ACUTE TOXICITY OF NICKEL TO BLUEGILL (*Lepomis macrochirus*), RAINBOW TROUT (*Salmo gairdneri*), AND PINK SHRIMP (*Penaeus duorarum*).

BIONOMICS

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INTRODUCTION

The current concern regarding the protection of aquatic life in surface waters has prompted the evaluation of the effects of exposure to chemicals on aquatic organisms. The primary objective of these studies was to provide the Environmental Protection Agency with information to evaluate the relative susceptibility of aquatic organisms to acute exposure to nickel. The acute toxicity of nickel to bluegill and rainbow trout in both a soft and a hard water, and to pink shrimp in sea water was estimated during static bioassays.

The bioassays with fishes were conducted at the Aquatic Toxicology Laboratory of E G & G, Bionomics, Wareham, Massachusetts. The shrimp bioassay was conducted at the Marine Research Laboratory of E G & G, Bionomics, Pensacola, Florida.

MATERIALS AND METHODS

The methodology for acute toxicity testing of fishes and shrimp closely followed the recommended bioassay procedures as described in Standard Methods (APHA, 1971) except for certain conditions described below.

The chemical evaluated in these bioassays was nickel, as nickel chloride ($NiCl_2 \cdot 6H_2O$, 25% nickel), a green granular substance manufactured by Matheson, Coleman & Bell (lot #10E17). Results for all tests were expressed as the median lethal concentration (LC50), the nominal concentration of the test compound in water causing 50 percent mortality of test animals. The LC50 value and its 95% confidence interval were calculated by converting the test concentrations and the corresponding observed percent response to logs and probits, respectively. These values were then utilized in a least squares regression analysis, and the LC50 value and its confidence interval were estimated from the calculated regression equation.

The animals used in these tests were bluegill (Lepomis macrochirus), rainbow trout (Salmo gairdneri) and pink shrimp (Penaeus duorarum). The bluegill were acquired from

a commercial fish hatchery in Nebraska, and had a mean wet weight of 1.1 g and a mean standard length of 37 mm. The rainbow trout were obtained from a commercial fish farmer in Washington, and had a mean wet weight of 1.0 g and a mean standard length of 32 mm. The shrimp were collected by laboratory personnel from Big Lagoon in Pensacola, Florida and had rostrum-telson lengths of 35-50 mm.

The bluegill and rainbow trout were held in 1700-l concrete raceways which are coated with an epoxy resin paint to prevent leaching of materials into the water. Flow of well water (having a temperature of 21 $\pm$ 1.0°C for the bluegill, and 12 $\pm$ 1.0°C for the rainbow trout) into these raceways was at a minimum flow of 4 l/minute, providing an adequate rate of turnover for holding these species. This water had a hardness of 35 mg/l as $CaCO_3$, a pH of 7.1 and a dissolved oxygen concentration of at least 6.0 mg/l (60% of saturation). These species were maintained in the laboratory hatchery facilities for at least 30 days prior to testing. During the 30 day period, mortality was <2%; no mortality was observed during the 48 hours immediately prior to testing, and these fish were judged to be in excellent condition. The shrimp were held in 1100-l fiberglass tanks in constantly flowing filtered (10 micrometers)

natural sea water. The salinity of this water was 25 parts per thousand (o/oo) and the temperature was 20 $\pm$ 1.0°C.

The static bioassays were conducted in 19.6-l wide-mouth soft-glass bottles containing 15 liters of test solution. Exposure mixtures for the bluegill bioassays were maintained in water baths at 21 $\pm$ 1.0°C by immersion coil heaters and mercury column thermoregulators. Test solutions for the rainbow trout and shrimp were maintained in water baths at 12 $\pm$ 1.0°C and 20 $\pm$ 1.0°C, respectively, by use of commercial refrigeration units. Each species was from the same year class, and the standard length of the longest fish or shrimp was no more than two times that of the shortest fish or shrimp. The bluegill and rainbow trout were acclimated to test conditions of temperature and water quality over a 96-hour period prior to testing. These species were not fed during the 48 hours immediately prior to testing or during the tests. The shrimp were acclimated to test conditions of water quality and temperature for at least seven days prior to testing. Water in the test vessels was not aerated. The test compound in the bluegill and rainbow trout bioassays was added to each jar in a solution of water. In the shrimp bioassays, the test material was introduced into each jar directly. Animals were introduced into the test vessels within 30 minutes after

the compound was added. Ten bluegill or rainbow trout were randomly assigned to each test vessel. Ten shrimp (2 replicates, 5 animals/vessel) were exposed to each concentration.

