Monitoring DEET in Water: Fundamental Study to Evaluate the Plausibility of Mimics

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Quick Facts on DEET History

- DEET (N,N-Diethyltoluamide, Fig. 1) was initially used by the US Army in the mid-1940s to protect soldiers from mosquitoes during jungle warfare.
- Nowadays DEET is widely used as an insect repellent incorporated in more than 140 commercially available repellent products.

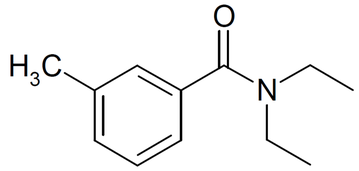

Figure 1: *Chemical structure of DEET*

Occurrence of DEET in the Environment

- DEET is washed from the skin when swimming or during showering. Consequently DEET is expected to occur in surface water connected to recreational water bodies or receiving treated wastewater.
- One of the first studies on wastewater contaminants in US streams reported the occurrence of DEET in 74% of 54 samples with a maximum concentration reaching 1.1 µg/L (Kolpin et al., 2002). Later studies confirmed the wide distribution of DEET in water, not only in the US but also in Europe (Weigel et al., 2004) with variable results regarding geographical and seasonal patterns in DEET concentration.
- DEET is commonly detected in laboratory blanks and the concentration reported in water are unexpectedly high.

Hypothesis

There are compounds that yield a false positive or result in elevated concentration for DEET using existing analytical methodologies.

Objective

Perform theoretical and preliminary research to test the plausibility of a DEET mimic occurring in the environment.

Approach

Step 1: Select and procure potential DEET mimics

- With chromatography and mass spectrometry detection, a mimic should have a mass and structure similar to DEET. Potential mimics were primarily identified through the NIST library, searching for the molecular mass of DEET ± 0.5 Da.
- Mimics were also further selected based on availability from commercial chemical suppliers.

Step 2: Analyze DEET and potential mimics

- As DEET has been reported in the environment using GC-MS and LC-MS/MS methods, authentic standards and selected mimics were analyzed and compared.
- GC-MS method was reproduced from *Kolpin et al. (2002)* while LC-MS/MS method was reproduced from *Trenholm et al. (2006)*.
- Compounds were analyzed in full scan mode in order to compare the mass spectrum and in MRM mode in order to compare the fragmentation pattern.

Step 3: Collect and analyze wastewater effluents for DEET and mimics

- Wastewater effluents were collected from five locations in four different states, including humid and dry areas expected to have dissimilar DEET concentrations.
- Samples were spiked with a DEET_d6 surrogate then split to perform both Liquid-Liquid Extraction (LLE) and Solid Phase Extraction (SPE) for GC-MS and LC-MS/MS analysis, respectively. Duplicate analysis was also performed on samples spiked with mimics (250 ng/L).
- In order to improve the identification of mimics, extracts were also analyzed by high resolution mass spectrometry (LC-QTOF).

Materials

Solvent and standards

- HPLC grade water, dichloromethane and methanol were procured from Fisher
- Standards of DEET were procured from Sigma-Aldrich, Alfa Aesar, Accustandard, Vertellus and Clariant
- Selected mimics were procured from Sigma-Aldrich

Chromatography

- LC was performed using an Agilent 1290 UHPLC with a C12 column (Phenomenex Synergi MAX-RP 250 x 4.60 mm; 80 A; 4µ particle size)
- GC was performed using an Agilent 7890A with a DB-5MS UI column (Length: 15 m; Diameter: 0.25 mm; Film: 0.25 µm)

Mass spectrometry

- SPE extracts were analyzed using an Agilent 6460 triple quadrupole mass spectrometer and an Agilent 6540 quadrupole time of flight mass spectrometer.
- LLE extracts were analyzed using an Agilent 7000 triple quadrupole mass spectrometer.

Results

Selection of potential DEET mimics

- More than 180 compounds were identified as potential mimics using the NIST library.
- Discrimination based on elemental composition, potential to give similar product ions as DEET, and commercial availability prioritized six potential mimics (Fig. 2). For instance, carbendazim, a fungicide, has a similar transition to DEET and potential to occur in surface water.

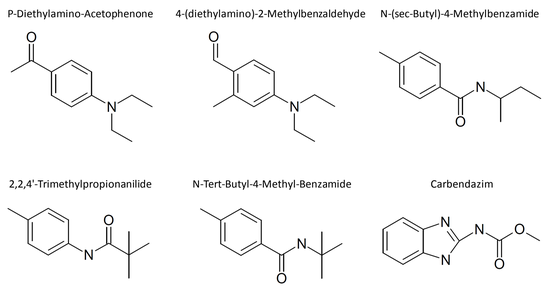

Figure 2: *Names and structures of potential DEET mimics selected for the study*

LC-MS and LC-MS/MS analysis

- LC-MS analysis further confirmed 2,2,4'-trimethylpropionanilide and N-tert-butyl-4-methylbenzamide as potential mimics based on retention time match (Fig. 3).
- As expected, the mass spectra of the potential mimics were similar to that of DEET, even though the $[M+H]^+$ and $[M+Na]^+$ ion ratio could be different (Fig. 4).
- LC-MS/MS analysis showed similar product ions for most of the compounds but the ratio of transitions were significantly different when compared to DEET (Fig. 5).

