

Nonylphenols and Ethoxylates in Water by LC/MS/MS

Parameter	Nonylphenol and Nonylphenol Ethoxylates (TEQ)			
MDLs and EMS Analyte Codes	<u>Analytes</u>	<u>CAS#</u>	<u>Approx. MDL</u> <u>µg/L</u>	<u>EMS Analyte codes</u>
	NP (Nonylphenol)	84852-15-3	0.4	N032
	NP1EO (Nonylphenol Monoethoxylate)	104-35-8	0.4	
	NP2EO (Nonylphenol Diethoxylate)	20427-84-3	0.4	
	NP3EO (Nonylphenol Triethoxylate)		0.5	
	NP4EO (Nonylphenol Tetraethoxylate)		0.5	
	NP5EO (Nonylphenol Pentaethoxylate)		0.5	
	NP6EO (Nonylphenol Hexaethoxylate)		0.5	
	NP7EO (Nonylphenol Heptaethoxylate)		0.5	
	NP8EO (Nonylphenol Octaethoxylate)		0.5	
	OP (Octylphenol)	140-66-9	0.4	
	OP1EO (Octylphenol Monoethoxylate)	2315-67-5	0.4	
	OP2EO (Octylphenol Diethoxylate)	2315-61-9	0.4	
	OP3EO (Octylphenol Triethoxylate)		0.5	
	OP4EO (Octylphenol Tetraethoxylate)		0.5	
	OP5EO (Octylphenol Pentaethoxylate)		0.5	
	OP6EO (Octylphenol Hexaethoxylate)		0.5	
	OP7EO (Octylphenol Heptaethoxylate)		0.5	
	OP8EO (Octylphenol Octaethoxylate)		0.5	
	Nonylphenol and Nonylphenol Ethoxylates (TEQ)		2.5	

Analytical method SPE extraction – LC/MS/MS

Introduction This method is for the quantitative determination of nonylphenol, octylphenol, and their ethoxylates in water samples by LC/MS/MS.

Endocrine disruptors (EDs), such as nonylphenol, affect reproduction in humans, as well as wildlife. Thus, the need to monitor EDs in waste water is of importance for public safety. For more than forty years alkylphenols such as NP, NPE, OP, and OPE have been used as detergents, emulsifiers, wetting agents and more. Their presence in the environment is solely due to human activities, and mainly from WWTPs (waste water treatment plant) and direct discharge. Over 80% of alkylphenol produced are nonylphenol based compounds. The rest are mostly octylphenol based compounds.

NPEs are degraded to shorter chain nonylphenol ethoxylates as well as shorter nonylphenol ethoxycarboxylates under aerobic condition, before being biodegraded to nonylphenol. Shorter ethoxylate chain alkylphenols have greater toxicity than longer ones. CCME describes Toxic Equivalent Factors from Environment Canada for NPnEO (1≤n≤8) and OPnEO(1≤n≤8) as half the relative toxicity of NP and OP.

Certified nonylethoxylate and octylethoxylate standards greater than NP3EO and OP2EO are almost nonexistent and therefore characterization of ethoxylate distribution in technical grade standards such as nonoxynol and triton-X are suitable alternatives.

Method summary Water samples are extracted using polymeric sorbent SPE. Cartridges are cleaned with dichloromethane (DCM) to eliminate all alkylated phenols leftover from manufacturing, packaging or handling. Then, SPE sorbents are conditioned with methanol and acidified water. Samples are spiked with a labelled surrogate solution and loaded onto the SPE. After washing the sorbent beds with a methanol solution in water, they are vacuum dried. Elution is done by percolating a methanol/DCM solution through the SPE cartridges. A labelled internal standard is added before LC/MS/MS analysis.

