PROTOCOL FOR PERFORMANCE TESTING OF DOMESTIC WASTEWATER TREATMENT TECHNOLOGIES

Prepared by:
Environment Canada in collaboration with Bureau de normalisation du Québec

For:
The Canadian Environmental Technology Verification Program

March 2015

TABLE OF CONTENTS

PROTOCOL FOR PERFORMANCE TESTING OF DOMESTIC WASTEWATER TREATMENT TECHNOLOGIES

1. INTRODUCTION

In Canada and other jurisdictions, different regulatory agencies and authorities having jurisdiction may have different requirements and performance criteria for approval and acceptance of domestic wastewater treatment technologies. To support their decisions, these agencies and authorities can benefit from scientifically defensible, verifiable performance data applicable to a range of possible end use requirements and operating conditions.

The intent of this *Protocol for Performance Testing of Domestic Wastewater Treatment Technologies* is to provide a common protocol for testing and verifying the actual performance of treatment devices under controlled conditions, in an independent, transparent manner. It is anticipated that independent verification of the performance data will assist regulatory agencies, authorities having jurisdiction and other affected stakeholders in evaluating treatment technology options.

This protocol was prepared following an agreement between Globe Performance Solutions, representing the Canadian ETV Program, and the Bureau de normalisation du Québec (BNQ), representing the Québec Government, to harmonise the verification protocols for domestic wastewater treatment technologies used by the two entities. The BNQ is a Standard Development Organization accredited by the Standards Council of Canada.

The protocol presented in this document is based on the existing *Performance validation procedure for domestic wastewater treatment technologies* in Québec.

This performance testing protocol is an effective approach for conducting testing in order to produce verifiable performance data on specific technologies under defined operating conditions. Environment Canada's Canadian ETV Program supports the use of this protocol to reduce uncertainty and to improve acceptance of independently generated performance data, thereby contributing to informed technology decisions.

It is understood that the ultimate decision to approve, select and implement a particular technology rests with the technology buyer, guided by the requirements of the respective authorities having jurisdiction within the affected jurisdiction(s).

2. PURPOSE AND FIELD OF APPLICATION

This document provides step-by-step procedures for conducting performance testing and verification of domestic wastewater treatment technologies.

3. REFERENCES

In this publication, a dated normative reference specifies the actual version used, while a non-dated normative reference refers to the most recent version of the applicable reference.

For the purposes of this publication, the following references (including any modifications, errata, corrections, amendments, etc.) contain requirements that must be taken into account and that are quoted when appropriate:

BNQ (Bureau de normalisation du Québec) [www.bnq.qc.ca]

CAN/BNQ 3680-600/2009	*Onsite Residential Wastewater Treatment Technologies*

Note: This is a National Standard of Canada and it is used for a conformity assessment program.

Canadian ETV Program - General Verification Protocol [www.etvcanada.ca]

The General Verification Protocol is used by Verification Entities in the verification process and offers a comprehensive and rigorous procedure so that all verifications are done in a consistent manner.

NSF (National Sanitation Foundation) [www.nsf.org]

NSF/ANSI-55	*Ultraviolet Microbiological Water Treatment Systems*, NSF International Standard/American National Standard for drinking Water treatment Units.

CEN (European Committee for Standardization) [www.cen.eu]

EN 12566-3	*Small wastewater treatment systems for up to 50 PT – Part 3: Packaged and/or site assembled domestic wastewater treatment plants*

ISO (International Organization for Standardization) [www.iso.org]

ISO/IEC 17025	*General requirements for the competence of testing and calibration laboratories*
ISO 5667-10:1992	*Water Quality -- Sampling-- Part 10: Guidance on sampling of waste waters*

MDDELCC (Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques) [www.mddelcc.gouv.qc.ca]

Guide d'échantillonnage à des fins d'analyses environnementales – Échantillonnage des rejets liquides

Cahier 1 Généralités

Cahier 2 Échantillonnage des rejets liquides

Modes de conservation pour l'échantillonnage de rejets liquides (eaux usées) — fascicule *DR-09-04*

Note: This document is intended to serve as guidance on sampling procedures and conservation of waste water for the province of Quebec.

USEPA (United States Environmental Protection Agency)
[www.epa.gov/nrmrl/std/etv/center-wqp.html]

Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction, ETV program, November 2000.

Verification Protocol for Secondary Effluent and Water Reuse Disinfection Applications, ETV program, October 2002.

4. DEFINITIONS

The following terms are defined as follows for use in this publication.

4.1 GENERAL TERMS

Applicant: Person or legal entity that makes a request for verification.

Processing equipment: System used to partially treat wastewater.

Average annual discharge limit (AADL): AADL is the higher limit of the prediction interval of the average of 12 time-independent results, based on a centile not exceeding 99% and a degree of confidence of 95% (see Appendix C).

Average periodic discharge limit (APDL): APDL is the higher limit of the prediction interval of the average of 3 time-independent results, based on a centile not exceeding 99% and a degree of confidence of 95% (see Appendix C).

Average seasonal discharge limit (ASDL): ASDL is the higher limit of the prediction interval of the average of 6 time-independent results, based on a centile not exceeding 99% and a degree of confidence of 95% (see Appendix C).

Technology: System made up of one or more pieces of processing equipment used to treat wastewater.

Modular technology: Prefabricated technology whose processing capacity is defined by the size of the model.

Test plan: Document that defines in detail a test's objective, design, methodology, procedural conditions and different steps.

For other definitions, refer to the Canadian ETV Program General Verification Protocol (2012).

4.2 ABBREVIATIONS

BOD_5: biochemical oxygen demand

BOD_5C: carbonaceous 5-day biochemical oxygen demand

COD: chemical oxygen demand

NTK: total Kjeldahl nitrogen

TP: total phosphorus

SS: suspended solids

5. TEST PROTOCOL

5.1 TEST OBJECTIVE

Testing seeks to evaluate whether or not a technology can be validated with respect to its performance and operational reliability. Testing is supervised by an independent third party, who is responsible for verifying the stringency of the process and for reporting results objectively.

5.2. TEST PLAN

The testing varies based on the technology and the wastewater supply source. Sampling must be done when the technology is in a normal state of activity.

The applicant needs to prepare a **test plan** based on the guidelines provided in this document, adapted to its technology and field of application.

The applicant is responsible for ensuring that the test plan secures all data and information required to demonstrate the performance and reliability of the technology or processing equipment.

5.3 DURATION OF TESTING

The technology must be operated under the reference conditions for at least 12 months, during which time raw water quality variation is representative of the anticipated variation under real conditions.

5.4 THIRD PARTY TESTING

The testing must be conducted under the supervision of a relevant third party.

Implementation or execution of performance testing by an independent third-party testing organization should include flow measurement, sampling, recording sample data and keeping a sampling log, monitoring all operating parameters and recording the conditions when samples were taken for laboratory analysis.

The testing organization is responsible for determining the prevailing operating conditions prior to and during sampling. These conditions must be presented and discussed in the test report.

The testing organization must write a test report that includes all compiled results, its own records and comments, an analysis and interpretation of results with respect to operating conditions and action taken, and the impact of water and mass balance on the equipment or process.

5.5 PARAMETERS AND ANALYSES

5.5.1 OPERATING PARAMETERS

Determining and reporting on system operating conditions prior to and during sampling includes the following:

- Reporting on/off time for equipment such as injection, recirculation and transfer pumps, and if applicable, operational speed, induction percentages of variable-frequency drives, or number of discontinuous equipment operation cycles, etc. Reporting the dates of equipment calibration.

- If applicable, reporting the rotational speed of the air blowers, the volume of air injected into the reactors, the number of operational aerators, the aeration rates for each reactor and distributor volume, etc.

- During testing, taking note of system status and measuring, and other instrument indicators and records (flow meters, temperature sensors, level gauges, alarms, etc.).

- Describing the operational cycles, equipment programming and monitoring system operation. If necessary, performing operational testing and check the calibration of instruments.

- Measuring the volume of water treated by the wastewater processing system on a continuous basis using a total flow meter or pump time recorder. If the latter is used, pump flow must be calibrated.

- Recording cumulative volume monthly and on each day of sampling.

When influent flow is controlled to set limits, a 50% to 200% variation in average flow is considered operationally representative of inherent treatment system flow. Flow variation must be affected daily, 25% of the time or less to 50% of average flow and 25% of the time to 200% or more of average flow. The variation can be controlled by means of either a sine or square wave. The applicable flow on the technology will thus correspond to average flow.

When the flow applied to the technology or processing equipment during testing is controlled to a constant value, the test cannot be representative of the variability of the performance caused by the variations of flow inherent in operating a processing system. If the applied flow is controlled to a constant value, that will be deemed the applicable maximum flow capacity of the processing system.

5.5.2 SAMPLING PROGRAM AND ANALYSIS

The sampling program described below includes the typical requirements; however, complementary measurements may be necessary. For example, transmittance measurement may be required if the applicant wishes to install ultraviolet disinfection processing equipment downstream from its technology.

Some test parameters may be eliminated if they are deemed superfluous to verification. The applicant is advised to contact the Canadian ETV Program for advice regarding sampling requirements to generate relevant data, including the required number of days for sampling.

