REQUEST FOR PROPOSALS

Development of a Scientific Criteria Document for Canadian Water Quality Guidelines for Polycyclic Aromatic Hydrocarbons

Water Guidelines Working Group
Canadian Council of Ministers of the Environment

1.0 BACKGROUND

The Canadian Council of Ministers of the Environment (CCME) is the primary minister-led intergovernmental forum for collective action on environmental issues of national and international concern. The 14 member governments work as partners in developing consistent environmental standards and practices.

CCME established the Water Guidelines Working Group (WGWG) to develop Canadian Environmental Quality Guidelines (CEQGs) for water. This includes Canadian Water Quality Guidelines (CWGQs) for the protection of aquatic life (including water, tissue residue, and sediment). CWQGs for the Protection of Aquatic Life are critical tools for environmental management, providing credible scientific guidance on long-term no-effect concentrations as well as guidance on impacts from short-term events, such as spills.

WGWG's Polycyclic Aromatic Hydrocarbon (PAH) Project Team (hereafter "the Project Team") is developing short- and long-term freshwater and marine CWQGs for the protection of aquatic life for PAHs. The guidelines will be based on the narcotic target lipid model (NTLM) and phototoxic target lipid model (PTLM) (Tillmanns *et al.* 2023; Marzooghi *et al.* 2017) and will include the ability to determine site-specific guidelines based on the location and water quality conditions of a water body.

A model and a corresponding beta version of a PAH guideline calculator have been developed and semi-validated. The PAH guideline calculator predicts short- and long-term narcotic and phototoxic water quality guidelines in marine and freshwater environments for individual PAHs and certain PAH groupings (e.g., groups of parent and associated alkylated PAHs).

A major factor for predicting phototoxic PAH guidelines is determining the light spectra reaching the aquatic receptor, which requires consideration of light attenuation factors in the atmosphere and water column. To that end, some of the previous work focused on determining how to account for light attenuation factors in these two media. Through this work, the Project Team decided to leverage the Tropospheric Ultraviolet and Visible Radiation Model (TUV) (Madronich 2021) to account for light attenuating variables in the atmosphere while a default light attenuation coefficient Kd(λ) and power model relating Kd(λ) to dissolved organic concentration (DOC) was developed to estimate the underwater solar irradiance spectra, at depth, in marine and freshwater ecosystems, respectively.

Through some of the previous work, the PTLM-related calculations required to predict narcotic and phototoxic PAH guidelines were translated into R code and operationalized in a PAH guideline calculator in a web-based software application (Shiny App). A sensitivity analysis also conducted as part of this work identified sensitive input variables in the PTLM with respect to calculated PAH guidelines.

Lastly, as part of the previous work, references in which *in situ* PAH phototoxicity was measured were reviewed to determine if they could be used to validate the PAH guideline calculator.

2.0 STATEMENT OF WORK

The Contractor will build on previous work to draft a Scientific Criteria Document (SCD) that explains how the short- and long-term freshwater and marine values for Canadian Water Quality Guidelines (CWQGs) for PAHs were derived.

3.0 SCOPE OF WORK

The project will commence by August 9, 2024 and will be completed by March 31, 2025.

The Contractor will be a professional science writer with a detailed understanding of biological systems and chemical hazard assessment.

The Project Team must be provided with an opportunity to review and provide comments on each draft deliverable. A minimum of four weeks is required for the Project Team to review and provide comments for each draft deliverable. The Contractor will incorporate Project Team comments into each next deliverable.

All deliverables will be written and structured in a clear, concise and user-friendly manner to inform a broad audience of federal, provincial and territorial decision-makers, practitioners and others involved in guideline development and implementation. Information will be presented in a consistent format. Tables, charts, graphs, or other visuals may be used where they aid in clarity and comprehension. All deliverables will follow the CCME style guide (to be provided to interested bidders upon request) and will be provided in English.

3.1 Tasks

Without limiting the scope of work, the Contractor shall carry out the main items of work as described herein.