Matrix	Freshwater, Groundwater, Seawater, Wastewater.
Interferences and Precautions	<p>a) Contaminants present in solvents, reagents, sample containers, or sample processing equipment may cause interferences or yield artefacts. Plastic containers should be avoided. High purity grade solvents should be used.</p> <p>b) Matrix dependant interferences can cause signal suppression or signal enhancement in the Electrospray Ionisation source (ESI). Extract dilution may help to dampen these effects.</p> <p>c) A method blank helps to demonstrate a contamination free procedure. Background subtraction of method blank is not allowed.</p> <p>d) Solvent blanks should be run before and after LC/MS/MS analysis to clean the system of alkylphenol contaminants.</p> <p>Solvent blanks should also be run after highly contaminated samples to eliminate carryover.</p>
Sample Handling and Preservation	<p>Container: Amber glass bottles (consult laboratory for volume requirements).</p> <p>Preservation: Acidify to pH <2 with HCl or sodium bisulfate (NaHSO₄) to extend hold times to 14 days.</p>
Stability	<p>Holding time:</p> <p>Sample: Extract unpreserved samples within 7 days of sampling. Hold time is extended to 14 days if preserved.</p> <p>Extract: Analyze extract up to 40 days after extraction.</p> <p>Storage: Refrigerate samples at ≤6°C. Keep extracts below ≤6°C.</p>
Procedure	<p>Calibration stock:</p> <p>Individual standards can be purchased as neat material or in solution but are only available for Nonylphenol, Octylphenol and mono- and di- ethoxylates. A technical grade mix must be used to calibrate for the remainder of the ethoxylates. This requires the technical grade mix to be characterized initially by HPLC to determine the ethoxylate concentration distribution. All identifiable isomers (branched and linear) of each substance class must be included with this analysis. Individual mono- and di-ethoxylate standards should be used to provide a more accurate quantification than technical grade mix for the primary components.</p> <p>Extraction:</p> <p>Shake samples prior to sub-sampling. If the amount of particulate matter in a sample is low enough to prevent clogging of the SPE cartridge (labs may establish a suitable limit, which may not exceed 1% by estimation), then a representative portion of the sample is extracted in total by SPE, using the elution solvent to extract the particulate fraction. Samples with higher levels of particulate are filtered on glass fibre filters. Filters with particulate should be extracted using the soil extraction protocol, with extracts combined before SPE extraction (or analyzed separately, with results combined to reflect the total concentration). Where extracts from the aqueous and particulate fractions will be combined for analysis, the surrogate(s) from the aqueous fraction should not be added to the particulate fraction (use of a secondary surrogate to independently monitor the particulate fraction is recommended).</p> <p>Samples are acidified and representative sub-samples are measured for extraction. Sub-samples are spiked with labelled surrogate solution.</p> <p>SPE cartridges are mounted on a vacuum manifold and cleaned by percolating DCM through the cartridge. DCM is flushed away under full vacuum. SPE are conditioned with methanol and acidified water. Cartridges should not go dry during or after conditioning. Samples are loaded on to the cartridges at a rate of 2-5mL per minute.</p> <p>Once all the samples have completely passed through the SPE beds, flasks are washed with a methanol/water solution and the solutions are added to the cartridges and eluted. SPE cartridges are dried under full vacuum for 15-30 minutes, until sorbent is visibly dry</p>

and free flowing.

Elution is done by percolating a methanol/DCM solution. Elution solution is drawn in the sorbent and left to soak for 1 minute before percolation. Extracts are diluted to volume with elution solution. A labelled internal standard solution is added to extracts before LC/MS/MS analysis.

UPLC Parameters

Column: ODS UPLC column
Mobile Phase A: Ammonium acetate in water
Mobile Phase B: Acetonitrile
Mode: Gradient elution

MS/MS Parameters

MS/MS transitions:

Analytes	Transitions (m/z)	ESI Polarity
NP	219->133;147	Neg.
NP1EO	282->127;265	Pos.
NP2EO	326->183;121	Pos.
NP3EO	370->227;353	Pos.
NP4EO	414->271;397	Pos.
NP5EO	458->315;440	Pos.
NP6EO	502->89;485	Pos.
NP7EO	546->89;529	Pos.
NP8EO	591->89;573	Pos.
OP	205->133;106	Neg.
OP1EO	268->113;250	Pos.
OP2EO	312->295;183	Pos.
OP3EO	356->339;295	Pos.
OP4EO	400->383;271	Pos.
OP5EO	444->427;315	Pos.
OP6EO	488->471;359	Pos.
OP7EO	532->515;403	Pos.
OP8EO	576->559;447	Pos.

Calculations

Nonylphenol and Nonylphenol Ethoxylates (TEQ) = ([NP] X 1) + ([NP 1EO] X 0.5) + ([NP2EO] X 0.5) + ([NP3EO] X 0.5) + ([NP3EO] X 0.5) + ([NP4EO] X 0.5) + ([NP5EO] X 0.5) + ([NP6EO] X 0.5) + ([NP7EO] X 0.5) + ([NP8EO] X 0.5) + ([OP] X 1) + ([OP1EO] X 0.5) + ([OP2EO] X 0.5) + ([OP3EO] X 0.5) + ([OP4EO] X 0.5) + ([OP5EO] X 0.5) + ([OP6EO] X 0.5) + ([OP7EO] X 0.5) + ([OP8EO] X 0.5)

For purposes of the TEQ calculation, use one-half of the reported detection limit for non-detected test results.

Toxic Equivalency Factors (TEFs) for NP, NPEs, OP, OPEs (relative to NP) for BC MOE prescribed substances.	
Nonylphenol (NP)	1
NPnEO (1≤n≤8)	0.5
Octylphenol (OP)	1
OPnEO (1≤n≤8)	0.5

Performance Requirements

Any analytical method options selected for this analysis must meet or exceed the performance requirements specified below.