5.5.2.1 SINGLE LOAD TEST PROGRAMS

The sampling and analysis program must include at least the following[1]:

- Thirty days of sampling in all, with 15 days once a week in the January-April period, 10 days once a week in the July-September period and 5 days uniformly distributed over the other months of the year. Samples are taken from the treatment process influent and effluent and at any intermediate points needed to assess the performance of the processing equipment. Changes to the sampling sequence need to be justified by equipment failure or breakdown and noted in the report by the testing organization.
- Analysis of the following parameters:
  - Mandatory:
    - Influent: COD, BOD_5C, SS and temperature
    - Effluent: COD, BOD_5C, SS, pH, and dissolved oxygen
  - May be required, depending on the desired verification
    - Influent: $BOD_5C_{soluble}$, TP, NTK, NH_4, fecal coliforms, alkalinity
    - Effluent: $BOD_5C_{soluble}$, TP, NH_4, NO_2-NO_3, fecal coliforms

[1] Based on the USETV protocol, http://www.epa.gov/nrmrl/std/etv/pubs/04_vp_wastewater.pdf

Table 5.5.2.1.1: Parameters and number of analyses

Single load tests

BASIC PARAMETERS	RAW WATER	TREATED WATER
	Number of samples	Number of samples
On-site dissolved oxygen	**optional**	**30**
On-site pH	**optional**	**30**
On-site temperature	**30**	**optional**
COD	**30**	**30**
BOD_5C	**30**	**30**
SS	**30**	**30**

REQUIRED PARAMETERS DEPENDENT ON THE DESIRED VERIFICATION	RAW WATER	TREATED WATER
	Number of samples	Number of samples
Soluble BOD_5C	**30**	**30**
TP	**30**	**30**
Ammonia nitrogen	**30**	**30**
Nitrates and nitrites	**optional**	**30**
NTK	**30**	**optional**
Fecal coliforms	**90**	**90**
Alkalinity	**30**	**optional**

Given the broad variability of fecal coliform results, a greater number of results are required to verify performance. Samples must be taken three times on each sampling day and individually analyzed. Since the results are often very different in summer and winter, performance can be established separately for the summer and winter seasons. Consequently, at least 30 results in July, August and September (10 triplicate samples, once in each week of sampling) and at least 45 results in January, February, March and April (15 triplicate samples, once in each week of sampling) need to be taken from effluent for fecal coliform measurement if performance is required for this parameter in each of the two seasons.

5.5.2.2 MULTIPLE LOAD TEST PROGRAMS

If the sampling program is meant for verification performance testing using a linear regression model for multiple loads, it must include at least the following:

- Fifteen days of sampling over a minimum of 13 weeks of continuous operation, once or twice a week per load and with at least four types of load. Samples are taken from the treatment process influent and effluent and at any intermediate points needed to assess the performance of the processing equipment. Changes to the sampling sequence need to be justified by equipment failure or breakdown and noted in the report by the monitoring firm.
- Analysis of the following parameters:
    - Mandatory:
        - Influent: COD, BOD_5C, SS and temperature
        - Effluent: COD, BOD_5C, SS, pH, and dissolved oxygen
    - May be required, depending on the desired verification
        - Influent: $BOD_5C_{soluble}$, TP, NTK, NH_4, fecal coliforms, alkalinity
        - Effluent: $BOD_5C_{soluble}$, TP, NH_4, NO_2-NO_3, fecal coliforms

Table 5.5.2.2.1: ***Parameters and number of analyses***

Multiple load testing

BASIC PARAMETERS	**RAW WATER**	**TREATED WATER**
	Number of samples	Number of samples
On-site dissolved oxygen	**optional**	**60 (15 X 4)**
On-site pH	**optional**	**60 (15 X 4)**
On-site temperature	**60 (15 X 4)**	**optional**
COD	**60 (15 X 4)**	**60 (15 X 4)**
BOD_5C	**60 (15 X 4)**	**60 (15 X 4)**
$BOD_5C_{soluble}$	**60 (15 X 4)**	**60 (15 X 4)**
SS	**60 (15 X 4)**	**60 (15 X 4)**

PARAMETERS DEPENDENT ON THE DESIRED VERIFICATION	**RAW WATER**	**TREATED WATER**
	Number of samples	Number of samples
TP	**60 (15 X 4)**	**60 (15 X 4)**
Ammonia nitrogen	**60 (15 X 4)**	**60 (15 X 4)**
Nitrates and nitrites	**optional**	**60 (15 X 4)**
NTK	**60 (15 X 4)**	**optional**
Fecal coliforms	**180 (45 X 4)**	**180 (45 X 4)**
Alkalinity	**60 (15 X 4)**	**optional**

Given the broad variability of fecal coliform results, a greater number of results are required to be able to verify performance. Specific samples must be taken three times on each sampling day and individually analyzed.

The following conditions must be fulfilled to ensure that the linear regression is significant:

- Only one control parameter (the independent variable) can change at a time during testing
- The control parameter (independent variable) must be manipulated to follow a normal distribution
- For each type of load, samples must be taken after biological processing has reached a steady state
- The performance of the technology must be dependent on the control variable to ensure that the model is representative of the variations associated with it. Thus, the probability that the slope of the regression line is different from zero must be lower than 99% (significance of the 1% bilateral α–test) with a 99% confidence level (power of the γ–test). For example, for 60 results and a 99% probability on a bilateral test with a 99% confidence level that the slope of the regression line is different from zero, the coefficient of determination must be greater than 0.36 ($r^2 > 0.36$) (Cohen, 1988).

During testing, the number of sampling days can be increased as testing proceeds in order to obtain the required minimum regression coefficient.

The discharge limit (statistically defined as the prediction interval) calculated from the regression line will be shown in the technology fact sheet for design of the processing equipment.

When the regression coefficient does not reach the required threshold of certainty, linear regression calculations cannot be accepted, which means that the statistical analysis should be performed on the basis of the average rate applied to the tests across-the-board.

5.5.2.3 ADDITIONAL PROCESSING EQUIPMENT TEST PARAMETERS

Depending on the processing objectives of the equipment, additional test parameters may be required for the influent and effluent (see Table 5.5.2.3.1). The monitored compounds may directly impact the operation of the processing equipment or peripheral components. It may be necessary to document the presence of these compounds in raw water in order to evaluate their impact on the short- or long-term performance of the processing equipment. The applicant is advised to contact the Canadian ETV Program for advice regarding the test plan for these additional parameters in order to adequately document the potential presence of these compounds and their implications on the operation of the processing equipment.

The observed values of the additional parameters during monitoring will be shown in the technology fact sheet.

Table 5.5.2.3.1: Additional test parameters

	Processing equipment				
Additional parameter	**Anaerobic**	**Photochemical**	**Electrochemical**	**Physiochemical**	**Liquid/solid separation**
Calcium	X	X	X		X
Volatile organic compounds	X				
Conductivity			X		
Dose		X	X	X	
Hardness		X	X		X
Iron		X	X		X
Oils and greases	X	X			X
Langelier index		X	X		X
Manganese	X	X	X		X
Redox potential	X		X		
Total dissolved solids		X	X	X	X
Sulfides and H_2S	X				
Transmittance		X			

5.5.3 SAMPLING

Sampling must be performed by a qualified person and comply with the provisions of ISO 5667 or an appropriate equivalent standard[2].

Sampling must be performed uniformly for the entire period and include the first and last week of testing.

It is recommended that a sampling plan be submitted prior to testing. The Canadian ETV Program should also be advised before any changes are made to the sampling plan.

Sampling for COD, BOD_5C, $BOD_5C_{soluble}$, SS, TP, NTK, NH_4 and NO_2-NO_3 analysis must be 24-hour composite samples. Automatic composite sampling must guarantee that wastewater volume is homogeneous and representative for the presence of solid matters at the entry and exit points of the treatment system.

While composite samples can be time-dependent, flow-dependent is preferred.

---

[2] In the Province of Quebec, refer to the *Guide d'échantillonnage à des fins d'analyses environnementales –Échantillonnage des rejets liquides – 1 & 2*
www.ceaeq.gouv.qc.ca/documents/publications/echantillonnage/generalitesC1.pdf,
www.ceaeq.gouv.qc.ca/documents/publications/echantillonnage/rejets_liquidesC2.pdf

Grab samples must be used for pH, temperature, dissolved oxygen and fecal coliform measurement.

The independent testing organization is required to certify in its report that the samples were taken by a qualified person and that sampling standards, methods and preservation deadlines were all met.

5.5.4 SAMPLE PRESERVATION AND ANALYSIS

Sample preservation, transportation and storage must meet the requirements of ISO 5667-10:1992, clause 5.4 or an appropriate equivalent standard. Also, as mentioned in clause 6.1, sample analysis must be done by an accredited laboratory.

In some cases, measurement can be performed by the organization that owns the facility, if its laboratories are recognized under international standard ISO/CEI 17025 and authorized by a signatory to the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement[3].

5.6 EVENT REGISTRY

The testing organization must keep a logbook of the conditions in effect during sampling, the chronology of events and the actions performed on the system. In particular, they must note and report the following:

- The type, quantity and frequency of added products (chemicals, nutrients, bacteria, enzymes and other additives) for the entire verification period.
- All noteworthy events (equipment breakdown, repairs, adjustments and minor changes made to the system, unclogging, scarification or replacement of filtration materials, etc.).
- Water and sludge levels in the conduits, tanks or other areas.
- Status of systems, equipment and instruments.
- Dates of equipment calibration.
- Age of sludge in the equipment or the processing chain (if required) and dates of residue extraction and quantities removed as well as the quantity and the destination of the extracted residues (sludge processing, landfill or recovery sites).

[3] For the purposes of reciprocity with Quebec, the Canadian ETV Program will accept testing and analyses carried out by laboratories accredited by *le Centre d'expertise en analyse environnementale du Québec* (CEAEQ), which is considered to be equivalent to ISO 17025.

5.7 CHANGES DURING OPERATION

No significant modification is to be made to the technology during testing. However, if such change does occur, testing must be re-initialized thereafter.

