Brief Communication

Deriving a Water Quality Guideline for Protection of Aquatic Communities Exposed to Triclosan in the Canadian Environment

Katie L Hill,† Roger L Breton,*,† Gillian E Manning,† R Scott Teed,† Marie Capdevielle,† and Brian Slezak‡
†Intrinsik Corporation, Ottawa, Ontario, Canada
‡Colgate-Palmolive Company, New York, New York, USA

ABSTRACT
Triclosan is an antibacterial and antifungal chemical used in a variety of consumer products, including soaps, detergents, moisturizers, and cosmetics. Aquatic ecosystems may be exposed to triclosan following the release of remaining residues in wastewater effluents and biosolids. In December 2017, Environment and Climate Change Canada (ECCC) released a federal environmental quality guideline (FEQG) report that contained a federal water quality guideline (FWQG) for triclosan. This guideline will be used as an adjunct to the risk assessment and risk management of priority chemicals identified under the Government of Canada’s Chemicals Management Plan (CMP). The FWQG value for triclosan (0.47 μg/L) was derived by ECCC using a hazardous concentration for 5% of species (HC5) from a species sensitivity distribution (SSD). We recalculated the FWQG after performing an independent analysis and evaluation of the available aquatic toxicity data for triclosan and compared our results with the ECCC FWQG value. Our independent analysis of the available aquatic toxicity data entailed conducting a literature search of all available and relevant studies, evaluating the quality and reliability of all studies considered using thorough and consistent study evaluation criteria, and thereby generating a data set of high-quality toxicity values. The selected data set includes 22 species spanning 5 taxonomic groups. An SSD was developed using this data set following the ECCC approaches. The HC5 from the SSD derived based on our validated data set is 0.76 μg/L. This HC5 value is slightly greater (i.e., less sensitive) than the value presented in ECCC’s final FWQG. Integr Environ Assess Manag 2018;14:437–441. © 2018 The Authors. Integrated Environmental Assessment and Management published by Wiley Periodicals, Inc. on behalf of Society of Environmental Toxicology & Chemistry (SETAC)

Keywords: Triclosan Water quality guideline Aquatic community protection Species sensitivity distribution

INTRODUCTION
Triclosan is a broad-spectrum antibacterial and antifungal chemical, used generally as a preservative in a variety of personal care products, including toothpaste, cosmetics, detergents, and moisturizers. Following the use of products containing triclosan, residues may be washed away and enter the wastewater treatment plants (WWTPs), where most (up to 98%) is removed via bio- and photodegradation, as well as sorption (Bock et al. 2010). However, a small fraction of triclosan may be released with the effluent into aquatic water bodies.

Under the Canadian Environmental Protection Act (Government of Canada 1999), Environment and Climate Change Canada (ECCC) and Health Canada (HC) assessed potential risks of triclosan to Canadians and their environment and published their final Assessment Report and Proposed Risk Management Approach in November 2016 (ECCC 2016a). The Assessment Report concluded that triclosan did not pose a risk to human health, but that it may enter the environment in a quantity or concentration or under conditions that may have an immediate or long-term harmful effect on the environment or its biological diversity. Subsequently, ECCC released a draft federal environmental quality guideline (FEQG) report for triclosan in February 2017, followed by the final FEQG report in December 2017 (ECCC 2017). The FEQG report described the approach and development of a federal water quality guideline (FWQG) for triclosan. The final FWQG is to be used as an adjunct to the risk assessment and risk management of priority chemicals identified under the Chemicals Management Plan (CMP; Government of Canada 2018). The final FWQG value for triclosan derived by ECCC is a hazardous concentration for 5% of species (HC5) of 0.47 μg/L, based on a chronic species sensitivity distribution (SSD) developed for freshwater organisms (ECCC 2017).