The dilution water used in the fish bioassay was the same as previously described for holding these fish. The hard water for these bioassays was prepared by adding 192 mg of $NaHCO_3$, 120 mg of $CaSO_4$, 120 mg of $MgSO_4$, and 8 mg of KCl per liter of deionized water. The resulting water had a pH of 7.6 and a total hardness of 200 mg/l as $CaCO_3$. The dilution water for the shrimp bioassays consisted of filtered (10 micrometers) natural sea water with a salinity of 25 o/oo and a pH of 8.0 $\pm$ 0.5. Concentrations of dissolved oxygen were measured with a combination temperature-oxygen probe and meter in selected concentrations at 0, 24, 48 and 96 hours of exposure.

Two series of concentrations were established within a bioassay, a series of range-finding (preliminary) concentrations and a series of definitive concentrations. The preliminary test was conducted to determine the approximate range of concentrations for evaluating the dose-response relationship. The definitive test, consisting of at least

five concentrations, evaluated the dose-response relationship to a degree allowing the LC50 to be calculated from the data with optimum accuracy. A control, which consisted of the same dilution water, conditions, procedures, and organisms, was maintained for each species tested.

RESULTS AND DISCUSSION

The estimated LC50 values (95% confidence intervals) for nickel and the species tested are presented in Table 1 along with highest nominal concentration tested at which there were no discernible effects on test animals due to exposure to nickel. A summary of observed mortality for each individual test concentration after 24, 48 and 96 hours of exposure to nickel is also presented (Table 2). The mortality syndrome among fish from those concentrations where mortality was observed was similar. Fish generally became dark and lethargic, lost equilibrium, and expired. Those bluegill exposed to nickel in soft water exhibited excessive mucus production at nominal concentrations $\geq$ 75.0 mg/l through 72 hours of exposure. This condition subsequently appeared to subside during the final 24 hours of exposure. Affected shrimp generally lost equilibrium, lay on their sides, and died.

The concentrations of dissolved oxygen, measured at 0, 24, 48 and 96 hours, are presented in Table 3. Final pH was 7.0 $\pm$ 0.5 for all test concentrations and controls where bluegill and rainbow trout were exposed in soft water. Comparable pH's for the test concentrations where bluegill and rainbow trout were exposed in hard water were 7.5 $\pm$ 0.5. Final pH was 8.0 $\pm$ 0.5 for all test concentrations and controls in the shrimp bioassay.

Water quality appeared to have no effect on the toxicity of nickel to bluegill or rainbow trout. Bluegill exhibited similar 96-hour LC50 values in both the soft and hard water bioassays (62.2 mg/l and 60.3 mg/l, respectively). Rainbow trout were also observed to have nearly equal sensitivities at 96 hours (13.7 mg/l and 16.3 mg/l for the soft and hard water, respectively). The shrimp exhibited less susceptibility to nickel than either of the other two species (112 mg/l).

LITERATURE CITED

A.P.H.A. 1971. Standard Methods for the Examination of Water and Wastewater. 13th Edition, 874 pp.

Table 1 -- Acute toxicity (LC50) of nickel[a] to bluegill[b] (Lepomis macrochirus), rainbow trout[c] (Salmo gairdneri) and pink shrimp[d] (Penaeus duorarum). These data are based on the results of static bioassays conducted at the Aquatic Toxicology Laboratory of E G & G, Bionomics, Wareham, Massachusetts or the Marine Research Laboratory of E G & G, Bionomics, Pensacola, Florida.

Species/ diluent	LC50 - (mg active ingredient/l) 24 hour	48 hour	96 hours	No discernible effect level at 96 hours (mg/l)
bluegill/ soft water	170.0 (130.0-222.0)[e]	115.0 (87.0-152.0)	62.2 (50.5-76.6)	42.0
bluegill/ hard water	170.0 (124.0-232.0)	110.0 (81.2-150.0)	60.3 (35.2-103.0)	37.0
rainbow trout/ soft water	196.0 (101.0-383.0)	51.0 (39.3-66.1)	13.7 (10.4-18.2)	5.6
rainbow trout/ hard water	312.0 (211.0-461.0)	94.3 (77.2-115.0)	16.3 (11.5-23.2)	4.9
pink shrimp/ sea water	>560	415 (276-624)	112 (76.8-163)	<56.0

[a] Nickel chloride ($NiCl_2 \cdot 6H_2O$), 25% nickel.