5.8 CONTENTS OF THE TEST REPORT

The test report should be prepared by the testing organization and must be signed by an engineer with a description of his/her mandate.

The test report should include the following items:

- Flow measurement procedures.
- Sample collection, preservation and transportation protocol.
- Evidence that the samples were taken by a qualified individual and that the applicable standards on sampling and preservation methods have been complied with.
- Presentation of all compiled analytical results (including laboratory analysis certificates in appendix). All results must be shown:
    - In table form, specifying sampling dates and, for periodic samples, the time of day. The tables must show AADL, ASDL and APDL (see Appendix C).
    - In illustrated form, based on sampling dates or corresponding number of days. The illustration must show AADL, ASDL and APDL (see Appendix C).
    - In illustrated form, based on the operating parameters to which the variable correlated and showing the confidence intervals and regression tolerance limits (see Appendix C).
- The operating conditions in effect before and during sampling.
- The type and quantity of additives used (coagulants, flocculants, oxidants or other additives), as well as their frequency of use during the entire test period.
- A description of all noteworthy events that occurred during the test period (equipment failure, repairs, adjustments, minor changes made to the system or other).
- An interpretation of the impact of action taken, operating parameters and events observed during testing on the results obtained.
- Water and mass balance impact on the equipment or treatment process.
- Records and comments.

A more complete outline of the required contents of the Test Report is provided in Appendix A.

5.9 TECHNOLOGIES WITHOUT SLUDGE MANAGEMENT EQUIPMENT

Verification certificates for technologies or treatment processes not equipped with sludge management equipment may be issued following analysis of the test report. However, in order to assess long-term process stability, the applicant will be required, when applying for renewal of the verification certificate, to provide at least three years of operating data of an installation that includes, but is not limited to, the following:

- Location of the treatment plant (and owner contact information, if applicable).
- Description and characteristics of the installation.
- Design data (flow, loads, etc.).
- Copies of owner's installation logs that include the following information:
    - Average observed monthly flow
    - Average observed monthly influent loads (BOD_5, MES)
    - Added chemical product quantities (coagulants, lime, etc.)
    - Maintenance and emergency work
    - Quantity of residues extracted from the processing system, if applicable
    - Quantity of replaced materials, if applicable
    - Results of effluent monitoring

The verification certificate and technology fact sheet will be updated once the above information has been received.

5.10 ULTRAVIOLET DISINFECTION EQUIPMENT

The requirements for performance testing of ultraviolet disinfection equipment are provided in Appendix B.

5.11 CALCULATION OF DISCHARGE TOLERANCE LIMITS

The United States Environmental Protection Agency (USEPA, 1991) proposes the adoption of a statistical method to define discharge standards for industrial plants. The proposed statistical method makes it possible to determine the probable maximum concentrations of discharge generated by a water treatment system by monitoring the effluent and the observed variations of the effluent.

Under the current protocol, the capacity of a technology to meet a discharge requirement is evaluated with this statistical method by monitoring the results of the test. The capacity is defined by a precise value such as Annual average discharge limit (AADL), Average seasonal discharge limit (ASDL) or Average periodic discharge limit (APDL). AADL, ASDL and APDL are determined by a statistical analysis of the monitoring data submitted for performance verification (see Appendix C). AADL, ASDL and APDL are specified as unrounded values.

Annual average discharge limit (AADL)

AADL is determined by the statistical method on the average of 12 results, based on a centile not exceeding 99% and a degree of confidence of 95% (see Appendix C).

Average seasonal discharge limit (ASDL)

ASDL is determined by the statistical method on the average of 6 results, based on a centile not exceeding 99% and a degree of confidence of 95% (see Appendix C).

Ammonia nitrogen, phosphorus and fecal coliform ASDL can be determined for the summer and winter periods when a z-test demonstrates a significant difference of seasonal performance with 95% degree of certainty.

Average periodic discharge limit (APDL)

The APDL is determined by the statistical method on the average of 3 results, based on a centile not exceeding 99% and a degree of confidence of 95% (see Appendix C).

Five-day biochemical oxygen demand (BOD_5), suspended solids, phosphorus and fecal coliform APDL can be determined for the summer and winter periods when a z-test shows a significant difference of seasonal performance with a 95% degree of confidence.

5.12 SCOPE OF APPLICATION

The protocol makes it possible to verify the performance of a technology or processing equipment for *commercial and institutional, community, and isolated dwelling* applications, as applicable.

Commercial and institutional

The *commercial and institutional* field of application relates to water treatment installations that service buildings whose wastewater flow exceeds that of an isolated dwelling and are not connected to a collection system, or to a treatment plant for seasonal establishments. Wastewater from this type of establishment is not considered to be industrial effluent.

Community

The *Community* field of application relates to any treatment plant that processes wastewater from a collection system servicing more than one building.

Isolated Dwelling

The protocol can also be used to verify the performance of a technology or processing equipment intended for onsite residential wastewater treatment used to treat wastewater from isolated dwellings. In this case, annual performance should be considered.

Note: For onsite residential wastewater treatment for isolated dwellings, there is a BNQ certification program based on the National Standard of Canada CAN/BNQ 3680-600.

In order to comply with the requirements of the verification process, the number of homes serviced and the extent of the network must be sufficient to generate low temperature conditions that are typical of what is generally observed in community networks. The temperature of wastewater required to certify the performance tests of a technology in the community field of application must be lower than 10°C over a period of 13 weeks during the verification process.

Field of application verification conditions

Performance verification for *commercial and institutional* or *community* applications must meet the following conditions:

Table 5.12.1 —Test conditions

Installation requirements	Fields of application	Performance conditions
Wastewater from a sewage system (T° < 10° C for 13 weeks)	• *Commercial and institutional* • *Community*	• Summer (*) • Winter (*) • Annual
Wastewater not from a sewage system	• *Commercial and institutional*	• Annual
High load wastewater from a sewage system (T° < 10 °C for 13 weeks)	• High load *commercial and institutional* • High load *community*	• Summer (*) • Winter (*) • Annual
High load wastewater not from a sewage system	• High load *commercial and institutional*	• Annual

(*) For demonstration purposes, summer and winter are defined as follows:
Summer = July, August and September and Winter = January, February, March and April.
Summer and winter performance can be recognized if average seasonal monitoring data are statistically different. Otherwise, only annual performance is recognized.

5.13 PERFORMANCE CATEGORIES

Users of this Protocol are advised to consult the appropriate regulations in the province or other jurisdiction where the technology will be used.

Performance categories are shown in Tables 5.13.1 (BOD_5 and suspended solids (SS) performance categories) and 5.13.2 (Fecal coliform, NH_4 and phosphorus performance categories).

A performance category is achieved when AADL, ASDL or APDL is lower than the value shown in Tables 5.13.1 and 5.13.2. The average annual performance category is based on AADL, while the average seasonal or periodic performance categories are respectively based on ASDL or APDL.

Table 5.13.1 - BOD_5 and suspended solids (SS) performance categories

BOD_5 mg/L		SS mg/L
25		25
20		20
15		15
10		10
5 [1]		5 [1]

[1] The detection and quantification limits of the measurement methodology are defined in the analytical methods section of the CEAEQ Web site (www.ceaeq.gouv.qc.ca/methodes/chimie_inorg.htm) or refer to the appropriate equivalent standard.

No performance category is defined in the processing equipment technology fact sheet. In such cases, AADL, APDL and ASDL are defined per Appendix C. Alternatively the applicant should refer to the appropriate requirements in the jurisdiction where the technology will be used.

Given the variability of fecal coliform and low concentration target measurements, each sample must be taken three times and analyzed individually for each sampling day. The performance of the treatment system will not be evaluated on the basis of the average of the three samples, but rather on complete results. As noted in clause 5.6 (Event Registry), the testing organization must report the conditions in effect during sampling, the chronology of events and the actions performed on the system. This includes the summer or winter seasonal performance achieved by a given technology during testing for fecal coliform reduction or any other temperature-dependent monitoring parameter.

Table 5.13.2 - Fecal coliform, NH_4 and phosphorus performance categories

NH_4 Mg N/L		TP mg/L		Fecal coliforms (UFC/100 ml)
10		1		50,000
5		0.3		2,000
1[4]		0.1[4]		200[3]

[3]The detection and quantification limits of the measurement methodology are defined in the analytical methods section of the CEAEQ Web site (www.ceaeq.gouv.qc.ca/methodes/bio_toxico_micro.htm) or refer to the appropriate equivalent standard.

[4]The detection and quantification limits of the measurement methodology are defined in the analytical methods section of the CEAEQ Web site (www.ceaeq.gouv.qc.ca/methodes/chimie_inorg.htm) or refer to the appropriate equivalent standard.

If the disinfection process uses ultraviolet radiation, the performance is defined after reactivation.

6. TECHNOLOGY PERFORMANCE VERIFICATION

6.1. VERIFICATION REQUIREMENTS

The performance of a technology can be confirmed for the categories shown in Tables 5.12.1 (Test conditions) and 5.13.1 (BOD_5 and suspended solids (SS) performance categories). These performance categories are attained when discharge limits computed with the method described in the Clause 5.11 are lower than the target category.

A test report, signed by a professional engineer, accompanied by a technology fact sheet, may be prepared by the Program when a technology presents test data for the technology that demonstrates sufficient treatment efficiency and operational reliability.

The testing must be carried out by a third party and the laboratory analyses must be carried out by a laboratory accredited in accordance with the ISO/CEI 17025 international standard, by a subscriber to the International Laboratory Accreditation Co-operation's (ILAC) Mutual Recognition Arrangement (MRA)[4].

