CHAPTER 9

Efficacy of Ultraviolet Radiation to Control *Prymnesium parvum* Cells and Toxicity

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Abstract

The effects of ultraviolet (UV) radiation on *Prymnesium parvum* cells and ichthyotoxicity were investigated using water from Lake Diversion, Texas. Reservoir water was toxic to fish on three of four testing days and sublethal on the remaining day. *P. parvum* cells were present in the water throughout the study. The water flowed through the UV unit at 11.5-11.6 CFM (i.e., cubic feet per min). The radiation was emitted at a mean dose of 210 (range = 193- 220) mJ/cm^2 and mean intensity of 91.5 (range = 84-96) mW/cm^2. The radiation completely destroyed all *P. parvum* cells and reduced toxicity from lethal to sublethal levels or from a sublethal to undetectable level.

Introduction

Prymnesium parvum, which produces toxins collectively known as prymnesins (Igarashi et al. 1996), has caused extensive fish mortality in rearing ponds at the Dundee State Fish Hatchery (DSFH) which necessitated a need for effective control of *P. parvum* cells and toxicity. This study was designed to determine whether ultraviolet (UV) radiation was a viable method to destroy *P. parvum* cells and ichthyotoxin. If UV radiation was determined to be effective, a treatment unit could be installed to sterilize incoming water to the hatchery. Water to the hatchery flows under gravity through a pipeline from Lake Diversion which is known to contain *P. parvum* and has experienced periodic fish kills attributable to the alga.

Materials and Methods

A UV-treatment unit was rented from Aquionics® and installed on a levee of a 0.1-ha rearing pond. Water flowed from the fill line of the pond through the UV unit and a flow meter into the rearing pond. A polyvinyl polycarbonate (PVC) pipe on either side of the treatment unit was fitted with a drain valve as close as possible to the unit. These drain valves allowed acquisition of untreated (inlet side of UV unit) and treated (outlet side of UV unit) water samples. The control and display panel of the UV unit was mounted on the safety railing of the pond. Water flow was adjusted with the pond fill valve to maintain a rate of approximately 327 L/min. The UV unit was in continuous operation for 11 days. The radiation dose and intensity and related data as well as water flow rates were recorded once or twice daily (Table 1). Water samples for cell counts were collected twice daily from the drain valves by flushing water through them for a few minutes and then simultaneously collecting some water from each drain valve in 19-L buckets. Three separate aliquots were

taken from each bucket for cell counts using a hemacytometer (Appendix A). Toxicity bioassays (Appendix B) also were performed on water collected in the same manner on the second, fourth, sixth, and eleventh day of operation. Bioassays were performed in duplicate for each sample.

Results and Discussion

Water was treated with a mean radiation dose of 210 (range = 193-220) mJ/cm^2 and mean intensity of 91.5 (range = 84-96) mW/cm^2 (Table 1). Mean cell density of the untreated water ranged from 0 to 14,000 cells/mL (Table 2), which is reflective of a patchy distribution of *P. parvum* in Lake Diversion. There were no viable cells in any of the treated water samples examined, indicating that UV radiation at the dose and intensity tested was effective at destroying *P. parvum* cells. This suggests that UV sterilization could prevent contamination of rearing ponds with *P. parvum* during pond filling. Furthermore, UV irradiation could be used to reduce or eliminate the number of viable *P. parvum* cells in water for fish transport and thereby lower the risk of unintentional introduction of *P. parvum* into lakes where the fish are stocked.

The bioassay results revealed that UV radiation did not always eliminate the toxin, but effectively reduced toxicity from lethal to sublethal levels or from sublethal to undetectable levels. The mortality data showed that toxicity was present in Lake Diversion water throughout the study occurring at lethal concentrations during the first three sampling days and at a sublethal concentration during the last sampling day. In the undiluted water with no co-factor (i.e., water that fish in rearing ponds would be exposed to), there were no mortalities in UV-treated water for the first three test dates (Table 3), although on those same days mortalities did occur in the other bioassay treatments (those with the cofactor). This observation indicates that toxicity was present at sublethal levels in the UV-treated water. On 8 October 2001, mortality occurred only in the untreated undiluted water without co-factor suggesting that the sublethal concentration of the toxin was further reduced to an undetectable level. These results suggest that, for a given radiation and water flow rate, detoxification is dependent upon toxin level such that complete removal is only accomplished at lower toxicity levels and at higher levels, toxicity is reduced but not eliminated.

