Environmental Safety of the Use of Major Surfactant Classes in North America

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The American Cleaning Institute (ACI) has been a leader in research and stewardship related to the environmental safety of surfactants used in cleaning products. As part of our efforts to promote sustainable use of surfactants in down-the-drain products, ACI has compiled the findings of research on the use, disposal, treatment, and aquatic risk of major surfactants in North American freshwater environments.

FIGURE 1. ENVIRONMENTAL FATE OF SURFACTANTS IN CONSUMER PRODUCTS WITH "DOWN-THE-DRAIN" DISPOSAL. THE HIGHLIGHTED SECTIONS REPRESENTS THE SCOPE OF STUDY.

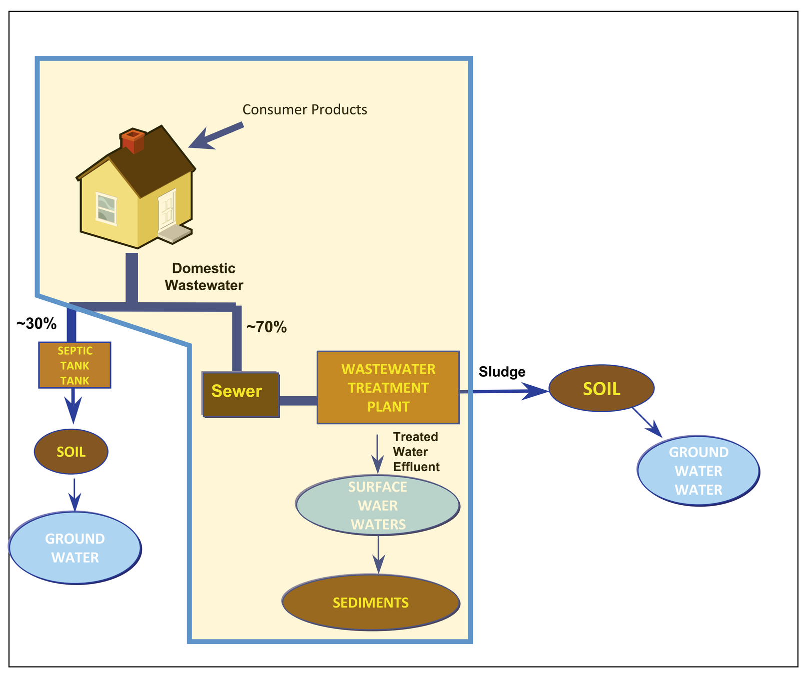


FIGURE 2. ANNUAL CONSUMPTION IN NORTH AMERICA OF ALKYL SULFATES (AS), ALCOHOL ETHOXYLATES (AE) AND ALKYL ETHOXYSULFATES (AES) AND LINEAR ALKYLBENZENE SULFATES (LAS). VOLUMES ARE EXPRESSED IN METRIC TONS.

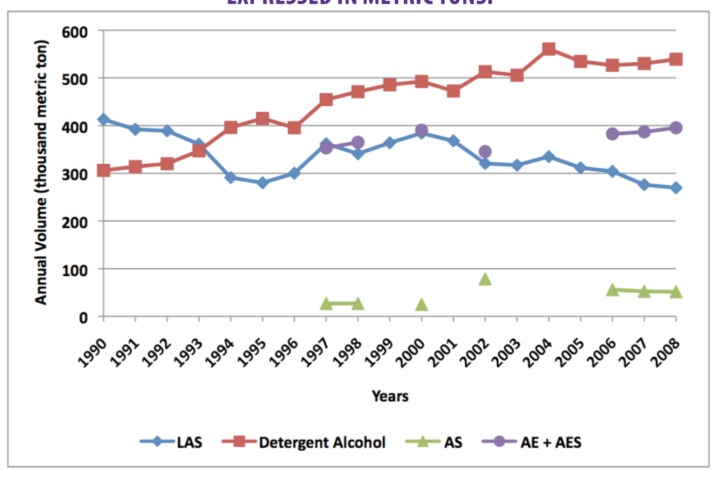


TABLE 1

Environmental Fate Properties of Surfactants. The major surfactants used in North America are classified as having rapid primary and ultimate biodegradability. Sorption to sediments generally increases with chain length.