Technology performance is verified in accordance with test conditions and observed results. For verification purposes, the selected flow is the average observed flow for the entire performance testing period (annual volume divided by 365 days), while loads are averages applied during the same period of time. The supplier of the technology must therefore ensure that the discharge flow and load conditions for which it wishes to receive verification are achieved during testing.

Note: Manufacturers are responsible for notifying of any problems with their technology that could affect performance, prior, during and after verification.

6.2. APPLICATION

In order for the performance of a given technology or processing equipment to be verified for a given condition (hydraulic, volume density and mass load), the applicant must submit the following supporting documentation with the application file:

- Prior to the start of testing:
  - A test plan (optional but recommended).
- Subsequent to testing:
  - A test report approved and signed by an engineer in compliance with clause 5.8 and Appendix A.
  - A declaration of third-party independence.
  - Operating manual.

In addition, for technology verification under the Canadian ETV Program, the applicant will be required to fulfill the formal application requirements specified in the Canadian ETV Program General Verification Protocol (GVP).

---

[4] For the purposes of reciprocity with Quebec, the Canadian ETV Program will accept testing and analyses carried out by laboratories accredited by *le Centre d'expertise en analyse environnementale du Québec* (CEAEQ), which is considered to be equivalent to ISO 17025.

APPENDIX A

TEST REPORT

APPENDIX A: TEST REPORT

A.1 TEST REPORT CONTENT

The test report must be divided into eight chapters and include at least the following:

CHAPTER 1 - DESCRIPTION OF THE TECHNOLOGY

- Names, brands and model numbers.
- Operational principles of the technology.
- Treatment chain (liquid and solid).
- Each component of the technology and its function.
- Specifications relating to the preliminary stages of processing.

When the proposed technology is based on conventional technology to which the applicant wishes to incorporate new features, the following information must be provided at the beginning of this chapter:

- The name of the conventional technology.
- The design criteria of the conventional technology and associated bibliographical references.
- A comparison between the proposed technology's design criteria to those of the conventional technology.
- An assessment of the potential impacts of these differences on the system's functioning or performance.
- A comparative analysis between the recommended pre-treatment for the proposed technology and the usual pre-treatment with the conventional technology.

CHAPTER 2 - OPERATIONAL LIMITS AND REQUIRED PRE-TREATMENT

- Specify the range of usable operating parameters (including flow) for each technology or model.
- Specify the concentration range for any parameter deemed critical to the correct performance of the technology for the target application.
- Indicate any other constraint on the use of the technology (excessive concentration of a contaminant, load or flow peak, etc.).
- If the technology requires preprocessing, provide the necessary specifications to a section of an applicable technical manual.

- As the case may be, specify if any design adjustments are required, particularly in regard to the reduction of water temperature in winter conditions and the effectiveness of the equipment over time.

CHAPTER 3 - TECHNICAL SPECIFICATIONS AND DESIGN CRITERIA

- Provide the technical specifications for each component that could affect the performance of the technology.
- Describe the suggested design criteria, redundancy equipment, emergency measures, ongoing monitoring, alarms, etc.
- State the capacity of the mechanical equipment.
- If processing unit dimensioning is based on a kinetic or other mathematical model, include the model and the values of the coefficients that were used.
- Include, as applicable, the equations or calculations on which the dimensioning of the processing units is based, as well as their verification studies.
- If applicable, provide the component scaling rules and prescribed design and operational application limits.

CHAPTER 4 - EXPECTED PERFORMANCE

- Indicate the expected performance of the technology, specifying the influent and treated water concentrations for each targeted control parameter.
- If applicable, state the proposed models or equations used to predict the performance of the technology or processing equipment.

CHAPTER 5 - PROCESSING BY-PRODUCTS AND EFFLUENT

- Provide the list and expected concentrations of by-products that could be formed during processing. As applicable, include the relationships between influent quality, product dosage and resulting by-product concentration.
- Indicate the types of residual water (sludge, sour and other process water) produced during treatment and provide an assessment of the projected input and output quantities.
- Include sludge and residual water management modes and equipment or processing sequence mass balance data, specifying input, production, accumulation (if applicable) and output.

CHAPTER 6 - DESCRIPTION OF THE MONITORED INSTALLATION

- Provide the address of the installation, as well as a site plan.

- Provide detailed plans and photographs of the installation being monitored for performance.
- Provide the specifications of each component of the system being monitored for performance.
- Specify the characteristics and technical specifications of the installation, as well as any differences between the installation being monitored and the proposed technology or model.

CHAPTER 7 - INTERPRETATION OF RESULTS

- Indicate the flows, applied loads and variations.
- Compare the real conditions of utilization with the design criteria (hydraulic load rate, organic load rate, retention time).
- Include observed results for the period of continuous operation compared to influent or effluent quality that enable the specification of design criteria such as hydraulic or mass load rates that were applied to the system during testing.
- Provide the mass balances and all available results on the production and evacuation of residual water and sludge.
- Compare achieved results with expected performance (verify matching with the mathematical models or equations used, as applicable).
- Provide an assessment of whether performance can be maintained beyond the trial period.
- Evaluate the potential for accumulation of sludge and other matter, equipment clogging, etc., and their impact on the performance and operation of the system.
- Graph the performance monitoring results with respect to the design or operational parameters, showing variable correlation, confidence intervals and regression tolerance limits (see Appendix C).
- Provide any other information that could be useful for interpreting the results.

CHAPTER 8 – OPERATIONAL GUIDE AND RECOMMENDATIONS

- Provide a user guide that specifies the operational, inspection and maintenance parameters and schedules recommended by the applicant.
- Specify recommended fixed frequency, if periodic, or indicate the criteria that justifies an action (pond sludge volume or height, filter surface or other water accumulation).
- Mention any action that took place on the authorized installations (e.g.: if specialists were called in, and indicate whether this type of intervention is envisaged in the user guide or operating manual).
- Provide evidence that the usage, inspection and maintenance recommendations contained in this guide or manual follow best practices, will enable target

performance to be maintained and match operational activities during performance monitoring.

APPENDIX – MODULAR SYSTEM SCALING CRITERIA

When requested by an applicant and for the purposes of verification of the performance of modular systems for scalable applications, the test report submitted must include the proposed scaling rules, a detailed definition of the prototype to full scale and a comparative study of the full-scale and modular systems. The test report must include the results of the operational tests performed on the various pieces of equipment and components of the full-scale prototype, including but not limited to:

- System response graphs
- Operational points
- System response times
- Phase distribution
    - load rates
    - transfer rates
    - efficiency rates
    - etc.
- Set points
- Control systems and loops
- Etc.

Theoretical considerations or equivalency notions submitted by applicants to support scaling rules and criteria are not taken into account in its analysis.

A.2 ENGINEER'S SIGNATURE

The test report must be signed by an engineer who is a member of the Association of Professional Engineers in the Province or State of practice.

APPENDIX B

ULTRAVIOLET DISINFECTION EQUIPMENT TESTING

APPENDIX B: ULTRAVIOLET DISINFECTION EQUIPMENT TESTING

B.1 BACKGROUND

The design principles for large multiple-lamp systems are well documented in the literature. The dose of UV delivered by these systems can be determined by well-known average intensity (I_{avg}) equations and equations that depend on the configuration of the reactor. The average intensity shown in the published references was determined by calculation methods such as the point-source summation method (PSS).

However, no publication currently mentions average intensity delivered by small prefabricated reactors. In general, manufacturers of such reactors use biodosimetry to determine delivered UV.

Only one protocol has so far been adopted by the international verification agencies for low transmittance wastewater (ETV/NSF — *Verification Protocol for Secondary Effluent and Water Reuse Disinfection Application*). However, this protocol was specifically developed to determine the amount actually delivered by large multiple-lamp UV reactors, in order to qualify them under American wastewater reuse programs (EPA/625/R-04/108 - *Guidelines for Water Reuse*).

A protocol was developed to calibrate the amount delivered by small prefabricated reactors (NSF/ANSI-55 - *Ultra-violet Microbiological Water Treatment Systems*), but this was in the field of drinking water, where application conditions are very different. As such, calibration based on the NSF/ANSI-55 protocol is not directly applicable to UV wastewater disinfection reactors.

This appendix proposes a protocol for the verification of the quantity delivered by small single-lamp UV reactors that were originally designed to produce drinking water, but that are today also marketed for wastewater applications. The suggested protocol is largely inspired by the *Ultraviolet Disinfection Guidance Manual* (USEPA, 2003: EPA 815-D-03-007) and *Ultraviolet Microbiological Toilets Treatment Systems* (NSF/ANSI-55).

B.2 TEST OBJECTIVE

Verification seeks to confirm the effective doses produced by a UV reactor under various operating conditions (flows, transmittances, temperatures, etc.).

Verification of the amount delivered by the device must be based on biodosimetry, with performance expressed in delivered dose (mJ/cm^2).

System designers can use the validated dose (D) to design a disinfection system by using a recognized mathematical model and by taking account of the specific operating conditions of the project.

B.3 UV REACTOR TEST PLAN

Verification of the dose delivered by the device must be based on biodosimetry.

Biodosimetry includes the development of a verification plan, calibration of phage response to the dose and calibration of amount delivered for a given flow. The applicant is advised to contact the Canadian ETV Program for advice regarding the test plan for the device.

It was previously possible to obtain a technology fact sheet for a processing chain that included a UV disinfection system without the delivered dose being calibrated by biodosimetry. This method of verification remains possible, but verification of the performance testing in this instance is limited to the characterized treatment chain, with results not applicable to other treatment chains. Applicants may refer to Clause 5.5.2.3 for details on treatment chain verification protocols.