<u>Task 1: Project Initiation Meeting</u>

The Contractor, Project Authority and Contract Authority will meet via videoconference within a week of the signing of the contract to discuss and agree upon the scope of the project, expectations

for deliverables and periodic reports, format of deliverables, expected timelines, and review Appendix 1 of this request for proposals, which provides the foundation of the SCD.

In advance of the project initiation meeting, the Contract Authority will provide the Contractor with the final reports from previous work, additional background information including unpublished reports and presentations, and references (see Appendix 3).

Task 2: Draft Scientific Criteria Document

By December 2, 2024 the Contractor, will develop and provide to the Project Authority and Contract Authority a draft SCD that incorporates Project Team comments. The SCD will provide sufficient detail, clarity and transparency to permit reproduction of the guidelines.

To draft the SCD the Contractor will use scientific literature and previous work mentioned in the background, including documents provided in advance of the Project Initiation Meeting.

As per Appendix 1, the SCD will include background information on PAHs, along with a detailed and logical description of how the PAH guidelines were developed, including the approach used, key decisions taken, assumptions made and calculations used to derive the final guidelines.

When populating sections 1-7 of the SCD, the Contractor will provide a high-level summary of the information, providing general information for PAHs as a class and not for the individual PAHs or PAH groupings given in Appendix 2.

For section 10.3.3 of the SCD, the Contractor will also search primary literature to support expert recommendations related to the minimum water depth at which guidelines will be calculated for freshwater lotic, lentic and marine waters.

For section 12 of the SCD, the Contractor will build on the Marzooghi (2024) report (to be provided to the contractor in advance of the project initiation meeting) and conduct a fulsome literature review for scientific studies which contain effect concentrations of phototoxic PAHs from studies conducted under natural irradiance and where the location and month of the experiments are noted. The Contractor will extract the relevant information and use this data to compare with results calculated using the PAH calculator for the purpose of validating its use in field settings.

The Contractor will supply draft chapters to the Project Authority and Contract Authority for sections of the table of contents according to the following schedule:

Section(s)	Date
1-7	Sept. 9, 2024
8-9	Oct. 7, 2024
10-12	Nov. 4, 2024
1-13 (Complete Draft SCD)	Dec. 2, 2024

The Project Authority and Contract Authority will have monthly progress meetings with the Contractor to ensure the draft SCD is on schedule and to address any issues identified by the Contractor. Videoconferences with the Contractor and Project Team will be organized on an as-needed basis.

Task 3: Revised Scientific Criteria Document

By February 3, 2025, the Contractor will provide to the Project Authority and Contract Authority a revised SCD that addresses all comments provided by the Project Team on the draft SCD. The Contractor and Project Team will meet via a maximum two-hour videoconference within two weeks of the Contractor receiving the Project Team's comments on the revised SCD. The Contractor will provide an overview of how the SCD was revised and respond to any questions the Project Team may have.

The Contractor will draft the meeting agenda for review by the Project Authority and Contract Authority a week before the meeting and finalize the agenda based on comments received. The Contract Authority will circulate the final agenda to all meeting participants three days before the meeting. The Contractor will Chair the meeting. The Contractor will not be responsible for logistics of the meeting such as web hosting, scheduling and creating an invite list. The Contract Authority may record the meeting for reference.

Task 4: Final Scientific Criteria Document

By March 28, 2025, the Contractor will provide the final SCD to the Project Authority and Contract Authority that addresses any outstanding comments or concerns received from the Project Team on the revised SCD.

Task 5: Project Close Meeting

By March 31, 2025, the Contractor, Project Authority and Contract Authority will meet to review the project to identify successes, challenges, and opportunities for improvement.

