all points of effluent discharge should be below the water or ice surface.

5 Qualifications of Analytical Laboratories

Onshore laboratories that are used for the analysis of samples described in these guidelines should be accredited to ISO/IEC 17025.[33]

For Canadian laboratories, at the time of publication of these guidelines, this accreditation service may be provided by the Canadian Association for Laboratory Accreditation (CALA) or the Standards Council of Canada (SCC).

[33]International Organization for Standardization (2005), *ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories - Second Edition*, available from Standards Council of Canada, Ottawa, Ontario at www.standardsstore.ca

6 References

6.1 Acts and Regulations

Canadian Environmental Assessment Act, S.C. 1992, c. 37, as published by the Minister of Justice, Ottawa, Canada, and available at http://laws-lois.justice.gc.ca

Canadian Environmental Protection Act, 1999, S.C. 1999, c. 33 as published by the Minister of Justice, Ottawa, Canada, and available at http://laws-lois.justice.gc.ca

Canada-Newfoundland Atlantic Accord Implementation Act, S.C. 1987, c. 3, as published by the Minister of Justice, Ottawa, Canada, and available at http://laws-lois.justice.gc.ca

Canada-Newfoundland and Labrador Atlantic Accord Implementation (Newfoundland) Act, R.S.N. 1990, c. C-2., as published by the Queen's Printer, St. John's, Canada, and available at http://assembly.nl.ca/Legislation/sr/statutes/c02.htm

Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act, S.C. 1988, c. 28., as published by the Minister of Justice, Ottawa, Canada, and available at http://laws-lois.justice.gc.ca

Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation (Nova Scotia) Act, S.N.S. 1987, c. 3. s. 1. as published by the Office of the Legislative Counsel, Halifax, Canada and available at http://nslegislature.ca/legc/index.htm

Canada Oil and Gas Operations Act, R.S. 1985, c. O-7, s. 1; 1992, c. 35, s. 2. as published by the Minister of Justice, Ottawa, Canada, and available at http://laws-lois.justice.gc.ca

Canada Oil and Gas Drilling and Production Regulations, SOR/2009-315, as published by the Minister of Justice, Ottawa, Canada, and available at http://laws-lois.justice.gc.ca

The Western Arctic Claim, The Inuvialuit Final Agreement, 1984 as published by the Minister of Justice, Ottawa, Canada, and available at http://laws-lois.justice.gc.ca

Labrador Inuit Land Claims Agreement Act, 2005, c. 27, as published by the Minister of Justice, Ottawa, Canada, and available at http://laws-lois.justice.gc.ca

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Nunavut Land Claims Agreement Act, S.C. 1993, c. 29, as published by the Minister of Justice, Ottawa, Canada, and available at: http://laws-lois.justice.gc.ca

Offshore Petroleum Drilling and Production Newfoundland and Labrador Regulations, 2009, O.C. 2009-386, as published by the Queen's Printer, St. John's, Canada, and available at http://www.assembly.nl.ca/legislation/sr/regulations/rc090120.htm

Nova Scotia Offshore Petroleum Drilling and Production Regulations, O.I.C. 2009-518, N.S. Reg. 336/2009, as published by the Office of the Legislative Counsel, Halifax, Canada and available at http://www.gov.ns.ca/just/regulations/regs/coprdrill.htm

6.2 Other References

In alphabetical order by author/agency

American Petroleum Institute (1991), *Procedure for Field Testing Oil Based Drilling Muds*, API Recommended Practice RP 13B-2, Appendix B (as amended or updated), available from API Publications, IHS, 15 Inverness Way East, c/o Retail Sales, Englewood, CO 80112-5776

American Public Health Association, American Water Works Association & Water Environment Federation (1998), *Standard Methods for the Examination of Water and Wastewater*, 20th Edition (as amended or updated), available from APHA, 800 I Street, NW Washington, DC 20001

Canada Nova Scotia Offshore Petroleum Board and Canada Newfoundland and Labrador Offshore Petroleum Board (2009), *Environmental Protection Plan Guidelines*, as published on their respective websites December 2009, and available at http://www.cnlopb.nl.ca/pdfs/guidelines/env_pp_guide.pdf or http://www.cnsopb.ns.ca/sites/default/files/resource/Draft_Environmental_Protection_Guidelines_2009.pdf

Canada Nova Scotia Offshore Petroleum Board and Canada Newfoundland and Labrador Offshore Petroleum Board (2009), *Guideline for the Reporting and Investigation of Incidents* , published on their respective websites June 2009, and available at
http://www.cnlopb.nl.ca/pdfs/guidelines/incrptgl.pdf and
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Environment Canada (2010), *Greenhouse Gas Emissions Reporting: Technical Guidance on Reporting Greenhouse Gas Emissions - Reporting of 2009 Emissions Data*, published by the Greenhouse Gas Division, Environment Canada, Gatineau QC K1A 0H3 and available at
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International Organization for Standardization (2005), *ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories - Second Edition*, available from Standards Council of Canada, Ottawa, Ontario at
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National Energy Board, Canada Nova Scotia Offshore Petroleum Board and Canada Newfoundland and Labrador Offshore Petroleum Board (NEB, *et.al.*, 2009), *Offshore Chemical Selection Guidelines For Drilling & Production Activities On Frontier Lands* , published on their respective websites April 2009, and available on their respective websites at
https://www.cer-rec.gc.ca/bts/ctrg/gnthr/2010ffshrwstgd/index-eng.html,
http://www.cnlopb.nl.ca/pdfs/guidelines/ocsg.pdf or
http://cnsopb.ns.ca/sites/default/files/resource/chemicalguidelines.pdf