B.4 THIRD PARTY TESTING

Biodosimetry must be performed by a company that specializes in this field.

B.5 SAMPLING

Sampling must be performed by a qualified person and comply with the provisions of the Onsite Residential Wastewater Treatment Technologies (CAN/BNQ 3680-600/2009), or refer to the appropriate equivalent standard[5].

B.6 SAMPLE PRESERVATION AND ANALYSIS

Sample preservation, transportation and storage must meet the Standard ISO 5667-10: 1992, paragraph 5.4 and follow the directives of publication *DR-09-04 – Modes de conservation pour l'échantillonnage de rejets liquides (eaux usées)* (www.ceaeq.gouv.qc.ca/documents/publications/echantillonnage/dr09_04rl.pdf), or refer to the appropriate equivalent standard[6], as well as the directives of the accredited analytical laboratory.

In some cases, measurement can be performed by the organization that owns the facility, if applicable, if its laboratories are recognized under international standard ISO/CEI

[5] In Quebec, refer to the *Guide d'échantillonnage à des fins d'analyses environnementales – Échantillonnage des rejets liquides – 1 & 2*
www.ceaeq.gouv.qc.ca/documents/publications/echantillonnage/generalitesC1.pdf,
www.ceaeq.gouv.qc.ca/documents/publications/echantillonnage/rejets_liquidesC2.pdf

[6] In Quebec,, refer to the document *DR-09-04 – Modes de conservation pour l'échantillonnage de rejets liquides (eaux usées)* available at
www.ceaeq.gouv.qc.ca/documents/publications/echantillonnage/dr09_04rl.pdf

17025 and authorized by a signatory to the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement[7].

B.7 VERIFICATION OF DELIVERED DOSES USING BIODOSIMETRY TESTING

The dose must be defined by biodosimetry testing with the MS-2 ATCC 15597 coliphage.

In order to determine the Reduction Equivalent Dose (RED), protocol NSF/ANSI-55 — 2004 must be used, with the following changes:

- Chapters 4.0, 5.0 and 8.0 are not applicable.
- Paragraphs 6.2.1, 7.2.2.1, 7.2.2.2 and 7.2.2.8 are not applicable.
- Paragraph 7.2.1.3 is modified as follows:
  - g) Determine the dose with the following dose percentages: 0, 15%, 30%, 45%, 60%, 75%, 90% and 105%. Exposure time for each dose must be determined using the following equation:

    Exposure time = dose/E_{avg}
  - h) Prepare 16, 60 X 20 mm Petri dishes including a sterile 10 X 3 mm agitator. Add a sufficient amount of suspension to each dish to a depth of 1 cm. Irradiate two dishes for each dose determined in paragraph 7.2.1.3 g.

- Paragraph 7.2.2.5 .1 is modified as follows:

7.2.2.5.1 Test target transmittances

At a minimum, the test must be performed for transmittance that is representative of the wastewater and a given flow. The test can be performed for several transmittances and designated flows.

If only one transmittance value is targeted, it must be 45%. If more than one transmittance value is targeted, the 45% value is mandatory, while the 55% and 65% values are recommended.

The sampling protocol given in paragraph 7.2.2.7 must be used for both reactors at 45% transmittance.

If more than one transmittance or flow is targeted, the protocol given in paragraph 7.2.2.7 may be used for only one reactor if the variation of the reduction equivalent dose of each engine to 45%

[7] For the purposes of reciprocity with Quebec, the Canadian ETV Program will accept testing and analyses carried out by laboratories accredited by *le Centre d’expertise en analyse environnementale du Québec* (CEAEQ), which is considered to be equivalent to ISO 17025.

transmittance is lower than 5%. Otherwise, the full protocol given in paragraph 7.2.2.7 must be followed for both reactors.

- Paragraph 7.2.2.5.2 is modified as follows:

7.2.2.5 .2 Measurement of normal output of the system

g) The variation of the intensity of the lamp must be evaluated for application conditions that are representative of the water to be treated. The equation of the variation of the intensity of the lamp must be determined from 25° C to 5° C in 5° increments. During testing, the intensity must be measured and recorded without interruption. During the measurement process, intensity must be stabilized (±1 mW/cm^2) for more than 30 minutes before being recorded.

h) The operating temperature of the lamp in the reactor must be measured under conditions that are representative of the water to be treated (from 25° C to 5° C in 5° increments). During testing, the temperature must be measured and recorded without interruption. During the lamp measurement process, temperature must be stabilized (±0.2 °C) for more than 30 minutes before being recorded.

The tests envisaged in the Sections g) and h) can be performed simultaneously using an equivalent method.

- Paragraph 7.2.2.7 is modified as follows:

Table B.1 — Sampling protocol for verification of disinfection performance testing

Sampling point		Entry	Exit
Day 0	System preparation	No sample	No sample
Day 1	Start-up (lamp off)	No sample	2 samples
	Start-up (lamp on)	3 samples	3 samples
	2 h	3 samples	3 samples
	4 h	3 samples	3 samples
	5 h (lamp off)	No sample	2 samples

After each period of stagnation, a minimum of 3 volumes must be purged from the UV reactor, pipes and other devices before sampling, in order to be certain that all initially-present water has been flushed.

All samples must be taken after 30 minutes of operation.

a) Install two systems as shown in figure 3 and check the installation with the water that will be used for the tests in accordance with manufacturer recommendations. If the reactor is equipped with a pre- or post-filter, they must be removed before testing. Install a 3-way valve immediately upstream of the disinfection unit in order to allow it to be bypassed. Determine the flow at each sampling point under various operational pressure levels. Determine the operational pressure required for each flow. The lamp can be deactivated during these tests.

d) Add sufficient PHBA (p-hydroxybenzoic acid) to reach target transmittance level.

The applicant is advised to contact the Canadian ETV Program for advice regarding the test plan. At a minimum, the following information should be provided:

- The name of the qualified independent firm mandated to perform the tests.
- The qualifications of the testing organization enabling it to perform its mandate.
- The name of the person (a professional with relevant experience and recognized status) who will produce and sign the report of the testing organization.
- A detailed description of the testing platform and the reactors used.
- A detailed description of the installation used for the tests, including a diagram.
- A description of the test and sampling conditions in each case, including
  - Target reference flows
  - Target reference transmittance levels.

B.8 EVENT REGISTRY

The testing organization must keep a logbook of the conditions in effect during sampling, the chronology of events and the actions performed on the system and must, in particular, note and report the following:

- The type, quantity and frequency of added products (chemical products, phages, bacteria, enzymes and other additives) during the entire testing period.
- All noteworthy events (equipment breakdown, repairs, adjustments and minor changes made to the system, replacement of parts or equipment, etc.).
- Status of systems, robots and instruments.
- Dates of equipment calibration.

B.9 CONTENTS OF THE TEST REPORT

The test report should be prepared by the testing organization and must be signed by an engineer with a description of his/her mandate.

The test report must include the following:

- Flow measurement procedures.
- Sample collection, preservation and transportation protocol.
- Evidence that the samples were taken by a qualified person and that all sampling standards, methods and preservation limits were met.
- A full presentation of all compiled analytical results (append laboratory analysis certificates). All results must be shown:
  - In table form, specifying sampling date and time of day. The tables must show both averages and standard deviations.
  - In illustrative form, based on the operating parameters (transmittance, flow, etc.) and showing the regression confidence intervals, if applicable
- The conditions in effect at time of sampling.
- The type, quantity and frequency of products added (chemical products, phages, bacteria, enzymes and other additives) during the entire testing period.
- Records and comments.

B.10 CONTENTS OF THE TECHNOLOGY FACT SHEET

The dose mentioned in the technology fact sheet should be based on biodosimetry. The corrected value of the dose that takes account of the ageing of UV lamps and clogging and ageing of the sleeves is shown in the technology fact sheet.

A correction factor that takes account of the effect of water temperature for submerged lamps must also be shown in the technology fact sheet.

If dose verification was based on multiple loads (transmittance/flow), the graph of the data regression equation can also be shown in the technology fact sheet.

APPENDIX C

STATISTICAL METHOD USED TO DEFINE DISCHARGE LIMITS

APPENDIX C: STATISTICAL METHOD USED TO DEFINE DISCHARGE LIMITS

The United States Environmental Protection Agency (USEPA, 1991) has proposed a statistical method to define discharge norms for industry. The proposed statistical method makes it possible to determine the maximum probable daily and monthly discharge concentration values that may be achieved by a treatment system based on monitoring results of treated effluent water and by taking account of observed (or estimated) effluent variation.

This appendix describes how to apply the statistical method to a data series obtained from processed effluent.

C.1 THE STATISTICAL METHOD PROPOSED BY THE USEPA

It is a recognized fact that many physical phenomena can be interpreted using characteristics that flow from the laws of statistics. It has also been observed that for any given contaminant, concentrations in processed effluent vary from one day to the next in spite of correct treatment system design and adequate operation.

The variability of discharge quality can be attributed to many factors, notably processing variations, fluctuation in flow rate or pollutant load, short-term adjustments to treatment equipment, wastewater temperature and, sometimes, ambient temperature, reliability of samples and measurements, etc. It is thus quite normal for the concentration levels of contaminants in treated water to be higher on certain days.

To take account of the intrinsic variability of effluent, the USEPA (1991) suggests applying two standards, one daily and the other monthly, that emerge from the statistical analysis of monitoring data. In setting a daily standard – which is in fact a maximum discharge limit – the EPA acknowledges that effluent concentrations at a given facility can on occasion exceed it. By also establishing a monthly norm, the USEPA constrains the use of high daily values and to that end, recommends that average daily and monthly standards applicable to a given installation correspondent respectively to the 99th centile and the 95th centile of the distribution of concentration data for treated effluent.