3.2 Payment and Deliverables

Payments will be based upon the Contractor's completion of tasks and as evidenced by the production of the specified deliverables listed below. Payments will be made only after receipt of such deliverables and acceptance thereof by the Project Authority and the Contract Authority. Except as otherwise specifically provided for herein or in the professional services contract entered into with CCME, CCME will not be required to pay for partially completed tasks or for any additional work that may be required that the Contractor may not have budgeted for in its proposal. CCME shall not be committed to any other basis of payment by virtue of CCME having requested or received information regarding the Contractor's method of determining its bid for the completion of the Project, including, without limitation, any information regarding estimates of time spent and hourly rates of the Contractor's employees, contractors and agents involved in the Project.

Payment will be made by CCME via electronic funds transfer (TelPay is CCME's current provider) to the Contractor according to the following schedule, subject to the deliverables listed below having been received and accepted by the Project Authority and the Contract Authority, and invoices having been submitted by the Contractor, and approved by the Project Authority and the Contract Authority and received by CCME. The Contractor will provide all necessary information to enable electronic funds transfers before initiating work on the project. If the electronic payment information provided by the contractor is incorrect and results in a returned payment, the Contractor will be responsible for reimbursing CCME for the service fees charged by CCME's electronic funds transfer provider.

Deliverables	**Payment Amount** (% of contract value, inclusive of all applicable taxes)	**Target Date**
Task 1-2: project initiation meeting, draft SCD	50%	December 2, 2024
Tasks 3-5: revised draft SCD, final SCD, project close meeting	50%	March 31, 2025

The Contractor agrees to initiate work on the project by August 9, 2024.

The Contractor must provide all deliverables in electronic format to the Project Authority and Contract Authority no later than the dates specified above. All records, including but not limited to documents, reports, briefing notes and correspondence, generated by the contractor during the course of this project must be prepared and delivered to the Project Authority and Contract Authority in English using *Microsoft Word* for word processing (including all drafts of the SCD), *Microsoft Excel* for data management (e.g., files supporting the PAH guidelines), and *Microsoft PowerPoint* for presentations and other graphics.

All deliverables are the property of CCME and CCME reserves the right to publish them. The copyright in all materials produced as a product of the services shall belong exclusively to CCME. The Contractor shall waive all moral rights to all materials produced as a product of the services. The Contractor must advise the Project Authority of any information provided by a third party on a confidential basis for the purpose of the study and is to transmit the original documents containing any such information to the Project Authority under separate cover.

All discussion papers, reports and correspondence produced by the Contractor are subject to review by people designated by the Project Authority. The Contractor must perform all work to the satisfaction of the Project Authority and the Project Team.

Sufficient flexibility is required of the Contractor to respond to changing schedules and developments.

3.3 Budget

The maximum budget for this project is $27,000 Canadian, inclusive of all fees, expenses and applicable taxes; proposals in excess of the maximum budget will not be considered. Proposed professional fees must be inclusive of all office and administrative costs. Project-specific expenses

such as travel costs, where required, must be estimated and included in the total estimated cost of the project. These project-specific expenses may be billed on an "as incurred" (or monthly) basis and payment will be made after written confirmation from the Project Authority that the expenses were authorized and approved. The Contractor must supply reasonable and adequate documentation to support the expense claims. Travel-related expenses must follow *CCME Guidelines for Reimbursement of Expenses*.

Bidders from HST jurisdictions are advised that CCME's office is located in Winnipeg, Manitoba and accordingly only GST should be applied.

4.0 PROPOSALS

4.1 The proposal shall not exceed a maximum of 10 pages in length, excluding appendices. The proposal must:

- ☐ Provide an outline of the intended approach including basic tasks, schedule of activities, and budget.
- ☐ Describe the personnel of the project team, areas of responsibility, related experience with guideline development or PAHs, time allotted and charge out rates.
- ☐ Document contingent procedures and personnel to be used if key team members become unavailable.
- ☐ Provide a brief description of any similar projects undertaken. Include the timeframe that the work was undertaken and key individuals involved in its completion.
- ☐ Include the names and contact information of three references.
- ☐ Include as an appendix *curricula vitae* and contact information of key team members.
- ☐ Include as an appendix:
    - ☐ the bidder's legal name and mailing address
    - ☐ the name and contact information of the bidder's authorized signing officer
    - ☐ the name and contact information for the bidder's administrator of the contract if different from the signing officer
    - ☐ the bidder's GST registration number or if exempt, proof of exempt status.

