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Fire Retardant and Foam Suppressant Chemicals May Be Toxic to Aquatic Invertebrates and Algae

Fire retardant and foam suppressant chemicals are toxic to the amphipod *Hyalella azteca*, the cladoceran *Daphnia magna*, and the green algae *Selenastrum capricornutum* at concentrations that are possible in aquatic ecosystems accidentally sprayed during fire-fighting. Adverse affects on algae and aquatic invertebrates may impair ecosystem functions, especially at higher trophic levels that include fish.

Millions of gallons of fire retardants and foam suppressants are used in the United States each year for control of range and forest fires. These chemicals are often applied in environmentally sensitive areas with endangered, threatened, or economically significant plant and animal species. Relatively little information is available on the toxicity of these chemicals to aquatic life and on their effect on the environment.

The extensively used ammonium-based compounds are essentially fertilizer formulations and are believed to cause minimal toxicological or ecological harm. However, fish kills have occurred in streams accidentally contaminated by fire retardant chemicals. Essentially no information is available on the effects of foam suppressants on aquatic life.

Acute Toxicity Tests Were Conducted

Acute toxicity tests were conducted by exposing *H. azteca* (amphipod) and *D. magna* (daphnid) in soft (hardness 41 mg/L as $CaCO_3$) and hard (hardness 163 mg/L as $CaCO_3$) reconstituted water and *S. capricornutum* (algae) in algal assay medium to three fire retardant and two foam suppressant chemicals. The ammonium-based fire retardants tested were Fire-Trol GTS-R, Fire-Trol LCG-R, and Phos-Chek D75-F; and the anionic surfactant based foam suppressants were Phos-Chek WD-881 and Silv-Ex.

Mature adult amphipods (0.68 ± 0.24 g) were exposed for 96 h, neonate daphnids (<24-h old) for 48 h, and algae (log growth phase) for 96 h to each chemical. Results of the amphipod tests were used to calculate the following standard measures of toxicity: the 96-h LC50 (lethal concentration) for amphipods, the 48-h EC50 (effective concentration) based on immobilization for daphnids, and the 96-h IC50 (inhibition concentration) based on biomass inhibition for algae.

Soft Water Raised Toxicity to Amphipods

Four of the five fire control chemicals were more toxic to amphipods in soft water than in hard water (Table). However, only one chemical was more toxic to daphnids in soft water than in hard water, and one was more toxic in hard water than in soft water. Of the three test organisms, algae were generally more sensitive than the two invertebrates to the three retardants, and all three test organisms were about equally sensitive to the two foams. The two foams were substantially more toxic than the three retardant chemicals to the two invertebrates. These results revealed that the five fire control chemicals can produce substantially different levels of toxicity in different test organisms. Thus, adverse effects in aquatic ecosystems will vary depending on the type of fire control chemical, water quality characteristics, and the aquatic plants and invertebrates present.

Potential for Environmental Effects

Fire-Trol GTS-R is prepared for field application by mixing 1.66 pounds of powder with 1 gallon of water to produce 1.10 gallons of mixed slurry. This mixture is equivalent to about 200,000 mg/L. An accidental drop of Fire-Trol GTS-R

in a soft water aquatic environment would require a dilution of more than 1,565-fold to dilute it to a concentration equivalent to the 96-h LC50—a concentration that would cause substantial mortality. Similarly, a field mixture of Fire-Trol LCG-R (270,400 mg/L) would have to be diluted at least 3,700-fold; and for Phos-Chek D75-F (144,00 mg/L) the dilution would have to be 2,710-fold. For daphnids, dilution factors for the three chemicals ranged from 320 to 1,000 and for algae 3,000 to 27,000.

A safety factor of 100 is commonly applied to acute toxicity data to estimate an environmentally safe concentration for aquatic organisms. Applying this safety factor to the above toxicity information would require a 156,500-fold dilution for Fire-Trol GTS-R, 370,000 for Fire-Trol LCG-R, and 271,000 for Phos-Chek D75-F to approach a safe concentration for amphipods.

Foam chemicals are applied at the rate of about 0.10 to 1% foam, which is equivalent to 1,000 to 10,000 mg/L. The 96-h LC50 of Silv-Ex to *Hyalella* in soft water is equivalent to a 0.0024% foam solution. This acute toxicity value is about 420 times less than the 1% foam field application rate. Consequently, if a foam solution came in contact with an aquatic environment it would have to be diluted 420-fold to reach the 96-h LC50 concentration for amphipods. Applying a safety factor of 100 to the above toxicity information would require a 42,000 dilution of the foam field application solution to approach a safe concentration. For Phos-Chek WD-881, the dilution would have to be 100,000-fold for amphipods. For daphnids, dilution factors for the two foams ranged from 90,900 to 250,000 and for algae 42,000 to 67,000.

Adverse effects from fire-fighting chemicals on primary producers such as algae and on important aquatic invertebrates such as amphipods and daphnids in the food web could lead to altered biodiversity and shifts in trophic pathways. Aquatic plants and invertebrates are important components of the food web supporting economically important fish species or endangered or threatened fish. Fire control managers should be cautious of their use of fire retardants or foams near lakes or streams with fish populations, especially waters with low flows incapable of diluting fire retardant chemicals to concentrations protective of aquatic primary producers or aquatic invertebrates.

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Table. Acute toxicity (LC50; mg/L; 95% confidence interval in parentheses) of five fire retardant chemicals to *Hyalella azteca, Daphnia magna,* and *Selenastrum capricornutum* exposed in soft and hard waters.[1]

Chemical	Water type	*Hyalella* 96-h LC50	*Daphnia* 48-h EC50	*Selenastrum* 96-h IC50
Fire-Trol GTS-R	Soft	127*[a] (92–172)	257[a] (211–327)	
	Hard	363[w] (292–450)	339[w] (270–418)	
	AAM[2]			18[a] (17–20)
Fire-Trol LCG-R	Soft	73*[b] (42–115)	848[b] (662–1036)	
	Hard	535[x] (424–654)	813[x] (627–992)	
	AAM			10[b] (10–11)
Phos-Chek D75-F	Soft	53*[b] (49–65)	140*[c] (113–177)	
	Hard	394[wx] (310–519)	280[w] (224–386)	
	AAM			48[c] (40-58)
Phos-Chek WD-881	Soft	10*[c] (6–17)	11*[d] (9–14)	
	Hard	22[y] (17–28)	4[y] (3–5)	
	AAM			24[d] (22–27)
Silv-Ex	Soft	24[d] (20–30)	7[e] (6–9)	
	Hard	27[y] (22–35)	7[z] (5–8)	
	AAM			15[a] (12–18)

[1]Values with different letters (a–d for comparison in soft water; w–y for comparison in hard water) or an asterisk (for comparison between soft and hard waters for each test chemical) are significantly different ($P = 0.05$).
[2]AAM = algal assay medium.