Federal environmental quality guidelines can serve as important evaluation tools in environmental monitoring to assess whether ambient concentrations of pollutants have the potential to pose risk to aquatic communities. These...
guidelines may also be used as risk management tools by providing a science-based starting point to derive site-specific effluent limits. As such, it is imperative that FEQGs are derived from a robust scientific perspective and that they use an up-to-date analysis of all reliable and relevant data available. In the case of triclosan, there is a large data set of relevant scientific studies, including published and proprietary studies. The goal of the present exercise was to conduct an independent collection of data, review study quality, and calculate the HC5 from an SSD developed using the best available data for triclosan. The methods used followed those described by ECCC, including a study quality evaluation component, selection of measurement endpoints for the SSD data set, and development of the SSD and corresponding HC5 value.

**APPROACH**

**Data collection**

A literature review was conducted to collect the available primary literature studies involving toxicity testing of freshwater aquatic species, with single chemical exposure to triclosan. The exposure durations considered included those of at least 7 days for aquatic plants, aquatic invertebrates, amphibians, and fish (subacute to chronic exposure), and at least 24 hours for algae. In addition to published studies, several proprietary studies were also included for consideration in the data set.

**Evaluation of available studies**

Studies were evaluated for reliability and relevance according to several criteria. The general categories assessed included 1) the study protocol, 2) the test organism used, 3) the design of the toxicity test, 4) the environmental conditions of the test, 5) the concentrations of triclosan assessed, 6) the use of control organisms, and 7) the analysis and reporting of study results. The quality rating for each study was determined based on the overall evaluation, whereby evidence of sufficient reporting of each category led to a quality rating of “Satisfactory.” A lack of reported details, or an issue in the design or execution of a component of the study, led to a rating of “Not Satisfactory” and exclusion from consideration for the SSD. Additional details regarding the criteria assessed are provided in the Supplemental Data. The evaluation criteria considered are similar to the guideline requirements of the Organisation for Economic Co-operation and Development (OECD), the Office of Prevention, Pesticides and Toxic Substances (OPPTS) of the United States Environmental Protection Agency, as well as the Klimisch et al. (1997) evaluation scheme, and was based on the Robust Study Summaries developed by Environment and Climate Change Canada (ECCC 2016b).

**Development of the species sensitivity distribution**

Toxicity studies that were rated of satisfactory quality were included for consideration in the SSD. The Protocol for Derivation of Water Quality Guidelines for the Protection of Aquatic Life, developed by the Canadian Council of Ministers of the Environment (CCME 2007) was used to select the data included in the SSD. The toxicity endpoints considered include apical effects (i.e., growth, mortality, and reproduction), according to the Type A long-term exposure guidelines. The measurement endpoints for each species were selected based on the CCME (2007) ranking system, with the following order of increasing preference: nonlethal EC50 < EC26–49 < LOEC < NOEC < MATC < EC11–25 < EC10 < ECx. According to CCME (2007), an EC10 is generally considered to be a no-effects threshold for the individuals of a species, unless a more appropriate species-specific no-effects threshold is determined. If more than one value was available for the preferred measurement endpoint for a given species, a geometric mean was calculated (e.g., geometric mean of two 21-d EC10 values for growth of Daphnia magna).

The SSD was generated using SSD Master v3.0 (Rodney et al. 2013), which is an MS Excel-based tool (Microsoft) that fits 5 different cumulative distribution functions (normal, logistic, extreme value, and Gumbel in log space; Weibull in arithmetic space). The ECCC also uses this tool to generate the SSDs for ecological risk assessments and guideline development. This software conducts and reports testing of the fit of each model to the data.

**RESULTS**

Thirty-seven studies were identified that tested the chronic toxicity of triclosan to freshwater species. Twenty-eight of these were peer-reviewed studies available in the open literature, and the remaining were proprietary registrant-conducted studies containing confidential business information (CBI) that were provided to us for this exercise. Individual data quality evaluations were conducted for each species tested in a study (e.g., if a study tested toxicity on 3 species, then 3 evaluations were conducted for that study). In total, 71 quality evaluations were conducted, which resulted in 35 Satisfactory and 36 Not Satisfactory evaluation ratings (see Supplemental Data for an overview of study evaluation results). Of the studies that failed to meet the criteria for a Satisfactory rating, the most common insufficiencies identified were related to the environmental conditions and maintenance of the test concentrations.

