CHAPTER 4

Toxicity of Copper Sulfate and Potassium Permanganate to Rainbow Trout and Golden Alga *Prymnesium parvum*

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Abstract

The effects of copper sulfate and potassium permanganate on *Prymnesium parvum* cell density and ichthyotoxicity and on rainbow trout *Oncorhynchus mykiss* survival were investigated in 0.1-ha plastic-lined hatchery ponds. Treatments were 4 mg/L $KMnO_4$, 1 mg Cu/L and 0.5 mg Cu/L as $CuSO_4$, and untreated ponds which received no chemical addition. Treatments were applied once and rainbow trout were stocked at 5 fish/pond 4 days thereafter. The $KMnO_4$ and 1 mg Cu/L treatments appeared to eradicate *P. parvum* and eliminate ichthyotoxin within 3 days after treatment application. The 0.5mg Cu/L did not appear effective to control cells or toxicity. *P. parvum* persisted in the control ponds throughout the study and sublethal levels of the toxin also existed in these ponds. The potassium permanganate demand of the toxic water was 2 mg/L. Rainbow trout survival did not significantly differ among treatment and control groups. The mortalities that occurred were caused by factors not measured in this study.

Introduction

In 2001, 7,000 rainbow trout *Oncorhynchus mykiss* died in ponds at the Dundee State Fish Hatchery (DSFH). These deaths were attributed to *Prymnesium parvum* ichthyotoxicity. Ammonium sulfate, which is used successfully to control *P. parvum* during warmer months, is ineffective in winter because of lower temperatures and pH levels (Shilo and Shilo 1953). Consequently, Sarig (1971) recommended copper sulfate as the most suitable chemical for controlling *P. parvum* in winter.

Copper sulfate is an effective algaecide (Boyd 1990), but it is toxic to many species of fish at or near the concentration necessary for algal control (Irwin 1997). Hipkins (2002) advised against using copper sulfate in trout ponds, probably because of the adverse effects of copper on growth and survival (Hansen et al. 2002a, b). However, the toxicity of copper is related to water quality characteristics such as hardness, alkalinity, pH, and dissolved organic carbon. Increases in these water quality variables result in decreased copper toxicity and subsequent increased in tolerance by fishes (USACE 1985; Straus and Tucker 1993) and higher concentrations required to control algae (Boyd 1990).

The water quality characteristics of DSFH include: total hardness, 959 mg/L as $CaCO_3$; calcium hardness, 255 mg/L as $CaCO_3$; total alkalinity, 75 mg/L as $CaCO_3$; total chloride, 1,304 mg/L and salinity, 4 ppt. During the period rainbow trout are cultured at DSFH (i.e., late November to early March), pH values of 7-8 are common. We hypothesized that use of relatively lower concentrations of copper than the recommended 2 mg Cu/L for most algal control may not harm trout but may kill the planktonic *P. parvum* in DSFH ponds. Besides copper sulfate, potassium permanganate has the potential to kill *P. parvum* or detoxify the ichthyotoxin. Potassium permanganate is reported to be toxic to bacteria and phytoplankton (Fitzgerald 1964; Kemp et al. 1966; Tucker and Boyd 1977) and to detoxify fish toxins such as rotenone and antimycin (Lawrence 1956; Marking and Bill 1975). We compared the effects of copper sulfate and potassium permanganate on *P. parvum* survival and ichthyotoxicity and survival of 229- to 250-mm rainbow trout.

Materials and Methods

Filling was begun 10 January 2002 for eight 0.1-ha study ponds One day later, the ponds were full and *P. parvum* ichthyotoxicity bioassay and cell count were performed using established protocols (Appendices A and B). The bioassay was performed on incoming lake water while cell count was performed on incoming lake water as well as on water from all study ponds. The study design was 4 X 2 (treatments X replicates) and ponds were randomly assigned to treatments of 4 mg/L potassium permanganate, 0.5 or 1 mg/L copper sulfate pentahydrate, or untreated (e.g., controls). Before chemical treatments were applied, a potassium permanganate demand test was performed (Boyd 1990) on water from the ponds designated for the potassium permanganate treatment. On 14 January 2002, *P. parvum* cell counts and ichthyotoxicity bioassays were performed on water samples from each study pond. Water samples were collected from 25-30 cm depths. One day later, copper analysis (APHA 1995) was performed on water samples from all ponds and five rainbow trout were stocked into each pond. Morning dissolved oxygen concentration, pH, and temperature were recorded daily for each pond using the Yellow Springs Instrument (YSI) Model 650 MDS data logger equipped with a YSI Model 600XL probe. On 21 January 2002, cell counts were performed and all ponds were drained to harvest the fish.