TABLE 2

Summary of ecotoxicity data for major surfactants normalized to the average structure measured from monitoring of municipal wastewater treatment plant (WWTP) effluent. Extensive toxicity data are available for LAS, AE, AS and AES. Surfactants typically are used as a mixture of differing chainlengths. Quantitative structure activity relationships (QSARs) for chronic toxicity have been developed for each of these surfactants. QSARs were used to normalize the diversity of structures to an average structure from WWTP monitoring studies to determine the predicted no effect concentration (PNEC) for each. PNECs were estimated from species sensitivity distributions (SSD) where 5% of the species are expected to be adversely affected (Hazard Concentration (HC5)). The HC5s have been compared to model experimental stream (Figure 3) no observed effect concentrations (NOECs) with similar structures. Figure 4 is the chronic toxicity SSD for AS/AES and displays the HC5 and comparison to experimental stream NOEC.

TABLE 3

Input parameters used in iSTREEM for predicting exposure concentrations. iSTREEM is a web-based computer model which predicts the concentration of a chemical used in "down-the-drain" products at the discharge of more than 9610 wastewater treatment plants, at the intake of downstream municipal drinking water treatment facilities, and in approximately 28,000 river reaches covering over 200,000 river miles across the continental United States.

TABLE 4

Predicted exposure concentrations (presented as % of U.S. river reaches < concentration) for mean and 7Q10 (low) flow conditions. 7Q10 represents the lowest 7-day average flow in a year that occurs during 7 consecutive days on average once every 10 years.

FIGURE 3. EXPERIMENTAL STREAM MESOCOSM OPERATED BY PROCTER & GAMBLE.

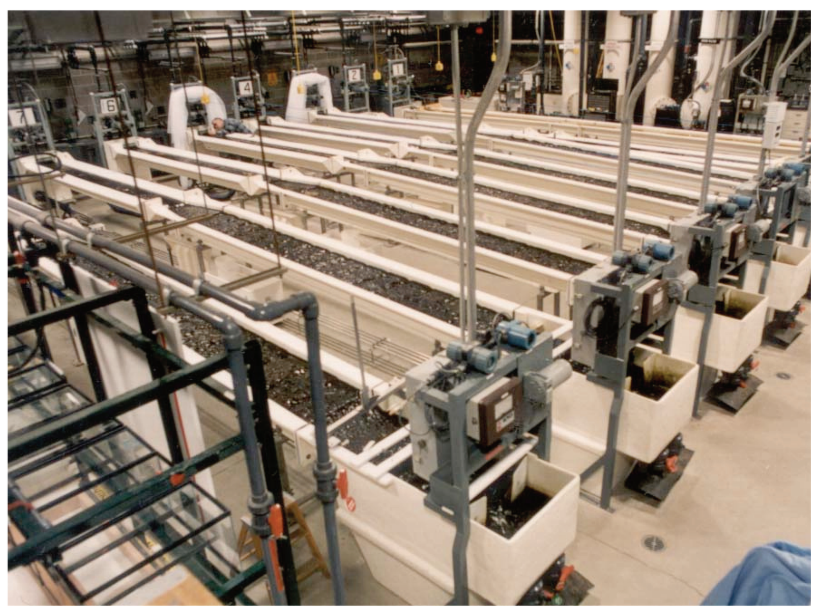


FIGURE 4. NORMALIZED SPECIES SENSITIVITY DISTRIBUTION FOR C13.5-E3S AND COMPARISON OF EXPERIMENTAL STREAM NOEC CONDUCTED WITH THE C12-15E3S (LIZOTTE ET AL. 2002).