Overall, satisfactory chronic toxicity data for triclosan were available for 22 unique aquatic species, including 7 algae, 1 aquatic plant, 5 aquatic invertebrates, 7 fish, and 2 amphibian species. The selected toxicity values and endpoint details are presented in Table 1, and the full table of toxicity data considered is provided in the Supplemental Data. Freshwater algae accounted for the most and least sensitive species, with toxicity values ranging from a 72-h EC10 geometric mean for growth of 0.57 μg/L for Desmodesmus subspicatus, to a 96-h maximum acceptable toxicant concentration (MATC) for growth of 354 μg/L for Closterium ehrenbergii (Drottar and Krueger 1999; Ciniglia et al. 2005; Roberts et al. 2014).

The selected data set was analyzed in SSD Master v3.0, with Hazen plotting position versus log10 transformation of
Table 1. Chronic aquatic toxicity data for triclosan, which were determined to be of satisfactory quality and selected for use in the species sensitivity distribution

| Species                        | Effect threshold | Effect endpoint | Concentration (μg/L) | Reference                                      |
|--------------------------------|------------------|-----------------|----------------------|------------------------------------------------|
| **Algae**                      |                  |                 |                      |                                                |
| Anabaena flos-aquae            | 96-h EC10        | Biomass         | 0.97<sup>a</sup>     | Orvos et al. 2002<sup>a</sup>                  |
| Closterium ehrenbergii         | 96-h MATC        | Growth          | 354<sup>a</sup>      | Ciniglia et al. 2005<sup>a</sup>               |
| Desmodesmus subspicatus        | 72-h EC10        | Growth          | 0.57<sup>b</sup>     | Drottar and Krueger 1999; Roberts et al. 2014  |
| Navicula pelliculosa           | 96-h EC25        | Growth          | 10.7<sup>a</sup>     | Orvos et al. 2002<sup>a</sup>                  |
| Nitzschia palea                | 72-h EC10        | Photosynthesis  | 194<sup>a</sup>      | Franz et al. 2008<sup>a</sup>                  |
| Pseudokirchneriella subcapitata| 96-h EC25        | Growth          | 2.44<sup>a</sup>     | Orvos et al. 2002<sup>a</sup>                  |
| Scenedesmus vacuolatus         | 24-h EC10        | Growth          | 1.09<sup>a</sup>     | Franz et al. 2008<sup>a</sup>                  |
| **Plant**                      |                  |                 |                      |                                                |
| Lemna gibba                    | 7-d MATC         | Growth          | 22<sup>b,c</sup>     | Fulton et al. 2009<sup>a</sup>; ECCC 2017<sup>a</sup> |
| **Aquatic invertebrate**       |                  |                 |                      |                                                |
| Ceriodaphnia dubia             | 7-d EC25         | Reproduction    | 170                  | Tatarazako et al. 2004<sup>a</sup>             |
| Chironomus dilutus             | 10-d LC10        | Survival        | 20<sup>a</sup>        | Dussault et al. 2008<sup>a</sup>               |
| Daphnia magna                  | 21-d EC10        | Reproduction    | 29<sup>a</sup>        | Wang et al. 2013<sup>a</sup>                   |
| Hyalella azteca                | 10-d LC10        | Survival        | 5<sup>a</sup>         | Dussault et al. 2008<sup>a</sup>               |
| Physa acuta                    | 42-d MATC        | Growth          | 3.2<sup>a</sup>       | Brown et al. 2012<sup>a</sup>                  |
| **Fish**                       |                  |                 |                      |                                                |
| Danio rerio                    | 9-d EC25         | Hatchability, fry survival | 160 | Tatarazako et al. 2004 |
| Gambusia affinis               | 35-d MATC        | Sperm count     | 76.6<sup>a</sup>      | Raut and Angus 2010<sup>a</sup>                |
| Misgurnus anguillicaudatus     | 30-d EC10        | Growth          | 9<sup>a</sup>         | Wang et al. 2013<sup>a</sup>                   |
| Oncorhynchus mykiss            | 61-d MATC        | Fry survival    | 49.3<sup>a</sup>      | Orvos et al. 2002<sup>a</sup>                  |
| Oryzias latipes                | 14-d MATC        | Hatchability    | 221                  | Ishibashi et al. 2004<sup>a</sup>             |
| Pimephales promelas            | 7-d LC10         | Survival        | 101                  | Fritsch et al. 2013                           |
| Tanichthys albonubes           | 30-d EC10        | Growth          | 87                   | Wang et al. 2013                              |
| **Amphibian**                  |                  |                 |                      |                                                |
| Rana catesbeiana               | 10-d NOEC        | Growth, development | >11.2<sup>a</sup>    | Veldhoven et al. 2006<sup>a</sup>             |
| Xenopus laevis                 | Chronic NOEC     | Survival, growth, development | >46.7<sup>b</sup> | Matsumura et al. 2005; Fort et al. 2010; Fort et al. 2011; Fort et al. 2017<sup>a</sup> |