4.2 Personal information requested above is required to enable CCME to evaluate the proposal. All individuals noted in the proposal should be advised of and approve the release of personal information for the purpose of the proposal and the bidder is responsible for obtaining such approval.

4.3 The Contractor shall not, without written consent of CCME, subcontract any obligation of the Contractor.

5.0 CONDITIONS

5.1 CCME reserves the right in its sole discretion to consider or reject any and all proposals. CCME reserves the further right to extend the deadline for proposals and to add, delete and/or change the terms of this Request for Proposals (RFP) and issue corrections and amendments to it.

CCME has made every effort to ensure the completeness and accuracy of the information contained in this RFP. CCME shall not be liable for any errors or omissions or responsible for any bidder interpretations or conclusions regarding the information contained in this RFP. Contractors who submit proposals will not acquire any legal or equitable rights or privileges whatsoever until a contract is signed with CCME. CCME will not pay any compensation for the preparation of the proposal and all proposals become the property of CCME.

5.2 The successful bidder is required to agree to a professional services contract with CCME. A sample CCME professional services contract is posted with this RFP. Bidders must identify in their proposals any changes requested to CCME's sample professional services contract and CCME reserves the right in its sole discretion to consider, accept, reject or amend such requested changes. CCME further reserves the right to revoke any offer to enter into a professional services contract. As part of a commitment to environmentally-sound business practice, it is CCME's practice to prepare, sign and transmit contracts electronically.

5.3 Proposal Deadline

The Contract Authority must receive proposals no later than July 26, 2024 noon Central Daylight Time; proposals received after the deadline will not be considered. The time stamp on CCME's email server shall be deemed to be conclusive evidence of time of receipt.

5.4 Method of Submission

Bidders must submit proposals by email to the Contract Authority in an unsecured electronic format, file size to be no larger than 5.0 MB, compatible with *MS Word* or *Adobe Acrobat*.

5.5 Ineligible Bidders

The following organizations and individuals, and organizations proposing such individuals as part of a project team, are ineligible to bid on this project:

5.5.1 Federal, provincial and territorial governments and all their departments and ministries and Crown corporations, boards, commissions and agencies and any officials and employees of them.

5.5.2 Members of the House of Commons and provincial and territorial legislative assemblies.

5.5.3 Persons providing administrative and related services to the CCME group responsible for the project.

5.5.4 Members and participants of CCME committees and groups, and for a period of six months after such membership ends.

5.5.5 Any company that is ineligible to bid on federal, provincial or territorial government contracts.

6.0 CONTACTS

Prospective bidders should direct questions to the Contract Authority.

6.1 Contract Authority

Olivier Berreville
Canadian Council of Ministers of the Environment
123 Main Street, Suite 360
Winnipeg, MB R3C 1A3
Tel: (204) 451-6571
Email: Oberreville@ccme.ca

6.2 Project Authority

Allison Dunn
Environment and Climate Change Canada
351 Boulevard Saint-Joseph
Tel: (819) 307-1920
Email: Allison.Dunn@ec.gc.ca

7.0 PROPOSAL EVALUATION

All assessments and weighting of criteria is at the sole discretion of CCME. The Project Team will evaluate proposals based on the following criteria:

Technical and Management Proposal Evaluation Criteria

TECHNICAL PROPOSAL	**Score**
Demonstrated understanding of the project scope and objectives	10
Technical approach and methodology to meet project objectives	10
Work plan feasibility and organization	10
Recognition of possible problems, proposed solutions and additional innovative suggestions	10
MANAGEMENT PROPOSAL	
Experience and qualification of Program/Project Manager	10
Experience and qualifications of project team members, and alternate team members in case of unforeseen availability: (a) qualifications of team members	15