Moreover, whenever available data is limited in number, the USEPA recommends an approach based on a combination of the assessment of effluent variability defined by the standard deviation in the series of measurements, and the uncertainty caused by the limited number of measurements.

The method suggested by the USEPA rests on the assumption that if a series of representative monitoring data of the performance of a treatment system shows that data is time-independent (any particular value does not depend on the preceding value), the distribution of processed effluent monitoring data will be normal, lognormal or delta-lognormal.

These assumptions imply that operational conditions do not change during the period of characterization of the performance of the treatment system, and that the latter is stable over time.

Consequently, conclusions drawn from statistical evaluation are valid for conditions observed during the period of performance characterization of any given treatment system.

C.1.1 Limits of measurement methods

An experimental method cannot detect the presence of a contaminant with certainty when it is present below a specific concentration. Also, an experimental method cannot determine with certainty the concentration of a contaminant when it is present below a specific concentration. These are, respectively, the limits of detection and quantification.

When many values of a sample of a population are below the detection limit, the USEPA (1991; 2004) recommends using the delta-lognormal method to perform statistical calculations.

C.2 STATISTICAL CALCULATIONS

For a population of observations that follows normal distribution, the average (μ) can be obtained from the following equation:

$$\mu = \sum_{i}^{n} y_i / n$$

y_i = each effluent concentration datum

n = number of data values

and the standard deviation (σ) can be obtained from the following equation:

$$\sigma = \sqrt{\frac{\sum_{i}^{n} (y_i - \mu)^2}{n-1}}$$

For a population of observations that follows normal distribution, the probability that a given value is less than a critical value can be defined as:

$$P(Z \leq \mathrm{z}) = \frac{1}{\sqrt{2\pi}} \int^{z} e^{-z^2/2}$$

C.2.1 Tolerance limit

Since the characteristics of an effluent have intrinsic variability, the objective of the verification process is not to define the average performance of the treatment system, but rather to define its capacity to meet annual or periodic requirements. Therefore, a single observation or group of observations should meet a given requirement over a given period of time. The objective is thus to define the tolerance limits that encompass the entire body of observations to an acceptable centile (1 - α).

When a group of representative observations of the population (n = a finite value) is available, the standard deviation of the group "s" may differ from the standard deviation of the population (σ). It is thus useful to determine the certainty (1 - γ) of "s" in assessing the limits. The tolerance limit can then be determined to a level of certainty and an acceptable centile using the following equation:

$$LT = \mu + k_{\alpha,\gamma} s$$

The tolerance factor $k_{\alpha,\gamma}$ is provided in statistical tables that were calculated for this purpose

(Walpole et al, 1998; NIST/SEMATECH, 2007).

Tolerance limit for an average

For a sample of observations where the standard deviation "s" has been determined, it is possible to determine the standard deviation $s_{\bar{y}}$ of a given sub-group of observations.

$$s_{\bar{y}} = \frac{s}{\sqrt{m}}$$

It is thus possible of to determine the tolerance limit for the average of a defined number of values (m) with the following equation:

$$LT = \mu + k_{\alpha,\gamma} s_{\bar{y}}$$

C.2.2 Data verification

In order to calculate the discharge limits for a given contaminant, it is necessary to compile the concentration effluent data and follow these steps:

1. Prepare a daily data distribution graph and verify the type of distribution.
2. Validate data in accordance with the type of distribution; then eliminate aberrant values.

   However, prudence must be observed when eliminating data, since a very high or very low result may in fact reflect a normal situation. When limited data is available, the elimination of a very high or very low value can significantly influence the average and other calculations that follow from it.

Prior to calculating value limits, data must be processed according to the assumptions that are inherent to statistical methods. Calculation of an average value or standard deviation can be made from a group of values that follows normal distribution. However, if the distribution of the group of values does not reflect this hypothesis, transformation is required to ensure normal distribution of values.

Logarithmic transformation of measurements is used to normalize the distribution of effluent observations when their distribution is lognormal.

Weighting of the average and standard deviation in proportion to the fraction of values under the detection threshold must start from the arithmetic value of the average and the standard deviation. This can require several additional transformations, depending on the form of the distribution.

C.2.3 Linear regression method

When the method of verification used is based on multiple loads, the anticipated performance for a given load rate can be estimated using linear regression, using the following formula:

$Z_i = a + b * x_i$

Z_i = prediction of the dependant variable given by the linear regression model as a function of the independent variable x_i

a = set to the origin of the regression line

b = slope of the regression line

x_i = value of the independent variable used for calculation

The linear regression line is obtained by the method of least squares. The probability that the slope of the line is zero must be lower than 1% (significance α of the bilateral test) with a certainty of 99% (power of the γ test = 0.99).

To calculate the discharge limits using the statistical method described in A3.3.1.1 (Calculation method for normal distribution) and A3.3.1.2 (Lognormal distribution calculation method),the calculated average (µ) is replaced by the prediction (Z_i) that is determined using the linear regression line ($Z_i = a + b * x_i$) in accordance with the value of the abscissa (x_i) used for calculation.

The distribution of the residues ($x_i - \bar{x}$) or (Z_i - y_i) must be normal. The discharge limits are determined by the following adaptation:

$$LT = Z_i + k_{a,\gamma} * \frac{s}{\sqrt{m}} * \sqrt{1 + \frac{1}{n} + \frac{(x_i - \bar{x})^2}{\sum_i^n (x_i - \bar{x})^2}}$$

where

$\bar{x}$ = the average value of the independent variable.

The transformation of the results to linearize the regression model remains possible if the statistical method of calculating the discharge limits is modified to adapt it to the transformation. The technology or equipment provider remains responsible for effecting the proposed transformations and adaptations. The applicant is advised to contact the Canadian ETV Program for advice regarding the statistical method.

C.3 DISCHARGE LIMITS

Discharge requirements for domestic wastewater treatment plants should be expressed as annual, periodic or seasonal averages.

Average annual effluent discharge requirement for a given treatment station is based on the average of 12 measurements taken at a rate of one sampling day per month. The seasonal average is defined by the average of 6 measurements taken during the specified requirement period. Periodic average is defined by the average of 3 measurements taken during the specified requirement period.

In order for there to be agreement between the requirements and calculated discharge limits, assessment of discharge limits must be made in a way that reflects the discharge requirement formulation.

To ensure that the normal performance of the technology meets the discharge requirements defined for the installation, the probability of not exceeding the tolerance is fixed at 99%, with a 95% confidence level. This defined tolerance level will be above observed levels and will need to remain above the discharge requirements.

Average annual discharge limit (AADL)

For the purposes of new technology performance verification, the tolerance limit for the annual average is determined using the proposed method in order to define discharge limits in accordance with a centile not exceeding 99%, with a confidence level of 95% for an average of 12 measurements.

Average seasonal discharge limit (ASDL)

For the purposes of new technology performance verification, the tolerance limit for the seasonal average is determined using the proposed method to define discharge limits in accordance with a centile not exceeding 99%, with a confidence level of 95% for an average of 6 measurements.

Average periodic discharge limit (APDL)

For the purposes of new technology performance verification, the tolerance limit for the periodic average is determined using the proposed method to define discharge limits in accordance with a centile not exceeding 99%, with a confidence level of 95% for an average of 3 measurements.

C.3.1 CALCULATION OF REQUIRED AVERAGE ARITHMETIC DISCHARGE LIMITS

The discharge limit calculation method must take into account the form of the statistical distribution of data and the calculation method used for discharge requirements. For BOD_5C, SS, nitrogen and phosphorus, discharge requirements correspond to the average calculated arithmetic value.

C.3.1.1 Calculation method for normal distribution

When the distribution of monitoring data is normal, calculations of tolerance limits can be made as follows:

Calculation of the average

$$\mu = \sum_{i}^{n} y_i / n$$

y_i = each effluent concentration datum

n = number of data values

Calculation of the standard deviation

$$s = \sqrt{\frac{\sum_{i}^{n} (y_i - \mu)^2}{n-1}}$$

Calculations of AADL, ASDL and APDL

$$AADL = \mu + k_{\alpha,\gamma} * \frac{s}{\sqrt{m}}$$

$$ASDL = \mu + k_{\alpha,\gamma} * \frac{s}{\sqrt{m}}$$

$$APDL = \mu + k_{\alpha,\gamma} * \frac{s}{\sqrt{m}}$$

AADL	=	Average annual discharge limit
ASDL	=	Average seasonal discharge limit
APDL	=	Average periodic discharge limit
µ	=	Average of the series of measurements
$k_{\alpha,\gamma}$	=	Tolerance factor for a number of data, with a confidence level α and a centile γ defined in the statistical tables.
s	=	Standard deviation of the series of measurements
n	=	Number of values in the series of measurements
m	=	Number of measurements of the annual (12), seasonal (6) or periodic (3) average.

C.3.1.2 Calculation method for lognormal distribution

Generally speaking, sewage treatment plant effluent monitoring data have lognormal distribution.

When the distribution is lognormal, it is necessary to transform arithmetic values into logarithmic values before performing calculations. This transformation brings distribution into normal form in order that the usual statistical methods can be applied.

Subsequent to statistical calculations, it is necessary to reconvert the results into arithmetic values to obtain AADL ASDL, and APDL.