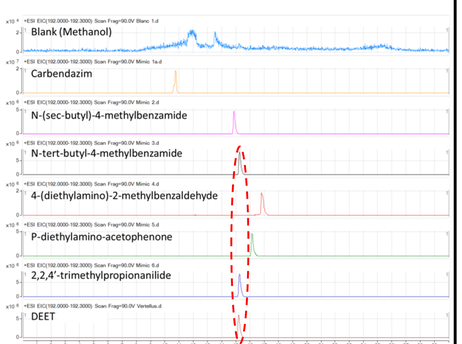

Figure 3: *Retention time of DEET and mimics in LC-MS analysis*

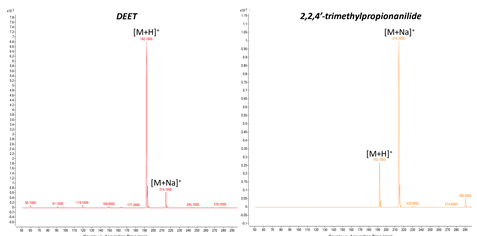

Figure 4: *Mass spectrum of DEET and a mimic (LC-MS)*

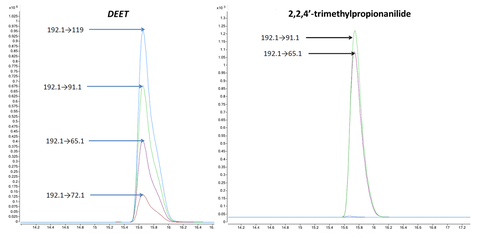

Figure 5: *Relative abundance of product ions of DEET and a potential mimic (LC-MS)*

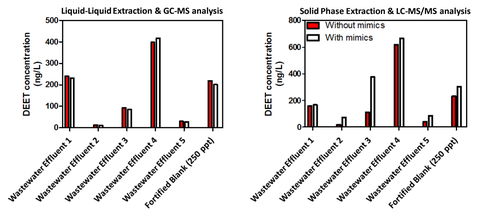

Figure 6: *Concentrations of DEET reported in wastewater effluents*

GC-MS and GC-MS/MS analysis

- 2,2,4'-trimethyl-propionanilide and N-tert-butyl-4-methylbenzamide were identified as potential mimics based on retention time.
- Mass spectra for DEET and mimics were similar with respect to chemical ionization but significantly different with respect to electron impact ionization.
- Our evaluation of mimics using GC-MS/MS demonstrated that fragmentation patterns matched DEET for precursor ion m/z 119 (two transitions), but not for precursor ion m/z 190 (nine transitions).

Analysis of wastewater effluents

- DEET concentrations in all five wastewater effluents were between 50 and 600 ng/L (Fig. 6).
- Although the trend is the same for GC-MS and LC-MS/MS, the DEET concentration reported can be substantially different, revealing a potential matrix effect.
- LC-MS/MS seems more prone than GC-MS to overestimation of DEET when mimics occur.
- High resolution MS/MS analysis using QTOF did not suggest the occurrence of a mimic in wastewater effluent (Fig. 7).

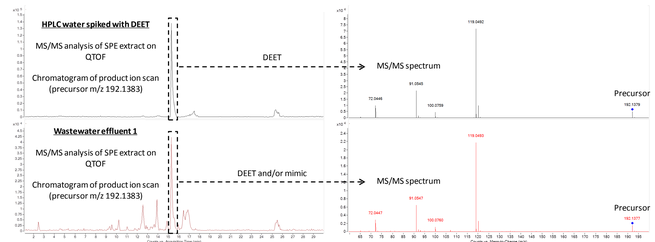

Figure 7: *QTOF analysis of wastewater effluent (MS/MS on m/z 192.1383)*

Conclusions

- GC-MS and LC-MS/MS can report substantially different values showing a potential matrix effect.
- The mimics selected may overestimate the concentration of DEET reported.
- Other potential mimics known to occur in wastewater have recently been identified and may be evaluated in future studies.

Acknowledgement

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References

Kolpin et al., (2002), Env. Sci. Tech. 36
Trenholm et al., (2006), Chemosphere 65
Weigel et al., (2004), J. Chrom. A 1023