(b) depth and breadth of the team's experience	
(c) depth and breadth of individual team members experience in similar assignments	
Experience of organization in similar assignments	10
Experience working with a range of stakeholders	10
Ability to communicate effectively and to provide leadership/ coordination/ management under multi-partnership team setting	10
Value for money	5
COMPLETENESS OF PROPOSAL	
All information described in section 4.1 has been provided	10

8.0 AWARD OF CONTRACT

The Project Team will determine award of the contract by August 2, 2024. The lowest or any bid will not necessarily be accepted.

Upon award, the work must proceed on a timely basis as outlined in the table of deliverables. The successful proponent must not commence work until a contract is in place.

Contractors can view the status of this project on the CCME website, www.ccme.ca, on the What's New page.

APPENDICES

Appendix 1: Annotated table of contents for Scientific Criteria Document (SCD)

Executive Summary

1.0 Introduction

2.0 Substance Identity
- define parent- and alkylated/heterocyclic-PAHs
- provide generic chemical structure(s)
- add a copy of the table from Appendix 2 of this document to Appendix of SCD, which includes listing of individual PAHs/PAH groupings measured by Canadian analytical laboratories

Supporting information:
- *Unpublished presentation and recording*

3.0 Sources, Emissions, Productions and Uses

Supporting information:
- *Unpublished presentation and recording*

4.0 Physical-chemical properties
- physical-chemical properties in this section will be similar to that which is provided in Environment Canada's risk assessment report (*Environment Canada, Health Canada 1994)*, and can be presented in tabular format and provide property ranges for PAHs as a class
- discuss how PAHs have the ability to absorb photons at specific wavelengths and present a molar absorption spectrum for one representative PAH, fluorine.

Supporting information:
- *Environment Canada, Health Canada 1994*
- *McGrath et al. 2018*
- *Tillmanns et al. 2023*
- *Marzooghi et al. 2017*
- *British Columbia Ministry of Water Land Resources Stewardship (BC WLRS) 2024*

5.0 Environmental Fate and Behaviour

6.0 Marine and Freshwater Concentrations in Canada

Supporting information:
- *Marvin et al. 2021*

7.0 Existing CCME (2007) PAH CWQGs and water guidelines from other jurisdictions

Supporting Information:
- *Tillmanns et al. 2023*
- *WCA Environment Ltd. 2019*
- *Unpublished presentation and recording*

8.0 Considerations for development of new/revised PAH Guidelines

8.1 Limitations of existing CCME guidelines
- old, confined to 11 parent PAHs
- don't include alkylated forms which predominate in petrogenic sources and are more toxic than parent PAHs

- don't systematically consider phototoxicity nor mixture toxicity

Supporting information:

- *Unpublished presentation and recording*

8.2 Limitations of developing guideline based on CCME (2007) or adoption of Guidelines from other jurisdictions

- insufficient toxicity data to develop guidelines according to CCME (2007)
- costly to generate new toxicity data to support Type A guidelines for 1000s of parent- and substituted-PAHs in the environment
- very few new PAH guidelines from other jurisdictions

Supporting information:

- *WCA Environment Ltd. 2019*
- *Unpublished presentation and recording*

8.3 New Approach

- leverage critical body burden-based quantitative structure-activity relationship (QSAR) models (NTLM and PTLM)
- systematically consider phototoxicity and mixture toxicity (this will be a high-level summary of the NTLM and PLTM approaches. Section 2.0 will give the details.)