[b] Bioassays conducted at 21 $\pm$ 1.0°C, mean wet weight of bluegill, 1.1 g.

[c] Bioassays conducted at 12 $\pm$ 1.0°C, mean wet weight of rainbow trout, 1.0 g.

[d] Bioassays conducted at 20 $\pm$ 1.0°C, rostrum-telson lengths of pink shrimp, 35-50 mm.

[e] 95% confidence interval.

Table 2 -- Concentrations tested and corresponding observed percentage mortalities for bluegill (Lepomis macrochirus), rainbow trout (Salmo gairdneri), and pink shrimp (Penaeus duorarum) exposed to nickel for 24, 48 and 96 hours.

Species/ diluent	Nominal concentration (mg/l)	% mortality observed		
		24 hour	48 hour	96 hour
bluegill/ soft water	320	100	100	100
	210	70	100	100
	140	30	50	100
	100	0	0	100
	75	0	10	60
	56	0	10	60
	42	0	0	0
	control	0	0	0
bluegill/ hard water	370	100	100	100
	240	90	100	100
	140	50	90	100
	100	0	0	100
	65	0	10	50
	37	0	0	0
	control	0	0	0

Table 2 -- Continued.

Species/ diluent	Nominal concentration (mg/l)	% mortality observed		
		24 hour	48 hour	96 hour
rainbow trout/ soft water	320.0	100	100	100
	210.0	10	100	100
	100.0	0	100	100
	75.0	0	60	100
	56.0	0	20	100
	42.0	0	20	100
	28.0	0	30	100
	24.0	0	0	60
	16.0	0	0	50
	7.5	0	0	10
	5.6	0	0	0
	control	0	0	0
rainbow trout/ hard water	420.0	100	100	100
	320.0	10	100	100
	210.0	0	100	100
	140.0	0	90	100
	100.0	0	80	100
	87.0	0	10	100
	65.0	0	20	100
	49.0	0	0	100
	32.0	0	0	90
	21.0	0	0	50
	14.0	0	0	10
	6.5	0	0	10
	4.9	0	0	0

Table 2 -- Continued.

Species/ diluent	Nominal concentration (mg/l)	% mortality observed		
		24 hour	48 hour	96 hour
pink shrimp/ sea water	560	30	80	100
	320	10	30	100
	180	0	0	50
	100	0	0	30
	56	0	0	10
	control	0	0	0

Table 3 -- Measured concentrations of dissolved oxygen during 96-hour exposures of bluegill (Lepomis macrochirus), rainbow trout (Salmo gairdneri) and pink shrimp (Penaeus duorarum) to nickel.

Species/ diluent	Nominal concentration (mg/l)	Dissolved oxygen (mg/l and % of saturation)			
		0 hour	24 hour	48 hour	96 hour
bluegill/ soft water	320	8.3(94)	-[a]	-	-
	210	8.2(92)	8.2(92)	7.6(85)	-
	100	8.0(90)	7.8(87)	7.2(80)	6.4(70)
	control	8.4(95)	8.0(90)	6.8(75)	5.4(60)
bluegill/ hard water	370	8.4(95)	-	-	-
	140	8.2(92)	8.2(92)	6.9(77)	-
	37	8.0(90)	7.1(79)	6.2(67)	5.1(56)
	control	8.4(94)	8.0(90)	6.6(73)	5.4(60)
rainbow trout/ soft water	320.0	9.2(85)	-	-	-
	210.0	9.2(85)	9.2(85)	-	-
	5.6	8.2(75)	6.8(62)	5.6(52)	6.2(57)
	control	8.8(80)	8.8(80)	6.8(62)	6.1(56)
rainbow trout/ hard water	420.0	9.2(85)	-	-	-
	210.0	9.5(87)	9.5(87)	-	-
	4.9	9.0(83)	8.2(75)	6.8(62)	5.5(51)
	control	9.1(84)	9.2(85)	8.3(76)	8.2(75)

Table 3 -- Continued.

Species/ diluent	Nominal concentration (mg/l)	Dissolved oxygen (mg/l and % of saturation) 0 hour	24 hour	48 hour	96 hour
pink shrimp/ sea water	560	6.8(89)	6.6(87)	6.7(88)	-[a]
	320	6.8(89)	6.8(89)	6.4(84)	-
	56	6.9(90)	6.8(89)	6.1(80)	5.7(75)
	control	6.8(89)	6.8(89)	6.0(79)	3.5(46)

[a] Dissolved oxygen not measured due to 100% mortality.