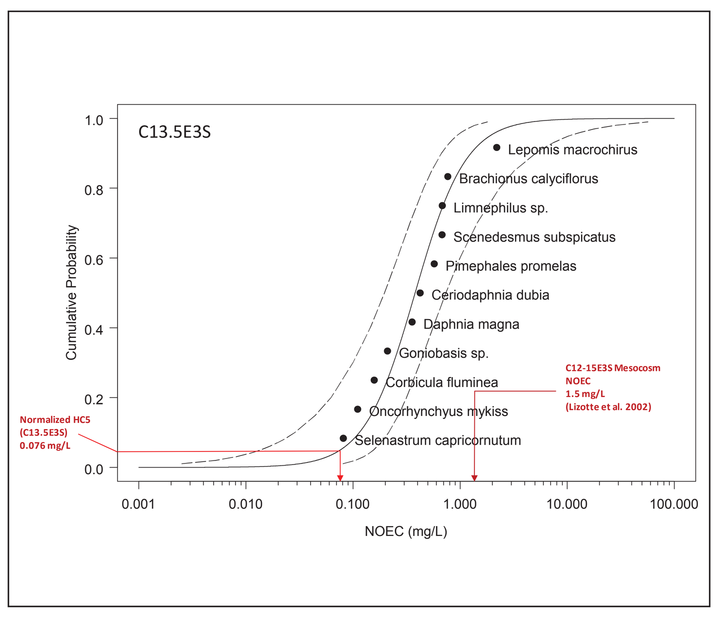
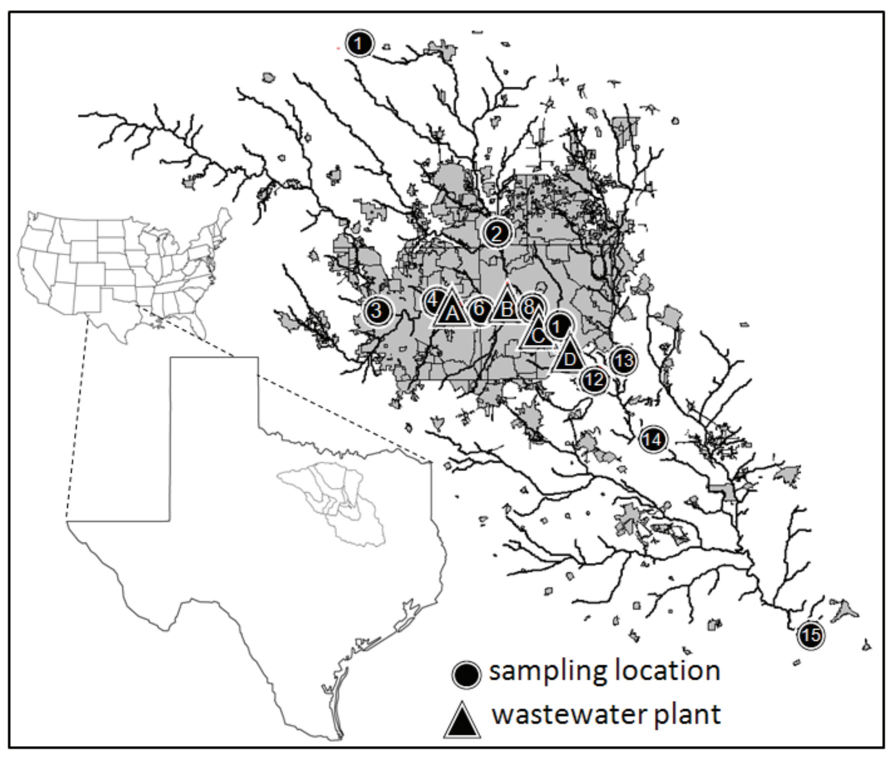


TABLE 5

Toxic Units (TU) for surface and pore waters for a worst-case scenario (Trinity River, Texas, USA) [Figure 5]; dilution of 1, effluent dominated). TU represent the ratio of measured surfactant constituent concentrations to the PNEC. The methodologies developed for assessing surfactant mixtures can be found on www.ACIScience.org. Because there is sufficient evidence that LAS, AES, and AE act with the same toxicological mechanism of action (i.e., narcosis), concentration addition was used to sum the surfactant TU for cumulative surface water (SW) and cumulative pore water (PW) TU for all surfactants. Analytical data from overlying water and pore water confirmed a low level of risk for LAS, AS, AES and AE combined.

FIGURE 5. STUDY AREA, NORTH CENTRAL TEXAS, WITH TRINITY RIVER SYSTEM, URBANIZED AREAS, SAMPLING LOCATIONS, AND WASTEWATER TREATMENT PLANTS SHOWN.



CONCLUSIONS

Both prospective assessments and retrospective studies show that the environmental risks of these large volume chemicals found in products widely dispersed across North America are LOW.

Table 1 - Environmental Fate Properties of Surfactants.

	Aerobic Biodegradation	Sorption
Alkyl Sulfates (AS)	Readily Biodegradable; Rapid Primary and Ultimate	Increases with chain length
Alcohol Ethoxylates (AE)	Readily Biodegradable; Rapid Primary and Ultimate	Increases with chain length; decreases with ethoxylation
Alkyl Ethoxysulfates (AES)	Readily Biodegradable; Rapid Primary and Ultimate	Little published information; generally seen to increase with chain length; likely decreases with ethoxylation
Linear Alkylbenzene Sulfates (LAS)	Readily Biodegradable; Rapid Primary and Ultimate	K_d varies greatly due to structural variability

Table 2 - Summary of ecotoxicity data for major surfactants normalized to the average structure measured from monitoring of municipal wastewater treatment plant (WWTP) effluent.