Supporting information:

- *Tillmanns et al. 2023*
- *Marzooghi et al. 2017*
- *Unpublished presentation and recording*

9.0 Target Lipid Model (TLM) approach

9.1 NTLM

- background of critical body burden theory
- NTLM assumptions
- Review of various NTLM iterations
- formation of NTLM equation
- NTLM equations (acute and chronic) (Tillmanns *et al.* 2023)

Supporting information:

- *Di Toro et al. 2000*
- *McGrath et al. 2004*
- *McGrath et al. 2009*
- *McGrath et al. 2021*
- *Tillmanns et al. 2023*
- *Unpublished presentation and recording*

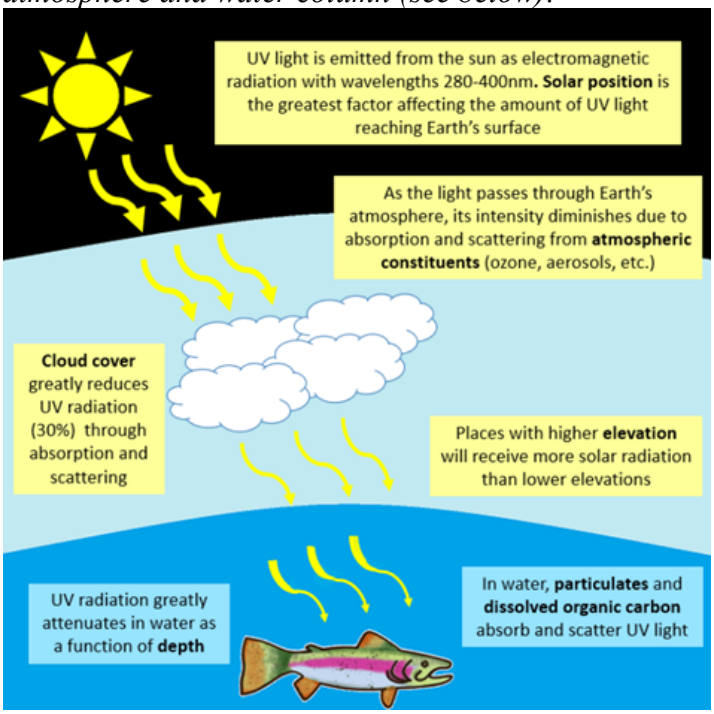
9.2 PTLM

- description of two different types of phototoxicity (photomodification and photosensitivity) and which types are considered in PTLM
- PTLM equation (PTLM formation, action spectrum, variables explained, including all the variables for Pabs (photons absorbed)
- derivation of chronic phototoxic CWQG using acute to chronic ratio (Tillmanns and Kennedy [in press])
- conceptual model of phototoxicity incorporating light attenuation factors,

breaking down which model applies to which media (i.e., TUV [atmosphere], Kd model [water])

Supporting information:

- *Marzooghi et al. 2017*
- *ARIS 2023*
- *Tillmanns and Kennedy (in press)*
- *Unpublished presentation and recording*
- *conceptual model demonstrating how light attenuates through the atmosphere and water column (see below):*



9.3 Accounting for light attenuation in PAH WQG prediction

- explain how atmospheric and aquatic constituents can both alter light intensity
- explain that the PAH calculator systematically considers light attenuating factors, first in the atmosphere through use of TUV model and then in water through use of Kd model/default

9.3.1 Accounting for light attenuation in atmosphere - TUV model explained including description of inputs

Supporting information:

- *ARIS 2023*
- *Madronich 2016*

9.3.2 Accounting for light attenuation in water column

- approaches for estimation of Kd
- review of light attenuation models

Supporting information:

- *ARIS 2023*
- *Unpublished report (44 p.)*

9.3.2.1 Freshwater Kd model

Supporting information:

- *Unpublished report (44 p.)*

9.3.2.2 Marine Kd model

- provide justification for use of default Kd for marine waters

Supporting information:

- *Unpublished report (44 p.)*

10.0 Parameterization of PAH calculator

- the parameterization will focus on the defaults used to generate PAH guidelines

10.1 NTLM inputs

10.1.1 Octanol-water partition coefficient (KOW)

- explain how the KOW is underpinning input parameter for the NTLM
- provide the range of KOWs for the PAHs in Appendix 2 of this document
- include Appendix in Excel format of the KOWs used for each of the PAHs given in Appendix 2 of this document

