



NATIONAL BIOLOGICAL SERVICE
U.S. DEPARTMENT OF THE INTERIOR

NBS INFORMATION BULLETIN

No. 52 1995

THE LAMPRICIDE TFM ONLY SLIGHTLY AFFECTS ALGAL PHOTOSYNTHESIS

In this study, we examined the effects of TFM on oxygen production by *Chlorella pyrenoidosa* and *Selenastrum capricornutum* in both high and low alkaline test solutions as a possible cause of large numbers of dead fish that occasionally result from a stream treatment. For more than 35 years, TFM has been used successfully in the Great Lakes basin to reduce the numbers of larval sea lampreys in tributary streams. To effectively kill sea lampreys, TFM must be pumped into a stream and maintained at the desired concentration for at least 9 h. Sea lamprey control agents are concerned about the death of nontarget organisms during stream treatments with TFM. The death of nontarget fishes might result from delays in daily stream reaeration combined with the decreased oxygen production by plants or the increased respiration by stream fauna. Either would decrease the pH of the stream and could increase the toxicity of TFM. If the fish are stressed and photosynthetic aeration of the stream is delayed by the presence of TFM, fish may die.

ALGAL CULTURES WERE EXPOSED TO A RANGE OF TFM CONCENTRATIONS

Monoculture test solutions of *C. pyrenoidosa* and *S. capricornutum* ($1\text{--}13 \times 10^4$ cell/mL) were exposed to a range of TFM concentrations. These concentrations included the LC99.9 for sea lampreys (the minimum concentration of TFM needed to kill sea lampreys) and the LC25 for rainbow trout (the maximum permissible concentration of TFM for a stream treatment). Alkalinities were 180–200 mg/L (as CaCO_3) in the high alkaline algal test solutions and 40–75 mg/L (as CaCO_3) in the low alkaline algal test solutions. At the start of the TFM exposure, the dissolved oxygen was reduced to about 3.0 mg/L in all trials by bubbling nitrogen through the algal test solution; pH was adjusted to 8.4–8.6 in the high alkaline algal test solution and to 7.9–8.1 in the low

alkaline algal test solution by bubbling CO_2 through the algal test solutions. The pH was adjusted to mimic natural stream conditions for the alkalinity of the algal test solution. A control and five concentrations of TFM were used for each test. Three replicates were exposed to each TFM concentration under a continuous light source for 9 h to mimic a stream treatment. After 9 h of TFM exposure, final dissolved oxygen and pH measurements were made.

OXYGEN PRODUCTION WAS INHIBITED SLIGHTLY BY TFM

Generally, oxygen production was less in the high alkaline test solution than in the low alkaline test solution and was greater for the *C. pyrenoidosa* than for the *S. capricornutum* (Table 1). When the algae were exposed to the lampricide TFM, oxygen production was slightly inhibited; the *C. pyrenoidosa* was more resistant to the TFM than the *S. capricornutum* (Table 1). In the high alkaline algal test solution with TFM at the LC99.9 for larval sea lampreys (about 6 mg/L TFM), final dissolved oxygen levels in the experimental cultures averaged about 11% lower than in the controls for *C. pyrenoidosa* ($n = 5$) and 19% lower for *S. capricornutum* ($n = 5$). With TFM at the LC25 for rainbow trout (about 15 mg/L TFM), final dissolved oxygen levels averaged about 20% lower than in the controls for *C. pyrenoidosa* and 37% lower for *S. capricornutum* (Table 2). In addition, the change in pH was less than 0.1 when the algae were exposed to TFM at the LC25 for rainbow trout.

In the low alkaline algal test solution with TFM at the LC99.9 for larval sea lampreys (about 1.4 to 1.7 mg/L TFM), final dissolved oxygen levels averaged about 2% lower than in the controls for both *C. pyrenoidosa* ($n = 4$) and *S. capricornutum* ($n = 6$). With TFM at the LC25 for rainbow trout (about 7

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mg/L TFM); final dissolved oxygen levels averaged about 9% lower than in the controls for *C. pyrenoidosa* and about 21% lower for *S. capricornutum* (Table 2). The change in pH was less than 0.2 when exposed to TFM at the LC25. The difference in pH between the controls and the TFM treated samples was not significant at the LC99.9 and LC25 levels for both the low and high alkaline culture media.

TREATMENTS WITH TFM SHOULD NOT AFFECT STREAM REAERATION

Our study results indicate that a 9-h TFM stream treatment at the LC99.9 for larval sea lampreys could decrease dissolved oxygen levels by about 2–19%, will change pH levels less than 0.1, and will not affect algae concentrations. If algae are the predominant source of oxygen in a stream, TFM concentrations used in most sea lamprey control treatments should not significantly inhibit stream reaeration after a typical diurnal decline in oxygen. Also, we believe that TFM alone does not affect net oxygen production and pH enough to cause the occasional fish kills recorded by sea lamprey control agents. However, our study did not determine how much TFM affects oxygen production by macrophytes.

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Table 1. Increase in dissolved oxygen for algae exposed to various concentrations of TFM for 9 h under lighted conditions at 12°C.

LC values	TFM concentration	Increase in dissolved oxygen (mg/L)	
	(mg/L)	<i>C. pyrenoidosa</i>	<i>S. capricornutum</i>
High alkaline test solution			
Control	0	2.8	2.0
LC99.9 ^a	6	2.5	1.6
LC25 ^b	15	2.3	1.2
Low alkaline test solution			
Control	0	4.8	2.8
LC99.9 ^a	1.4—1.7	4.7	2.7
LC25 ^b	7	4.3	2.2

^aConcentration of TFM found by toxicity tests to kill 99.9% of sea lamprey larvae at the specified alkalinity.

^bConcentration of TFM found by toxicity tests to kill 25% of rainbow trout at the specified alkalinity.

Table 2. Percent reduction in dissolved oxygen compared to controls for algae exposed to TFM for 9 h under lighted conditions at 12°C.

LC values	TFM concentration (mg/L)	Reduction in dissolved oxygen (%)	
		<i>C. pyrenoidosa</i>	<i>S. capricornutum</i>
High alkaline test solution			
LC99.9 ^a	6	11	19
LC25 ^b	15	20	37
Low alkaline test solution			
LC99.9 ^a	1.4—1.7	2	2
LC25 ^b	7	9	21

^aConcentration of TFM found by toxicity tests to kill 99.9% of sea lamprey larvae at the specified alkalinity.

^bConcentration of TFM found by toxicity tests to kill 25% of rainbow trout at the specified alkalinity.