Normal model parameters

| Parameter | Value |
|-----------|-------|
| L         | 1.03  |
| s         | 0.813 |
| HCS       | 0.764 |

ECCC = Environment and Climate Change Canada; FEQG = federal environmental quality guideline; HC5 = hazardous concentration for 5% of species; L = location parameter; MATC = maximum acceptable toxicant concentration; s = scale parameter.

<sup>a</sup> Toxicity values and/or references indicate instances aligning with those selected by ECCC in the FEQG (ECCC 2017).

<sup>b</sup> Geometric mean calculated from multiple studies.

<sup>c</sup> ECCC (2016a) reports a 7-d MATC of 28 μg/L. However, Fulton et al. (2009) was found to be of satisfactory quality and thus we included this geometric mean toxicity value in the data set.
the measurement endpoint concentrations. The log-normal distribution was selected as the best fitting model based on a combination of the Anderson-Darling (AD) goodness-of-fit statistic and by visual inspection of the fit in the lower tail (i.e., where the HC5 is estimated; Figure 1). Additional details regarding the other models analyzed in SSD Master v3.0 are provided in the Supplemental Data. The log-normal distribution was also selected by ECCC to derive the FWQG (ECCC 2017), and it is commonly used by other regulatory authorities (e.g., Registration, Evaluation, Authorisation and Restriction of Chemicals [REACH] in the European Union; Aldenberg et al. 2001). The normal model is described by Equation 1, where \( x \) is the concentration in \( \mu g/L \), \( f(x) \) is the proportion of taxa affected, \( \text{erf} \) is the error function, \( L \) is the location parameter, and \( s \) is the scale parameter of the model.

\[
f(x) = \frac{1}{2 \left( 1 + \text{erf} \left( \frac{x - L}{s \sqrt{2}} \right) \right)}.
\]

(1)

The resulting HC5 value for the SSD, based on the normal model, is 0.76 \( \mu g/L \).

**DISCUSSION AND CONCLUSIONS**

The data set used to derive the HC5 in the present exercise is similar to the data set applied by ECCC to derive their FWQG; however there are a few notable differences. Based on our expanded Satisfactory quality data set, additional measurement endpoints (as per the CCME 2007 ranking system) were selected for 4 species. These include data for *D. subspicatus*, *Ceriodaphnia dubia*, *Oryzias latipes*, and *Xenopus laevis*. Data for 3 additional fish species were included in the present data set but were not included in the final FEQG data set: *Danio rerio*, *Pimephales promelas*, and *Tanichthys albonubes*. Additionally, data for the amphibian *Pseudacris regilla* (Marlatt et al. 2013) that were included in the ECCC FWQG data set were excluded herein due to a ‘Not Satisfactory’ evaluation (see Supplemental Data for further details).

Overall, the HC5 of 0.76 \( \mu g/L \) for chronic exposure of triclosan to freshwater aquatic life generated in the present study is slightly greater (i.e., less sensitive) than the HC5 of 0.47 \( \mu g/L \) calculated by ECCC in their final FWQG (ECCC 2017).