Transformation into logarithmic values is made using the following equation:

$$\mathbf{w_i = ln\ (y_i)}$$

y_i = each effluent concentration datum

w_i = logarithmic value of each effluent concentration datum

Calculation of the average

$$\mu_w = \sum_i^n w_i / n$$

μ_w = average of the logarithmic value of effluent concentration data

w_i = logarithmic value of each effluent concentration datum

n = number of data values

Calculation of the standard deviation

$$s_w = \sqrt{\frac{\sum_i (w_i - \mu_w)^2}{n-1}}$$

Calculations of AADL, ASDL and APDL

E (y) $= \exp\left[\mu_w + \frac{(s_w)^2}{2}\right]$

Var (y) $= \exp\left[2\mu_w + (s_w)^2\right]\left[\exp\left[(s_w)^2\right] - 1\right]$

Var (y) $_m$ [1] $= \frac{Var(y)}{m}$

$E(y)_m$ = E(y)

σ_m $= \sqrt{\ln\left(\frac{Var(y)_m}{[E(y)]^2} + 1\right)}$

μ_m $= \ln(E(y)) - 0{,}5(\sigma_m)^2$

AADL [2] $= E(y)_m + k_{\alpha,\gamma}\sqrt{Var(y)_m}$

ASDL [3] $= \exp\left(\mu_m + k_{\alpha,\gamma}\sigma_m\right)$

APDL [3] $= \exp\left(\mu_m + k_{\alpha,\gamma}\sigma_m\right)$

[1] Since requirements are based on an arithmetic average, the standard deviation of a group of arithmetic averages must be determined on the arithmetic value.

[2] The USEPA assumes that the distribution of a series of averages of 12 values follows a normal distribution.

[3] When the distribution of a group of data follows lognormal distribution, the USEPA assumes that the distribution of a series of averages of less than 10 values follows lognormal distribution.

AADL	=	Average annual discharge limit
ASDL	=	Average seasonal discharge limit
APDL	=	Average periodic discharge limit
μ_w	=	Average of the logarithmic value of measurements
s_w	=	Standard deviation of the logarithmic value of measurements
Var(y)	=	Standard deviation of a series of measurements
$Var(y)_m$	=	Standard deviation of a series of averages
E (y)	=	Average of a series of measurements
$k_{\alpha,\gamma}$	=	Tolerance factor of for a number of data, with a confidence level α and a centile γ defined in the statistical tables
μ_m	=	Logarithmic value of the calculated average
σ_m	=	Logarithmic value of the standard deviation calculated for a series of annual or periodic averages
n	=	Number of data values in the series of measurements
m	=	Number of measurements in the annual (12), seasonal (6) or periodic (3) average

C.3.1.3 Calculation method for delta-lognormal distribution

When a delta (δ) proportion of values falls below the detection threshold of the method of measurement (D), the distribution becomes delta-lognormal.

If distribution is delta-lognormal, the weighting of the average and the standard deviation in proportion to the fraction of values under the detection threshold must be performed on the arithmetic values of the average and the standard deviation. This may require several additional transformations, depending on the form of the distribution.

It is then necessary to transform the values above the threshold of detection (yc) into logarithmic values before performing the calculations. This transformation brings the distribution of the values located above threshold of detection into normal form so that the usual statistical methods can be applied to this series of values.

According to the USEPA, the value of the desired tolerance limit centile may be determined by formulating the hypothesis that the calculated average can be weighted in the following proportion:

$$\mu(U) = \delta D + (1 - \delta)\mu(yc)$$

The variance can be weighted in the following proportion:

$$Var(U) = \delta D_2 + (1 - \delta)(Var(yc) + [\mu(yc)]^2) - \mu(U)$$

Calculation of the delta (δ) proportion of the values that are below the detection threshold of the measurement method:

$$\boldsymbol{\delta = r/k}$$

r = number of measurements below the detection threshold

k = total number of measurements

δ = number of measurements below the detection threshold

Transformation of measurement data above the detection threshold into logarithmic values is made with the following equation:

$$\mathbf{w_i = \ln(y_i)}$$

y_i = each concentration datum in the effluent

w_i = logarithmic value of effluent concentrations above the detection threshold

Calculations for the average of n_m values

Calculation of the average of the logarithmic values of data above the detection threshold

$$\mu_w = \frac{\sum_{i}^{k-r} w_i}{(k-r)}$$

μ_w = average of the logarithmic value of effluent concentration data above the detection threshold

w_i = logarithmic value of effluent concentration data above the detection threshold

k − r = number of data values above the detection threshold

Calculation of the standard deviation of the data series (s_w) converted into logarithmic values:

$$s_w = \sqrt{\frac{\sum_{i}^{k-r} (w_i - \mu_w)^2}{(k-r) - 1}}$$

AADL, ASDL and APDL calculations

E(y) $= \exp\left[\mu_w + \frac{(s_w)^2}{2} \right]$

Var(y) $= \left(E(y)\right)^2 \left(\exp\left[(s)^2 \right] - 1 \right)$

E(Y*) $= \delta D + (1-\delta) E(y)$

Var(Y*) $= \delta D^2 + (1-\delta)\left[Var(y) + \left(E(y)\right)^2 \right] - E(Y^*)$

A $= \dfrac{Var(Y^*)}{\left[m\left(E(Y^*) - \delta^m D \right)^2 \right]}$

B $= \dfrac{-\left[\delta^m D^2 (1-\delta^m) \right]}{\left[E(Y^*) - \delta^m D \right]^2}$

C $$= \frac{\left[2\delta^{m}D\right]}{\left[E(Y^*)-\delta^{m}D\right]}$$

σ_m^2 $$= \ln\left\{\left(1-\delta^{m}\right)\left[1+A+B+C\right]\right\}$$

μ_m $$= \ln\left[\frac{\left(E(Y^*)+\delta^{m}D\right)}{(1-\delta^{m})}\right]-0{,}5\,\sigma_m^{\;2}$$

γ $$= \frac{(0{,}99-\delta)}{(1-\delta)}$$

AADL $$= \exp\left(\mu_m + k_{\alpha,\gamma}\,\sigma_m\right)$$

ASDL $$= \exp\left(\mu_m + k_{\alpha,\gamma}\,\sigma_m\right)$$

APDL $$= \exp\left(\mu_m + k_{\alpha,\gamma}\,\sigma_m\right)$$

AADL	=	Average annual discharge limit
ASDL	=	Average seasonal discharge limit
APDL	=	Average periodic discharge limit
μ_w	=	Average of the logarithmic values of measurements above the detection threshold
s_w	=	Standard deviation of the logarithmic values of measurements above the detection threshold
Var (y)	=	Standard deviation of measurements above the detection threshold
E (y)	=	Average of measurements above the detection threshold

Var(Y*)	=	Weighted standard deviation of measurements
E(Y*)	=	Weighted average of measurements
$K_{\alpha,\gamma}$	=	Data series tolerance factor with confidence level α and centile γ as defined in the statistical tables
μ_m	=	Logarithmic value of the weighted average for an annual or periodic series of averages
σ_m	=	Logarithmic value of the weighted standard deviation for an annual or periodic series of averages
$k - r$	=	Number of values above the detection threshold of the measurement method
δ	=	r/k
n	=	Number of values in the series of measurements
m	=	Number of measurements in the annual (12), seasonal (6) or periodic (3) average

C.3.2 CALCULATION OF REQUIRED AVERAGE GEOMETRIC DISCHARGE LIMITS

The discharge limit calculation method must take into account the form of the statistical distribution of data as well as the discharge requirement calculation method. For fecal coliforms, the discharge requirement corresponds to the calculated geometric average for the period.

Consequently, the standard deviation of a group of geometric averages must be determined by using the standard deviation of logarithmic values.

C.3.2.1 Lognormal distribution calculation method

Generally speaking, effluent treatment plant monitoring data follow lognormal distribution.

When distribution is lognormal, it is necessary to transform data into logarithmic values prior to performing calculations. This transformation brings distribution into normal form to enable the usual statistical methods to be applied. Once statistical calculations have been made, results must be reconverted into arithmetic values to obtain AADL, ASDL and APDL.

The following equation is used to transform data into logarithmic values:

$$\mathbf{w_i = \ln (y_i)}$$

x_i = individual effluent concentration datum

y_i = logarithmic value of each effluent concentration datum

Calculation of the average

$$\mu_w = \sum_i^n w_i / n$$

μ_w = average logarithmic value of effluent concentration data

w_i = logarithmic value of each effluent concentration datum

n = number of data values

Calculation of the standard deviation

$$s_w = \sqrt{\frac{\sum_i (w_i - \mu_w)^2}{n-1}}$$

Calculations of AADL, APDL and ASDL

$$\sigma_m = \frac{s_w}{\sqrt{m}}$$

$$\textbf{AADL} = \exp\left[\mu_w + k_{\alpha,\gamma}\,\sigma_m\right]$$

$$\textbf{ASDL} = \exp\left[\mu_w + k_{\alpha,\gamma}\,\sigma_m\right]$$

$$\textbf{APDL} = \exp\left[\mu_w + k_{\alpha,\gamma}\,\sigma_m\right]$$

AADL	=	Average annual discharge limit
ASDL	=	Average seasonal discharge limit
APDL	=	Average periodic discharge limit
μ_w	=	Average of the logarithmic values of measurements
s_w	=	Standard deviation of logarithmic values of measurements
σ_m	=	Calculated standard deviation for a series of annual or periodic geometric averages
$\kappa_{\alpha,\gamma}$	=	Data series tolerance factor with confidence level α and centile γ as defined in the statistical tables
nr	=	Number of values in the series of measurements
m	=	Number of measurements in the annual (12), seasonal (6) or periodic (3) average

C.3.2.2 Delta lognormal distribution calculation method

When a delta (δ) proportion of values falls below the detection threshold of the method of measurement (D), the distribution becomes delta-lognormal. The weighting of the average and the standard deviation in proportion to the fraction of values under the detection threshold must be performed on the arithmetic value of the average and the standard deviation. This may require several additional transformations, depending on the form of the distribution.