10.2 TUV inputs

- focus on inputs where decisions were required to generate the terrestrial light spectrum at water surface

10.2.1 Date
10.2.2 Cloud cover
10.2.3 Surface albedo
10.2.4 Aerosols
10.2.5 Ozone column

Supporting information:

- *ARIS 2023*
- *Unpublished report (44 p.) and supporting email correspondence*
- *BC WLRS 2024*

10.3 Pabs inputs

10.3.1 Texp (duration of light exposure)
10.3.2 Molar absorption coefficient (ε)

- explanation of how molar absorption coefficient is read-across from parent-PAH to alkylated-PAH when molar absorption spectrum unavailable
- refer to and provide an Appendix that includes all the absorption spectra used in the PAH calculator and which PAHs use a surrogate chemical for their absorption spectra

10.3.3 Depth for:

a. freshwater lakes
b. freshwater rivers
c. marine waters

Appendix B of ARIS (2023) provides recommendations for minimum water depths for lentic and lotic freshwater environments and published literature (Haegele and Schweigert 1985; Haegele *et al.* 1981; Nakashima and Taggart 2002; Nakashima and Wheeler 2002;

Stephenson *et al.* 2009) indicates marine species on the east and west coasts of Canada have shallow spawning requirements. The Contractor will seek literature to support minimum water depths recommended by experts for freshwater environments and Canada's Arctic Ocean.

Supporting information:

- *ARIS 2023*
- *Haegele and Schweigert 1985*
- *Haegele et al. 1981*
- *Nakashima and Taggart 2002*
- *Nakashima and Wheeler 2002*
- *Stephenson et al. 2009*
- *Supporting email correspondence*

11.0 Sensitivity Analysis of PAH calculator

- synthesize and document formally the sensitivity analysis conducted in BC WLRS 2024

Supporting Information:

- *BC WKRS 2024*

12.0 Validation of the PAH calculator

- build on the work of Marzooghi (2024)
- conduct a fulsome literature review to identify additional papers which contain effect concentrations of phototoxic PAHs from studies conducted under natural irradiance and where the location and date of the experiments are noted

12.1 Results of literature review

12.2 Comparison of study results with estimated phototoxic lethal concentration affecting 50% of organisms (PLC50) values from PAH calculator

12.3 Recommendation for further validation of PAH calculator

Supporting Information:

- *Marzooghi 2024*
- *fluorene example from Finch et al. (2017)*

13.0 Example WQGs in table format for fluorene based on representative latitude/longitude in Canada and for full range of DOC concentrations for which freshwater Kd model is calibrated (i.e., 0.2-61.5 mg/L)

13.1 Freshwater guidelines

13.1.1 Short-term narcotic guidelines

13.1.2 Short-term phototoxic guidelines

13.1.3 Long-term narcotic guidelines

13.1.4 Long-term phototoxic guidelines

13.2 Marine Guidelines

13.2.1 Short-term narcotic guidelines

13.2.2 Short-term phototoxic guidelines

13.2.3 Long-term narcotic guidelines

13.2.4 Long-term phototoxic guidelines

Supporting Information:

- *BC WLRS 2024*

14.0 References

Appendix 2: PAH and PAH groupings routinely measured by commercial analytical laboratories