Accuracy and Precision requirements are distinct from daily QC requirements, and apply to measures of long-term method performance (averages and standard deviations). Achievement of these requirements is to be demonstrated during initial and ongoing method revalidation studies. For Initial Validations, averages of at least 8 Lab Control Samples or Reference Materials must be assessed. Ongoing Revalidations (performance reviews) should assess QC data encompassing longer periods (e.g. 6 months to 1 year). A minimum frequency of 2 years is recommended for Ongoing Revalidations.

Accuracy Requirement: Laboratories must demonstrate method accuracy (measured as

average recovery) through repeat analysis of Laboratory Control Samples at concentrations above ten times the MDL. Average accuracy must be between 70-130% for all analytes.

Precision Requirement: Laboratories must demonstrate method precision through repeat analysis of Laboratory Control Samples at concentrations above ten times the MDL. Precision measured as percent relative standard deviation (%RSD) must be <20% for all analytes.

Sensitivity Requirement: Where possible, the method should support Reporting Limits (and MDLs) that are less than 1/5 of applicable numerical standards. The method is not fit-for-purpose if an MDL exceeds a guideline, standard, or regulatory criteria against which it will be used for evaluation of compliance.

Quality Control

Summary of QC Requirements		
QC Component	Minimum Frequency	Minimum Data Quality Objectives
Method Blank (MB)	One per batch (max 20 samples)	Less than reported DL
Laboratory Control Sample (LCS)	One per batch (max 20 samples)	60-140%
Laboratory Duplicate (DUP)	One per batch (max 20 samples)	≤30% RPD [or within 2x reported DL for low level results]
Surrogate Compounds	All samples	50-140%
Matrix Spike	One per batch (max 20 samples)	50-140%
Internal Standards	All samples	Peak area counts for all internal standards in all injections must be within ± 50% of the average peak area calculated during the initial calibration.
Calibration Verification Standard (CVS)	Minimum 1 per initial calibration	80-120%
Continuing Calibration Verification (CCV)	One per batch (max 20 samples)	70-130%
If DQOs are not met, repeat testing or report qualified test results. DQOs do not apply to MS results where sample background exceeds spike amount.		

Method Blank: Required. An aliquot of reagent water that is treated exactly like a sample including exposure to equipment, solvents and reagents, sample preservatives, internal standards and surrogates that are used in the analysis batch.

Laboratory Duplicates: Required. Data quality objectives are listed above.

Laboratory Control Sample (Method Spike): Required. Prepare a Laboratory Control Sample by fortifying a field sample with known concentrations of the analytes.

Surrogate Compounds: Required. Suggested: 4-n-NP-¹³C₆, NP3EO-¹³C₆ and/or OP1EO-¹³C₆.

Calibration Verification Standard (CVS): Required. A CVS from a source separate from the calibration standard must be analyzed with each initial calibration to monitor calibration accuracy.

Continuing Calibration Verification (CCV): Required. A mid-point calibration standard must be analyzed throughout the instrument run at least every 20 samples and at the end of the run to monitor calibration drift.

Prescribed Elements The following components of this method are mandatory:

1. Analysis must be done by LC/MS/MS with a MRM transition for each compound, except Nonylphenol and Octylphenol may be analyzed by GC/MS or GC/MS/MS.
2. Confirmation of LC/MS/MS test results must be done with a second MRM transition.
3. All identifiable isomers of each nonylphenol substance class (branched and linear) must be included with this analysis.
4. Different surrogate standards must be used with ESI negative and ESI positive modes. Suggested: 4-n-NP-¹³C₆, NP3EO-¹³C₆ and/or OP1EO-¹³C₆.
5. Different internal standards must be used with ESI negative and ESI positive modes. Suggested: BPA-d₁₆, NP2EO-¹³C₆.
6. A representative portion of any particulate matter present in samples must be extracted and analyzed. Where particulate matter exceeds 1% of sample volume (by estimation), it must be separated by filtration and extracted separately, with extracts or final results combined to give a total concentration.
7. TEQ calculations must be conducted as specified.
8. If this method is utilized for seawaters or brine samples, method validation for that matrix must be conducted prior to use using Matrix Spikes and/or Reference Materials.
9. Sample container materials, preservation, storage, and hold time requirements may not be modified. Samples analyzed beyond the stated holding time must be qualified. Refer to latest version of "BC MOE Sample Preservation and Hold Time Requirements" for updates.
10. All performance requirements and QC requirements must be met.

Apart from these limitations, and provided performance requirements are met, laboratories may introduce modifications to this method to improve quality or efficiency.

References

ASTM D7485-09. Determination of Nonylphenol, p-tert-octylphenol, Bisphenol A, Nonylphenol Monoethoxylate and Nonylphenol Diethoxylate in Environmental Waters by Liquid Chromatography/Tandem Mass Spectrometry, 2009.

CCME 2002. Canadian Water Quality for the Protection of Aquatic Life, Nonylphenol and its Ethoxylates, Canadian Council of Ministers of the Environment.

Revision History

Sept 15, 2017 First version added to BC Lab Manual in support of 2017 CSR updates.