Time and Temperature-Dependent Acute Toxicity of Aromatic Hydrocarbons

Tjalling Jager[1], Tom Parkerton[2], Eric Febbo[2], Bob Blattenberger[2], Martin Connelly[2], Dan Letinski[2]
[1] Theoretical Biology, Vrije Universiteit De Boelelaan 1085, NL-1081 HV, Amsterdam, The Netherlands,
email: tjalling@bio.vu.nl - http://www.bio.vu.nl/thb http://www.cem-nl.eu
[2] ExxonMobil Biomedical Sciences, Annandale, NJ, USA

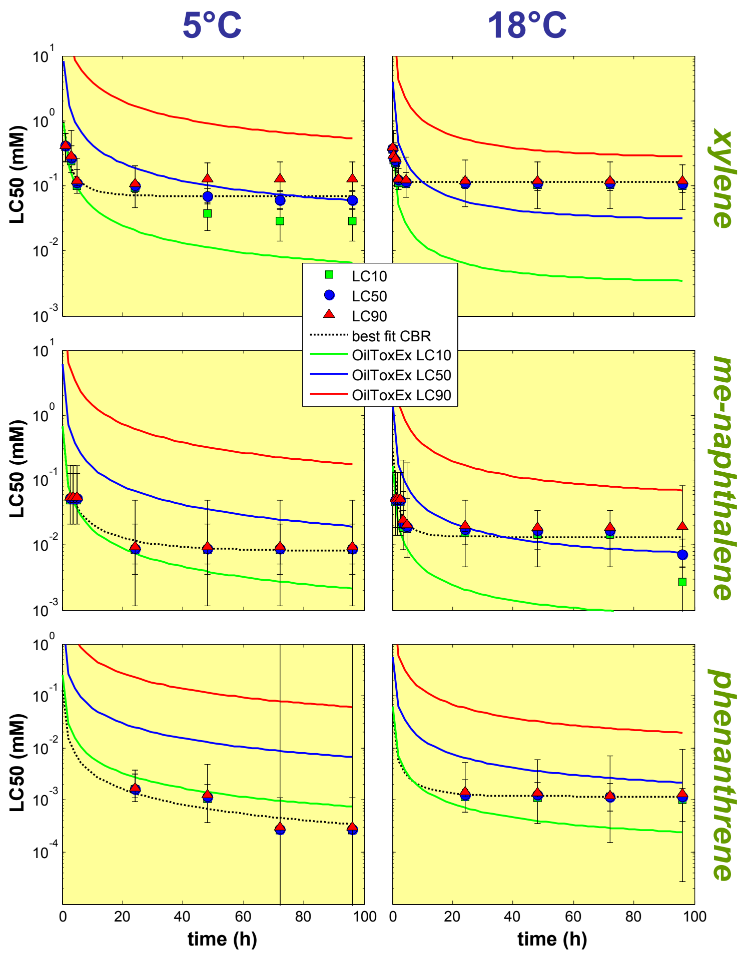
CEM Netherlands Center for Environmental Modeling

ExxonMobil

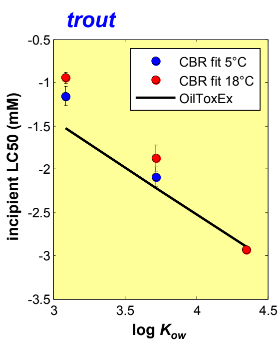
Introduction

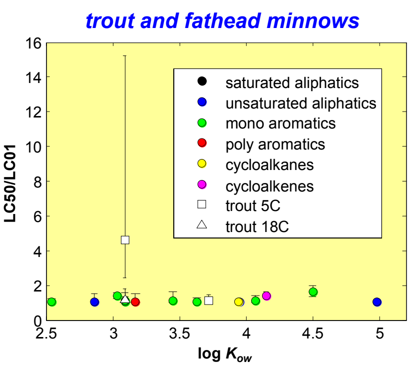
Most toxicity tests are performed under constant conditions. However, in field cases, such as oil spills, organisms are exposed to time-varying concentrations and at different temperatures than in the laboratory. Toxicity predictions for such conditions require modelling approaches. The OilToxEx model (*1*) was developed to estimate the impact of oil spills, and applies the critical body residue (CBR) approach to assess time-dependent toxicity.

In this poster, we compare OilToxEx predictions to new aquatic toxicity data for three aromatic hydrocarbons with trout at two test temperatures, as well as earlier published data for fathead minnows.