Appendix A: Organizations Participating in the Working Group

Canada-Newfoundland and Labrador Offshore Petroleum Board

Canada-Nova Scotia Offshore Petroleum Board

National Energy Board

Indian and Northern Affairs Canada

Environment Canada

Fisheries and Oceans Canada

Natural Resources Canada

Natural History Society of Newfoundland and Labrador

Inuvialuit Game Council

Canadian Association of Petroleum Producers (North)

Canadian Association of Petroleum Producers (NL)

Canadian Association of Petroleum Producers (NS)

Appendix B: Methodological Approach to Determining the 24-Hour Average Oil-In-Water Concentration in Produced Water

Data Generation

The Boards believe that the minimum amount of information necessary to evaluate treatment performance may be obtained from samples collected at intervals of 12 hours or less.

Operators may collect samples at intervals of 12 hours or at some set interval of lesser duration (i.e. 8-hours, 6-hours, etc.), or at opportunistic times throughout the day. The interval between samples should not exceed 12 hours.

Sampling and Analytical Method

The methods for sampling and analysis of oil in produced water should be in accordance with *Standard Methods for the Examination of Water and Wastewater*, 20th Edition (or as amended or updated), 5520 Oil and Grease, 5520 C Partition-Infrared Method and 5520 F Hydrocarbons.[34] All samples of produced water, the analysis of which is intended to support compliance monitoring, should be collected at a point that is upstream of the discharge location and downstream of the last treatment unit. The sampling port should be designed to facilitate collection of a representative sample.

Single Point Data

The results of individual analyses represent single points of data and are measures of system performance at a single point in time. As appropriate, these data may be used to infer explanations for observed phenomena associated with an approved discharge (eg. sheens, sea surface effects).

Computation of the 24-hour Average

A rolling 24-hour average value as an indicator of system performance has been in use for a number of years. The performance target for this average is set at 44 mg/L in these guidelines. This average is backward looking and is intended to represent performance over the last 24-hours. It is not a daily average, calculated once per day, but is intended to be recalculated at each sample interval. This value may be calculated in a number of ways.

[34] APHA *et al.* 1998

A “Volume-Weighted Average” that includes all samples collected during the past 24-hour period is considered the optimal approach to calculating a central position for that data.

The use of the volume-weighted average improves the flexibility of averaging in that it allows for sampling at times of opportunity and corrects for flow rate variability.

If C_i is an analytical result for a sample taken in the last 24-hour period during which “n” samples have been taken, and V_i is the cumulative produced water discharge volume at the time the sample was collected, the volume-weighted average may be calculated as follows:

$$24-HourVolumeWeightedAverage = \frac{(C_1 + C_2)(V_2 - V_1) + ... + (C_{n-1} + C_n)(V_n - V_{n-1})}{2(V_n - V_1)}$$

The volume-weighted average of all samples collected in the past 24-hour period should be calculated after the analyses of the most recent sample is complete.

Where an operator has a, more or less, steady rate of flow through its produced water system, it may use an alternate method known as a “Time-Weighted Average”.

If C_i is an analytical result for a sample taken at time “T” in the last 24-hour period during which “n” samples have been taken over the averaging period (where the average flow rate of produced water discharge is considered constant over that period), the time weighted average may be calculated as follows:

$$24-HourTimeWeightedAverage = \frac{(C_1 + C_2)(T_2 - T_1) + ... + (C_{n-1} + C_n)(T_n - T_{n-1})}{2(T_n - T_1)}$$

The time-weighted average of all samples collected in the past 24-hour period should be calculated after the analyses of the most recent sample is complete.

Where an operator wishes to apply a simple arithmetic average to the determination of system performance, this decision should reflect two criteria:

- discharge volume rates do not vary significantly over periods between sample collection; and
- samples are collected at fixed intervals of equal duration.

Although this method is inferior to the volume-weighted average and time-weighted average, it may be substituted if an operator is unable to support its sampling activities with timely volume or flow rate measurements.

If C_i is an analytical result for a sample taken in the last 24-Hour period during which “n” samples have been taken at intervals of equal duration, the arithmetic average may be calculated as follows:

$$24-HourArithmeticAverage = \frac{C_1 + C_2 + ... + C_{n-1} + C_n}{n}$$

The arithmetic average of all samples collected in the past 24-hour period should be calculated after the analysis of the most recent sample is complete.