Results and Discussion

Due to inadequate pond availability, the study design was limited to two replicates per treatment or control so these results should be considered preliminary. The initial *P. parvum* cell counts from the study ponds ranged from 1,000 to 6,000 cells/mL, whereas the source water was 3,000 cells/mL. These cell counts indicate relatively light densities of *P. parvum* in both the water source and the study ponds.

Cell count data suggest that *P. parvum* was eradicated in the 1.0-mg/L copper sulfate and 4.0-mg/L potassium permanganate treatment ponds (Table 1). The potassium permanganate demand of the pond water was between 0.0 and 1.0 mg/L, thus the effective concentration of potassium permanganate was <4 mg/L. Although the ponds treated with 0.5-mg/L copper sulfate were initially free of cells following treatment, cells were subsequently seen in one of these ponds. Thus, it appears the 0.5-mg/L copper sulfate is not as effective as 1 mg/L for controlling *P. parvum*. Cell counts indicate that *P. parvum* persisted in the control ponds throughout the study.

The incoming water from the lake was toxic at the time of pond filling and remained so through at least three days when the bioassay performed on 14 January 2001 indicated high fish mortality in water from the control ponds (Table 2). Potassium permanganate at 4.0 mg/L appeared most effective in reducing ichthyotoxicity in this 3-day period whereas some toxicity persisted in the copper sulfate treated ponds.

The copper analysis revealed residual concentrations that increased with the increasing concentration applied to ponds (Table 1). The ambient copper concentration measured in the control ponds averaged 0.057 mg/L and was higher that the average concentration of 0.007 mg/L in ponds treated with potassium permanganate. The lower copper concentrations in the potassium permanganate treated ponds may have resulted from reduction of the Cu^{2+} by the potassium permanganate and subsequent precipitation of free copper.

Survival of rainbow trout was high in all study ponds, averaging 80% for potassium permanganate, 90% for 0.5 mg/L copper sulfate, and 100% for both the1 mg/L copper sulfate and control ponds (Table 1). Because of the small number of trout stocked into each pond, it is difficult to discern with confidence the treatment effects on trout survival. However, because no fish died in the ponds treated with 1 mg/L copper sulfate ponds, the mortality in the ponds treated with 0.5 mg/L copper sulfate probably was not due to copper poisoning. Similarly, the mortalities in the potassium permanganate and 0.5 mg/L copper sulfate treated ponds could not be attributed to ichthyotoxicity. The toxicity was relatively highest in the control ponds and lowest in the permanganate ponds (Table 2) and yet trout mortality was highest in the potassium permanganate pond whereas there was no mortality in the control pond. Obviously, factors not measured in this study caused the trout mortalities.

TABLE 1.—Residual copper concentrations (mg/L), mean rainbow trout survival (%), and *Prymnesium parvum* density (cells/mL) in water samples from ponds treated with potassium permanganate, copper sulfate, or untreated (control).

	Treatment			
Date	$KMnO_4$ 4 mg/L	$CuSO_4 \cdot 5H_2O$ 0.5 mg/L	$CuSO_4 \cdot 5H_2O$ 1.0 mg/L	Control
	Residual copper			
15 Jan 2002	0.005	0.220	0.209	0.036
	0.008	0.139	0.228	0.078
Mean	0.007	0.180	0.219	0.057
	Survival			
21 Jan 2002	80	90	100	100
	***P. parvum* density**			
11 Jan 2002	3,000	1,000	2,000	6,000
	2,000	2,000	4,000	5,000
Mean	2,500	1,500	3,000	5,500
14 Jan 2002	0	0	0	2,000
	0	0	0	1,000
Mean	0	0	0	1,500
21 Jan 2002	0	0	0	3,000
	0	1,000	0	2,500
Mean	0	500	0	2,750

TABLE 2.—Mean fish mortality (percent) observed in bioassays conducted on incoming lake water (11 January 2002) and on pond water (14 January 2002). Ponds were full and treated with potassium permanganate, copper sulfate, or left untreated (control) on 11 January 2002.

		Treatment			
			$CuSO_4 \cdot 5H_2O$		
Bioassay water	Incoming water	$KMnO_4$4 mg/L	0.5 mg/L	1.0 mg/L	Control
Undiluted + cofactor	100	0	12.5	25	75
Diluted (1:5) + cofactor	25	0	12.5	0	0
Control	0	0	0	0	0