					PNEC	
Surfactant	Most Sensitive Species	QSAR Citations	Average Structure	No. Species in Chronic SSD	HC5 (mg/L)	Stream Mesocosm NOEC (mg/L)
AS/AES	Invertebrates and fish	1	C13.5-E3S	11	0.076	1.5
AE	Invertebrates and fish	2	C13.7-E7.7	17	0.098	0.105
LAS	Invertebrates and fish	3	C11.6-2-phenyl	19	0.190	0.362

(1) Dyer et al. (2000)
(2) Boeije et al. (2006)
(3) Fendinger et al. (1994)

Table 3 - Input parameters used in iSTREEM for predicting exposure concentrations.

	Chemicals		
Parameters	LAS	AE	AES
National volume use (metric tons)	269,500 (1)	141,976 (1)	268,077 (1)
Per capita use per day (g)	2.19	1.35	2.87
WWTP Process (% removal)			
Activated Sludge	99.4 (2,3,4)	99.6 (4,6,7)	98.0 (4)
Oxidation Ditch	98.0 (2)	99.8 (7)	97.3 (8)
Rotating Biological Contactor	96.5 (2,3)	99.7 (7)	96.6 (8)
Lagoon	98.5 (2)	98.6 (7)	97.0 (8)
Trickling Filter	79.7 (2,3,4)	93.0 (4,7)	83.5 (4)
Primary	27.0 (5)	18.9 (4)	22.6 (8)
In-stream degradation (1/d)			
River Loss	0.7 (9)	31.2 (9)	24 (9)
Influent Adjustment Factors	0.5*	0.86*	0.082*
* Based on Comparison of Predicted 2003 Influent vs. Measure Influent			
Note: Removal values with multiple references are the weighted average removals from all of the studies.			

(1) SRI (2009); (2) McAvoy et al. (1993); (3) Trehy et al. (1996); (4) McAvoy et al. (1998);
(5) Rapaport and Eckhoff (1990); (6) McAvoy et al. (2006); (7) Morrall et al. (2006);
(8) Based on weighted removal ratios of LAS and AE; (9) Federle and Schwab (unpublished data)

Table 4 - Predicted exposure concentrations (presented as % of U.S. river reaches < concentration) for mean and 7Q10 (low) flow conditions.

Percentile River Miles	LAS (mg/L) Mean Flow	LAS (mg/L) Low Flow	AE (mg/L) Mean Flow	AE (mg/L) Low Flow	AES (mg/L) Mean Flow	AES (mg/L) Low Flow
90%	1.4×10^{-2}	7.4×10^{-2}	8.94×10^{-4}	$5.3 \text{ X } 10^{-3}$	9.32×10^{-4}	$5.3 \text{ X } 10^{-3}$
75%	3.9×10^{-4}	1.01×10^{-2}	1.4×10^{-5}	2.52×10^{-4}	1.36×10^{-5}	2.61×10^{-4}
50%	3.8×10^{-5}	4.07×10^{-4}	$<1 \times 10^{-8}$	$<1 \times 10^{-8}$	$<1 \times 10^{-8}$	$<1 \times 10^{-8}$
25%	1.07×10^{-6}	2.4×10^{-7}	$<1 \times 10^{-8}$	$<1 \times 10^{-8}$	$<1 \times 10^{-8}$	$<1 \times 10^{-8}$
10%	$<1 \times 10^{-8}$	$<1 \times 10^{-8}$	$<1 \times 10^{-8}$	$<1 \times 10^{-8}$	$<1 \times 10^{-8}$	$<1 \times 10^{-8}$

Table 5 -Toxic Units (TU) for Surface and Pore Waters for a worst-case scenario (Trinity River, Texas, USA).

Parameter	Units	*n*	Mean	SD	Range
Surfactant SW Sum	TU	10	0.01	0.02	0.07-0.14
Surfactant PW Sum	TU	10	0.24	0.06	0.11-31

REFERENCES

All references cited in this poster can be found at www.ACIScience.org

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