If the delta distribution is lognormal, the logarithmic values of measurements above the detection threshold (x_C) follow normal distribution.

According to the USEPA, the value of the desired tolerance limit centile can be determined by formulating the hypothesis that the calculated average can be weighted in the following proportion:

$$\mu(U) = \delta D + (1 - \delta)\mu(xc)$$

The variance can be weighted in the following proportion:

$$Var(U) = \delta D_2 + (1 - \delta)\ (Var\ (xc) + [\mu(xc)]^2) - \mu(U)$$

Calculation of the delta (δ) proportion of the values which are below the detection threshold of the measurement method:

δ= r/k

r = number of measurements below the detection threshold

k = total number of measurements

δ = number of measurements below the detection threshold

The transformation of the values above the detection threshold into value logarithmic equation is made with the following equation:

$w_i = \ln(y_i)$

y_i = each concentration datum in the effluent

w_i = logarithmic value of effluent concentrations above the detection threshold

Calculations for an average of n_m values

Calculation of the average of the logarithmic values of data above the detection threshold:

$$\mu_w = \frac{\sum_{i}^{k-r} w_i}{(k-r)}$$

μ_w = average of the logarithmic value of effluent concentration data above the detection threshold

w_i = logarithmic value of effluent concentration data above the detection threshold

k − r = number of data values above the detection threshold

Calculation of the data series standard deviation (s_w) converted into value logarithmic values:

$$s_w = \sqrt{\frac{\sum_{i}^{k-r} (w_i - \mu_w)^2}{(k\text{-}r) - 1}}$$

AADL, APDL and ASDL calculations

$$\mu_C = \delta \ln(D) + (1-\delta)\mu_w$$

$$\frac{(\sigma_c)^2}{m} = \frac{\left\{\delta[\ln(D)]^2 + (1-\delta)\left(\mu_w{}^2 + s_w{}^2\right) - \mu_c{}^2\right\}}{m}$$

$$(\sigma_c)_m = \sqrt{\frac{(\sigma_c)^2}{m}}$$

AADL $= \exp\left(\mu_c + k_{\alpha,\gamma}(\sigma_c)_m\right)$

ASDL $= \exp\left(\mu_c + k_{\alpha,\gamma}(\sigma_c)_m\right)$

APDL $= \exp\left(\mu_c + k_{\alpha,\gamma}(\sigma_c)_m\right)$

AADL	=	Average annual discharge limit
ASDL	=	Average seasonal discharge limit
APDL	=	Average periodic discharge limit
μ_w	=	Average of the logarithmic values of measurements above the detection threshold
s_w	=	Standard deviation of the logarithmic values of measurements above the detection threshold
$K_{\alpha,\gamma}$	=	Data series tolerance factor with confidence level α and centile γ as defined in the statistical tables
μ_c	=	Weighted average of the logarithmic values of measurements
$(\sigma_C)_m$	=	Weighted standard deviation of a the logarithmic values of a series of annual or periodic averages
k-r	=	Number of values above the detection threshold of the measurement method
δ	=	r/k

n	=	Number of values in the series of measurements
m	=	Number of measurements in the annual (12), seasonal (6) or periodic (3) average

Table C.1 - $K_{\alpha.95}$ tolerance factor

95% Confidance level								
	Centile							
	$t_{f50/95}$	$t_{f55/95}$	$t_{f60/95}$	$t_{f70/95}$	$t_{f80/95}$	$t_{f90/95}$	$t_{f95/95}$	$t_{f99/95}$
k	**0,50**	**0,55**	**0,60**	**0,70**	**0,80**	**0,90**	**0,95**	**0,99**
2	0,000	2,454	4,943	10,237	16,450	25,007	32,138	45,462
3	0,000	0,639	1,287	2,666	4,284	6,513	8,370	11,840
4	0,000	0,410	0,826	1,710	2,748	4,178	5,369	7,595
5	0,000	0,326	0,657	1,361	2,188	3,326	4,274	6,046
6	0,000	0,283	0,571	1,183	1,900	2,889	3,713	5,252
7	0,000	0,257	0,518	1,073	1,724	2,621	3,369	4,766
8	0,000	0,239	0,482	0,999	1,605	2,440	3,136	4,436
9	0,000	0,227	0,456	0,945	1,519	2,308	2,967	4,197
10	0,000	0,217	0,437	0,904	1,453	2,209	2,838	4,015
11	0,000	0,209	0,421	0,872	1,401	2,130	2,737	3,872
12	0,000	0,203	0,408	0,846	1,359	2,066	2,655	3,756
13	0,000	0,198	0,398	0,824	1,324	2,013	2,587	3,659
14	0,000	0,193	0,389	0,806	1,295	1,968	2,529	3,578
15	0,000	0,189	0,381	0,790	1,269	1,930	2,480	3,508
16	0,000	0,186	0,375	0,776	1,247	1,896	2,437	3,448
17	0,000	0,183	0,369	0,764	1,228	1,867	2,400	3,394
18	0,000	0,181	0,364	0,754	1,211	1,841	2,366	3,347
19	0,000	0,178	0,359	0,744	1,196	1,818	2,337	3,306
20	0,000	0,176	0,355	0,736	1,182	1,797	2,310	3,268
25	0,000	0,169	0,340	0,703	1,130	1,718	2,208	3,124
30	0,000	0,163	0,329	0,682	1,095	1,665	2,140	3,027
33	0,000	0,161	0,324	0,672	1,079	1,640	2,108	2,982
35	0,000	0,160	0,321	0,666	1,070	1,626	2,090	2,957
40	0,000	0,157	0,316	0,654	1,050	1,597	2,052	2,902
45	0,000	0,154	0,311	0,644	1,035	1,573	2,021	2,859
50	0,000	0,152	0,307	0,636	1,022	1,554	1,997	2,824
55	0,000	0,151	0,304	0,629	1,011	1,537	1,976	2,795
60	0,000	0,149	0,301	0,624	1,002	1,524	1,958	2,770
65	0,000	0,148	0,299	0,619	0,994	1,512	1,943	2,748
70	0,000	0,147	0,297	0,614	0,987	1,501	1,929	2,729
75	0,000	0,146	0,295	0,611	0,981	1,492	1,917	2,712
80	0,000	0,146	0,293	0,607	0,976	1,484	1,907	2,698
85	0,000	0,145	0,292	0,604	0,971	1,476	1,897	2,684
90	0,000	0,144	0,291	0,602	0,967	1,470	1,889	2,672
95	0,000	0,144	0,289	0,599	0,963	1,464	1,881	2,661
100	0,000	0,143	0,288	0,597	0,959	1,458	1,874	2,651
150	0,000	0,139	0,281	0,581	0,934	1,424	1,831	2,601
200	0,000	0,137	0,277	0,573	0,920	1,402	1,802	2,557
250	0,000	0,136	0,274	0,567	0,911	1,388	1,783	2,529
300	0,000	0,135	0,272	0,563	0,904	1,377	1,770	2,508
400	0,000	0,134	0,269	0,557	0,895	1,363	1,751	2,481
500	0,000	0,133	0,267	0,554	0,889	1,354	1,739	2,463
600	0,000	0,132	0,266	0,551	0,884	1,347	1,730	2,449
700	0,000	0,132	0,265	0,549	0,881	1,342	1,723	2,439
1000	0,000	0,131	0,263	0,545	0,874	1,332	1,709	2,419
$\propto$	0,000	0,126	0,253	0,524	0,842	1,280	1,645	2,327

BIBLIOGRAPHY

Cohen J., 1988. Statistical power analysis for the behavioural sciences, 2e edition, Lawrence Erlbaum associates, Publisher, Hillsdale, N.J..

ETV/NSF, 2002. *Verification Protocol for Secondary Effluent and Water Reuse Disinfection Application*, Water Quality Protection Center, Environmental Technology Verification Protocol, NSF

MDDELCC, 2009. *Procédures d'évaluation des technologies de traitement des eaux usées d'origine domestiques*.

NIST/SEMATECH, On line reading 10-29-2007, e-Handbook of Statistical Methods, http://www.itl.nist.gov/div898/handbook/.

NSF/ANSI 40, *Residential wastewater treatment systems*, http://www.nsf.org/ (This standard applies to technologies having rated treatment capacities of 1514 litres per day [400 gal US/d] to 5678 litres per day [1500 gal US/d] and it has two treatment classes.)

Walpole R.E., Myers R.H. and Myers S.L., 1998. Probability and Statistics for engineers and scientists, Prentice Hall Inc., N.J. USA, 739 p.

USEPA, 1991. Technical support document for water quality based toxics control, Office of Water enforcement and permits, U.S. EPA, Washington D.C..

USEPA, 2003. *Ultraviolet Dinsinfection Guidance Manual*, Office of Water, EPA, EPA 815-D-03-07.

USEPA, 2004a. Appendix E: Modifed Delta-Lognormal Distribution, in Technical developpement document for the final effluent limitation guidelines and new source performance standards for the concentrated aquatic animal production point source category (revised august 2004), Engineering and analysis division, Office of science and technology, U.S. EPA, Washington, D.C..

USEPA, 2004b. *Guidelines for Water Reuse*, EPA/625/R-04/108, *Office of water, Office of research and development, EPA*, Washington D.C.