A significant difference between OilToxEx predictions and trout data is apparent for LCx in time. OilToxEx predicts large differences between LC10 and LC90, whereas the measured LCx's span only a limited concentration range. Discrepancies in the shape of the LCx pattern with time also reflect differences in assumed versus actual substance elimination rates.





Incipient LC50s from the trout data agree with the OilToxEx predictions.
Analysis of both trout and fathead minnow data shows that an LC50/LC01 ratio of 1-2 is more appropriate. However, field populations may show greater variation in toxicological response due to larger differences between individuals (e.g., weight, lipid content, genetic background).

Test Compounds	o-xylene, 2-methyl naphthalene, phenanthrene
Species	rainbow trout (± 1.5 grams)
Doses	control plus 5 or 2 (phen.) concentrations
Test temperature	5°C and 18°C
Test duration	4 days (several time points) plus one day depuration
Body residues	dead fish, survivors at end of test, and one dose after 6 and 24 h depuration

Fish test data

Toxicity tests were conducted with juvenile rainbow trout (see table). Data for fathead minnows (±24°C) were taken from the original reports (see *2*); data for hydrocarbons only.

OilToxEx predictions

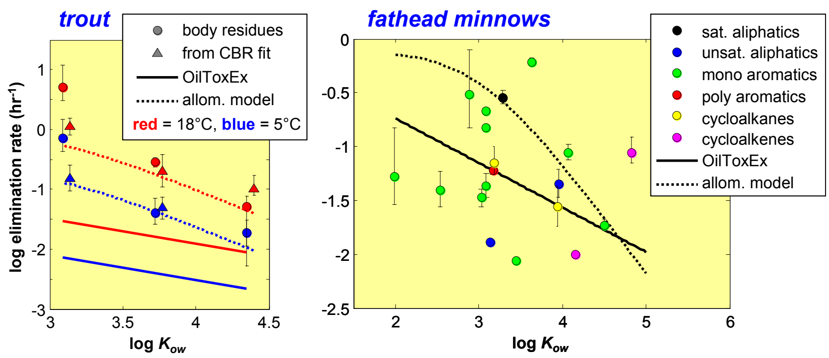
OilToxEx follows the CBR approach, assuming that an individual dies immediately when an internal threshold concentration is exceeded (which varies between individuals). As a result, LC50 decreases in time according to:

$$LC50(t) = LC50(\infty)\frac{1}{1-e^{-k_e t}}$$

QSAR estimates based on K_{ow} are applied for incipient LC50 (species-dependent) and elimination rate (temperature-dependent). To estimate the actual percentage mortality, a dose-response curve is assumed with a fixed slope, LC50/LC01 = 100.

Modelling

The body-residue data for trout were analysed using a one-compartment model, yielding the whole-body elimination rate. A log-logistic dose-response curve was fit to the survival data at each time point independently, yielding estimates for LCx and slope. LC50s in time were described by the CBR model, providing estimates for incipient LC50 and elimination rate based on toxicity. For all data, only model estimates that were judged to be reliable (confidence interval spanning less than a factor of 10) are shown.



Trout elimination rates derived from time-variable LC50's generally agree with values from body residues, but for xylene the latter are clearly higher. An allometric model (3) (parameterised for juvenile trout) provides better estimates than the general equation used in OilToxEx, although xylene is still deviating (biotransformation?).
For fathead minnows, toxicity-based elimination rates show large differences between compounds and unlike predicted elimination rates show little relationship to K_{ow}. It is unlikely that these elimination rates reflect whole-body residues.

Summary / Recommendations

- Experimental data confirm the incipient LC50 and temperature dependence of elimination as predicted by OilToxEx.
- Elimination rate predictions can be improved by including species and size dependence, such as in the allometric model.
- OilToxEx predictions could also be improved by using a steeper concentration response, i.e., LC50/LC01 = 2 vs. the default of 100.
- Preliminary results suggest that elimination rates derived from the CBR model may not reflect whole-body residues, questioning the underlying assumption of a constant critical internal threshold (*4*).
- Further improvement requires more mechanistic studies and consideration of other models (e.g., *5*).

References

(*1*) French-McCay, DP (2002). *Environ. Toxicol. Chem.* 21:2080-2094.
(*2*) Russom, CL *et al.* (1997). *Environ. Toxicol. Chem.* 16:948-967.
(*3*) Sijm, DTHM, A Van der Linde (1995). *Environ. Sci. Technol.* 29:2769-2777.
(*4*) Zhao, Y, MC Newman (2007). *Environ. Toxicol. Chem.* 26:543-547.
(*5*) Bedaux, JJM, SALM Kooijman (1994). *Environ. Ecol. Stat.* 1:303-314.