**Acknowledgment**—The authors acknowledge contributions to this paper provided by Colleen Priest and Adric Olson of Intrinsik Ltd. and Yvonne Clemow of Intrinsik Corp. This research was supported by the Colgate-Palmolive Company.

**Disclaimer**—The authors declare no conflicts of interest.

**Data Accessibility**—The Supplementary Material file contains the toxicity data considered in this paper. SSD Master, which is an Excel-based tool used to generate the species sensitivity distribution, is available upon request to the corresponding author Roger Breton at rbreton@intrinsik.com.

**SUPPLEMENTAL DATA**

Table S-1. Study quality evaluation results
Table S-2. Data from Satisfactory studies considered for use in the species sensitivity distribution
Table S-3. Summary statistics for the triclosan chronic aquatic toxicity dataset analyzed in SSD Master v3.0 (log base 10 transformation of the effect threshold concentrations)
Figure S-1. Species sensitivity distributions for the chronic toxicity of triclosan to freshwater aquatic organisms, displaying the 4 log-transformed models analyzed in SSD Master v3.0.

**REFERENCES**

Aldenberg T, Jaworska J, Traas T. 2001. Normal species sensitivity distributions and probabilistic ecological risk assessment. In: Posthuma L, Suter II G, Traas T, editors. Species sensitivity distributions in ecotoxicology. Boca Raton (FL): Lewis. p 49–102.

Bock M, Lyndall J, Barber T, Fuchsman P, Perruchon E, Capdevielle M. 2010. Probabilistic application of a fugacity model to predict triclosan fate during wastewater treatment. Integr Environ Assess Manag 6:393–404.

Brown J, Bernet MJ, Bernet RJ. 2012. The influence of TCS on the growth and behavior of the freshwater snail. *Physa acuta*. J Environ Sci Health A Tox Hazard Subst Environ Eng 47:1626–1630.

[CCME] Canadian Council of Ministers of the Environment. 2007. A protocol for the derivation of water quality guidelines for the protection of aquatic life. In: Canadian water quality guidelines, 1999. Winnipeg (MB): ISBN 1-896997-34-1.

Cingla C, Cascone C, Lo Giudice R, Pinto G, Pollio A. 2005. Application of methods for assessing the geno- and cytotoxicity of triclosan to C. ehenbergii. J Hazard Mater 122:227–232.

Dussault EB, Balakrishnan VK, Sverko E, Solomon KR, Sibley PK. 2008. Toxicity of human pharmaceuticals and personal care products to benthic invertebrates. *Environ Toxicol Chem* 27:425–432.

[C]ECC Environment and Climate Change Canada. 2016a. Assessment report: Triclosan. November, 2016. Gatineau (QC). En 14-259/2016E-PDF.

[EC]ECC Environment and Climate Change Canada. 2016b. Summary of public comments received on preliminary assessment and risk management scope for triclosan (CAS RN 3380-34-5). [cited 2018 February 25]. http://www.ec.gc.ca/ese-ees/default.asp?lang=En&n=042414AC7-1

[EC]ECC Environment and Climate Change Canada. 2017. Canadian Environmental Protection Act, 1999—Federal environmental quality guidelines: Triclosan. December 2017. En14-300/2017E-PDF.

Fort DJ, Mathis MB, Hanson W, Fort CE, Navarro LT, Peter R, Buche C, Unger S, Pawlowski S, Plautz JR. 2011. Triclosan and thyroid-mediated metamorphosis in anurans: Differentiating growth effects from thyroid-driven metamorphosis in Xenopus laevis. *Toxicol Sci* 121:292–302.
Fort DJ, Mathis MB, Pawlowski S, Wolf JC, Peter R, Champ S. 2017. Effect of triclosan on anuran development and growth in a larval amphibian growth and development assay. J Appl Toxicol 37:1182–1194.

Fort DJ, Rogers RL, Gorsuch JW, Navarro LT, Peter R, Plautz JR. 2010. Triclosan and anuran metamorphosis: no effect on thyroid-mediated metamorphosis in Xenopus laevis. Toxicol Sci 113:392–400.