Acenaphthene
Acenaphthylene
Acridine
Anthracene
Benz(a)anthracene
Benzo(a)pyrene
Benzo(b&j)fluoranthene
Benzo(e)pyrene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
Biphenyl
Chrysene
Dibenz(a,h)anthracene
Dibenzothiophene
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
C1 Acenaphthenes
C1 Benz(a)anthracenes/Chrysenes
C1 Benzofluoranthenes/Benzopyrenes
C1 Biphenyls
C1 Dibenzothiophenes
C1 Fluoranthenes/Pyrenes
C1 Fluorenes
C1 Phenanthrenes/Anthracenes
Retene
1-methylnaphthalene
2-methylnaphthalene
Naphthalene
Perylene
Pyrene
Quinoline
C2 Acenaphthenes
C2 Benz(a)anthracenes/Chrysenes
C2 Benzofluoranthenes/Benzopyrenes
C2 Biphenyls
C2 Dibenzothiophenes
C2 Fluoranthenes/Pyrenes
C2 Fluorenes
C2 Naphthalenes
C2 Phenanthrenes/Anthracenes
C3 Benzanthracenes/Chrysenes
C3 Dibenzothiophenes
C3 Fluoranthenes/Pyrenes
C3 Fluorenes
C3 Naphthalenes
C3 Phenanthrenes/Anthracenes
C4 Benzanthracenes/Chrysenes
C4 Dibenzothiophenes
C4 Fluoranthenes/Pyrenes
C4 Naphthalenes
C4 Phenanthrenes/Anthracenes
Indane
Dibenzofuran

Appendix 3: Reference List

Unpublished Supporting Documents

ARIS. 2023. Report on Estimating Light Attenuation in Support of the BC Water Quality Development for Phototoxic PAHs. Prepared for British Columbia Ministry of Water Land Resources and Stewardship (BC WLRS), Victoria, BC. 62 pp.

[BC WLRS] British Columbia Ministry of Water Land Resources Stewardship. 2024. PAH guideline calculator and sensitivity analysis.

Marzooghi, Solmaz. 2024. Assessment of Field Research on Phototoxic PAHs and Potential Validation of PTLM for Study Verification, Prepared under contract for BC WLRS. 11 pp.

WCA Environment Ltd. 2019. Review and Interpretation of Scientific Information to support development of environmental (aquatic) quality standards for polycyclic aromatic hydrocarbons (PAHs) – RFB No. COA 2405. Prepared for Ontario Ministry of Environment and Climate Change. 111 pp.

Published Supporting Documents

Di Toro, D.M., J.A. McGrath and D.J. Hansen. 2000. Technical basis for narcotic chemicals and PAH criteria. I. Water and tissue. Environ Toxicol Chem 19: 1951–1970.

Environment Canada, Health Canada. 1994. Canadian Environmental Protection Act: Priority Substances List assessment report: polycyclic aromatic hydrocarbons [PDF] Ottawa (ON): Government of Canada.

Finch, B.E., Mazooghi, S., Di Toro, D.M., and Stubblefield, W.A. 2017. Phototoxic potential of undispersed and dispersed fresh and weathered Macondo crude oils to Gulf of Mexico marine organisms. Environ Toxicol Chem 36:2640-2650.

Haegele, C.W. and Schweigert J.F. 1985. Distribution and characteristics of herring spawning grounds and description of spawning behavior. Can J Fish Aquat Sci 42(Suppl 1): 39−55.

Haegele, C.W., Humphreys R.D., and Hourston, A.S. 1981. Distribution of eggs by depth and vegetation type in Pacific herring (*Clupea harengus pallasi*) spawnings in southern British Columbia. Can J Fish Aquat Sci 38: 381−386.

Madronich, S. 2016. Instructions for using the web-based TUV Quick Calculator. Retrieved from: *https://www.acom.ucar.edu/Models/TUV/Interactive_TUV/InstructionsWebTUV.pdf*

Madronich, S. 2021. Tropospheric Ultraviolet and Visible Radiation Model (TUV). Retrieved from: https://www2.acom.ucar.edu/modeling/tropospheric-ultraviolet-and-visible-tuv-radiation-model).

Marvin, C., Berthiaume, A., Burniston, D.A., Chibwe, L., Dove, A., Evans, M., Hewitt, M., Hodson, P.V., Muir, D.C.G., Parrott, J., Thomas, P.J., Tomy, G.T. 2021. Polycyclic aromatic compounds (PACs) in the Canadian environment: aquatic and terrestrial environments. Environ. Pollut. https://doi.org/10.1016/j.envpol.2021.117442 .

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