TABLE 1.—Ultraviolet radiation characteristics and flow rate (cubic feet per min) of water subjected to radiation to destroy *Prymnesium parvum* and its ichthyotoxin.

Date	Time	Intensity (%)	Intensity (mW/cm^2)	Low UV Set point	Cumulative Run time (h)	Temperature (ºC)	Dose (mJ/cm^2)	Wiper delay	Wiper cycles	Flow (CFM)
27 Sep 01	1430	98	84	70	47	20	193	2	90	11.5
28 Sep 01	1300	101	86	70	69	19	197	2	101	11.6
29 Sep 01	0901	105	90	70	89	19	207	2	111	11.5
29 Sep 01	1342	105	90	70	94	20	204	2	113	11.6
30 Sep 01	0853	108	92	70	113	19	211	2	122	11.6
30 Sep 01	1310	107	91	70	117	20	209	2	124	11.5
1 Oct 01	1100	108	92	70	140	19	211	2	135	11.5
1 Oct 01	1500	108	92	70	143	19	211	2	137	11.5
2 Oct 01	0900	110	94	70	161	19	216	2	145	11.6
2 Oct 01	1430	108	92	70	167	19	211	2	148	11.6
3 Oct 01	1030	108	92	70	187	19	211	2	158	11.5
3 Oct 01	1500	105	90	70	191	19	207	2	160	11.5
4 Oct 01	0900	109	93	70	209	19	213	2	168	11.5
4 Oct 01	1500	108	92	70	215	19	211	2	171	11.5
5 Oct 01	0800	109	93	70	232	18	213	2	180	11.5
5 Oct 01	1300	110	90	70	237	18	216	2	182	11.5
7 Oct 01	0900	112	96	70	256	18	220	2	203	11.6
7 Oct 01	1255	110	94	70	260	18	216	2	205	11.5
8 Oct 01	1100	111	95	70	282	18	218	2	216	11.5
Mean		107.4	91.5	70		18.9	210.3	2	151	11.5

TABLE 2.—Mean densities (range) of *Prymnesium parvum* in UV-treated and untreated water from Lake Diversion. Treated water passed through a UV unit at 11.5 CFM and subjected to radiation of 210.3 mJ/cm^2 at 91.5-mW/cm^2 intensity. Untreated water received no UV-radiation.

		Prymnesium parvum density (cells/mL)	
Date	*N*	Untreated water	Treated water
27 Sep 01	6	9,000 (2,000 – 30,000)	0
28 Sep 01	3	4,000 (2,000 – 6,000)	0
28 Sep 01	6	8,333 (4,000 – 16,000)	0
30 Sep 01	6	6,000 (2,000 – 10,000)	0
1 Oct 01	6	6,667 (2,000 – 16,000)	0
2 Oct 01	6	6,333 (2,000 – 10,000)	0
3 Oct 01	6	4,667 (0 – 10,000)	0
4 Oct 01	6	1,667 (0 – 4,000)	0
5 Oct 01	6	2,000 (0 – 4,000)	0
7 Oct 01	6	333 (0 – 2,000)	0
8 Oct 01	6	666 (0 – 2,000)	0

TABLE 3.—Bioassay (toxicity) results for untreated and treated water. Treated water passed through a UV unit at 11.5 ft^3/min and subjected to radiation of 210.3 mJ/cm^2 at 91.5-mW/cm^2 intensity. Untreated water received no UV radiation.

		Whole water with cofactor		1:5 Dilution with cofactor		Whole water with no cofactor	
Date	Water type	Test fish	Dead fish	Test fish	Dead fish	Test fish	Dead fish
28 Sep 01	Untreated	3	3	3	3	3	3
	Treated	3	3	3	2.5	3	0
1 Oct 01	Untreated	4	4	4	4	4	0.5
	Treated	4	4	4	0	4	0
3 Oct 01	Untreated	4	4	4	4	4	4
	Treated	4	4	4	0	4	0
8 Oct 01	Untreated	4	4	4	0	4	0
	Treated	4	0	4	0	4	0