Franz S, Altenburger R, Heilmeier H, Schmitt-Jansen M. 2008. What contributes to the sensitivity of microalgae to triclosan? Aquat Toxicol 90:102–108.

Fritsch EB, Connon RE, Werner I, Davies REUE, Beggel S, Feng W, Pessah IN. 2013. Triclosan impairs swimming behavior and alters expression of excitation contraction coupling proteins in fathead minnow (Pimephales promelas). Environ Sci Technol 47(4):2008–2017.

Fulton BA, Brain RA, Usenko S, Back JA, King RS, Brooks BW. 2009. Influence of nitrogen and phosphorus concentrations and ratios on Lemna gibba growth responses to triclosan in laboratory and stream mesocosm experiments. Environ Toxicol Chem 28:2610–2621.

Government of Canada. 1999. Canadian Environmental Protection Act (CEPA). Canada Gazette Part III, vol. 22, no. 3.

Government of Canada. 2018. Chemicals Management Plan. [cited 2018 February 25]. https://www.canada.ca/en/health-canada/services/chemical-substances/chemicals-management-plan.html

Ishibashi H, Matsumura N, Hirano M, Matsuoka M, Shiratsuchi H, Ishibashi Y, Takao Y, Arizono K. 2004. Effects of triclosan on the early life stages and reproduction of medaka Oryzias latipes and induction of hepatic vitellogenin. Aquat Toxicol 67:167–179.

Klimisch HJ, Andreass M, Tillmann U. 1997. A systematic approach for evaluating the quality of experimental toxicological and ecotoxicological data. Regul Toxicol Pharmacol 25:1–5.

Marlatt VL, Veldhoen N, Lo BP, Bakker D, Rehaume V, Vallée K, Haberl M, Shang D, van Aggelen GC, Skirrow RC et al. 2013. Triclosan exposure alters postembryonic development in a Pacific tree frog (Pseudacris regilla) Amphibian Metamorphosis Assay (TREMA). Aquat Toxicol 126:85–94.

Matsumura N, Ishibashi H, Hirano M, Nagao Y, Watanabe N, Shiratsuchi H, Kai T, Nishimura T, Kashiwagi A, Arizono K. 2005. Effects of nonylphenol and triclosan on production of plasma vitellogenin and testosterone in male South African clawed frogs (Xenopus laevis). Biol Pharm Bull 28:1748–1751.

Orvos DR, Versteeg DJ, Inauen J, Capdevielle M, Rothenstein A, Cunningham V. 2002. Aquatic toxicity of triclosan. Environ Toxicol Chem 21:1338–1349.

Raut SA, Angus RA. 2010. Triclosan has endocrine-disrupting effects in male western mosquitofish, Gambusia affinis. Environ Toxicol Chem 29:1287–1291.

Roberts J, Price OR, Bettles N, Rendal C, van Egmond R. 2014. Accounting for dissociation and photolysis: A review of the algal toxicity of triclosan. Environ Toxicol Chem 33:2551–2559.

Rodney SI, Teed RS, Moore DRJ. 2013. Determination of hazardous concentrations with species sensitivity distributions. Version 3, April, 2013. Prepared by Intrinsik Environmental Sciences, Ottawa, ON, for Canadian Council of Ministers of the Environment.

Tatarazako N, Ishibashi H, Teshima K, Kishi K, Arizono K. 2004. Effects of triclosan on various aquatic organisms. Environ Sci 11:133–140.

Veldhoen N, Skirrow RC, Osachoff H, Wigmore H, Clapson DJ, Gunderson MP, Van Aggelen G, Helbing CC. 2006. Corrigendum to “The bactericidal agent triclosan modulates thyroid hormone-associated gene expression and disrupts postembryonic anuran development.” Aquat Toxicol 80:217–227.

Wang XN, Liu ZT, Yan ZG, Zhang C, Wang WL, Zhou JL, Pei SW. 2013. Development of aquatic life criteria for triclosan and comparison of the sensitivity between native and non-native species. J Hazard Mater 260:1017–1022.