ASSESSMENT OF HYDRAZINE RELEASE WATER QUALITY IMPACTS IN THE DISCHARGE CANAL AT THE ST. LUCIE POWER PLANT

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Introduction

Florida Power & Light Company (FPL) is requesting a permit modification to the St. Lucie Power Plant's (PSL) NPDES permit for the discharge of hydrazine via permitted outfalls. These discharges into the St. Lucie discharge canal would occur during regularly scheduled periodic facility maintenance and refueling activities. The discharge would be from primary and secondary wet lay-up sources.

The report describes the lay-up discharges, canal flows, and resulting canal hydrazine concentrations. Canal flows are dependent upon plant intake and cooling water discharges. The volumetric discharge of hydrazine sources is limited and expected hydrazine concentrations in the canal would be dependent upon water flow into the canal. The report analyzes the hydrazine concentration in the discharge canal based upon a conservative flow rate of 125,000 gallons per minute (gpm) from the operation of one circulating water pump.

Discharge Scenarios

In order to accurately assess the impacts of the hydrazine releases, the following assumptions were used in the model.

The wet lay-up hydrazine discharges will be from two sources, the steam generator (the primary source) and from secondary sources (condenser volume and feedwater heater volume). The Primary Source discharge will include two batch releases of 160,000 gallons each with a discharge rate of 300 gallons per minute (gpm); the hydrazine concentration for the discharge is 250 mg/L. The Primary Source point of discharge will be approximately 150 feet downstream of the PSL Unit No. 1 condenser discharge at the south bank of the canal at mid-depth (see Figure 1).

The Secondary Source discharge will include two batch releases of 800,000 gallons each with a discharge rate of 480 gpm. The hydrazine concentration for the Secondary Source discharge is 50 mg/L. The Secondary Source point of discharge will be upstream of the PSL Unit No. 1 condenser intake.

The hydrazine releases from the Primary and Secondary sources will occur independently over a 4-day period. However, some overlap of the discharges may occur.

The above hydrazine releases were evaluated in the discharge canal when flow in the canal was from one circulating pump (i.e., 125,000 gpm). A summary of the discharge canal hydraulic characteristics (e.g., velocity, travel time, etc.) under this flow condition is presented in Table 1.

Impact Assessment Methodologies

The hydrazine releases to the discharge canal were first analyzed using a simple mass balance approach. The mass balance model assumes that there will be uniform mixing in the canal by the time the flow reaches the headwall where the outfall structure is located. This assumption is reasonable for the Secondary Source discharges inasmuch as the release will occur upstream of the condenser and thus result in significant mixing and turbulence for mixing of the two water streams. For the Primary Source discharges, the completely mixed assumption may not be valid due to the location of the point of discharge with respect to the condenser discharge and the canal bank. As such, a transverse mixing model was used to assess the degree of mixing within the canal.

The transverse mixing model used is presented in Fischer et al. (1979). The model assumes that the hydrazine release contributes a negligible amount of flow, momentum, or buoyancy to the discharge stream and that it may be effectively treated as a point source of mass. These assumptions are all valid for the case at PSL. A key parameter of the Fischer model is the transverse mixing coefficient (E_t). Fischer recommends a range of E_t values of:

$$E_t = 0.6du^* \pm 50\%$$

Where: d = average depth
u^* = shear velocity

In the case at PSL, the estimation of E_t was performed using $E_t = 0.4du^*$ to account for both the curves in the canal and the trapezoidal cross section. The use of this conservative value is reasonable because it accounts for the geometry of the canal system; actual values may be slightly higher due to the enhanced mixing conditions which will occur at the canal bridge crossing with State Road A1A and the turbulence associated with the endwall at the outfall structure.

Aqueous Degradation Rates

Hydrazine, which is a strong reducing or anti-oxidant agent, is inherently unstable in natural waters where oxygen is present. Several studies have been published which examine hydrazine degradation in natural waters (Slonim and Gisclard, 1976; Ou and Street, 1987); these studies show that hydrazine degradation is rather slow in sterile waters or waters such as drinking water which have only small concentrations of bacteria present, and quite rapid in natural waters such as river and pond water.

Slonim and Gisclard examined hydrazine degradation in several different types of water, including river, pond, and tap water. Their estimated tap water decay constant is 0.184 day^{-1} compared to 2.17 and 0.329 day^{-1} for river and pond water, respectively. Given the estimated tap water decay constant, a conservative approach was taken in this assessment by taking no credit for hydrazine degradation. It is possible that the behavior of seawater will more closely approximate river than tap water; as such the simulations of hydrazine fate in the canal will probably under estimate the extent to which hydrazine degradation occurs and over estimate hydrazine concentrations.

Results

The results of the mass balance modeling of the hydrazine in the discharge canal are presented in Table 2. As seen in this table, the average completely mixed hydrazine concentration for the Primary Source discharge is estimated to be 0.60 mg/L and is 0.19 mg/L for the Secondary Source discharge, exclusive of any possible degradation.

The results of the transverse mixing modeling for the discharges are presented in Table 3 for the Primary Source discharge and Table 4 for the Secondary Source discharge. As seen in these tables, the Primary Source release at the sidewall does not mix completely across the canal by the time the flow reaches the endwall. Conversely, the Secondary Source release which passes through the condenser is fairly uniformly mixed across the canal. In all cases, the average concentration in the canal will be equal to the mass balance values presented. However, for the Primary Source discharges, the range of values encountered at the endwall can be expected to range from over 2 times the average to 0.1 times the average. For the Secondary Source releases, the range of values encountered at the headwall is expected to be about 30% of the average.

Discussion and Summary

The results of the modeling efforts presented above show the following:

1. For the Primary Source discharge, the resultant hydrazine concentration at the endwall will average 0.60 mg/L and will spatially range from 1.63 to 0.01 mg/L.

2. For the Secondary Source discharge, the resultant hydrazine concentration at the endwall will average 0.19 mg/L and will spatially range from 0.25 to 0.13 mg/L.

3. The natural decay of hydrazine in the canal waters cannot be readily quantified but has been assumed to be low; therefore, hydrazine degradation was not factored into calculated hydrazine concentrations.

As noted in the above, the expected hydrazine concentration at the endwall of the PSL discharge canal will average 0.60 mg/L for the Primary Source discharge and 0.19 mg/L for the Secondary Source release. While these values indicate that the hydrazine concentration will be relatively low at the end of the canal (the discharge monitoring location); it is of note that actual concentrations released to the environment will be considerably lower. For example, the 125,000 gpm discharge will result in a 30:1 dilution in the near field mixing zone of the discharge canal effluent with the ocean. Thus, the proposed wet lay-up hydrazine releases to the discharge canal are expected to result in relatively low concentration in the canal and very low concentrations in the receiving water.

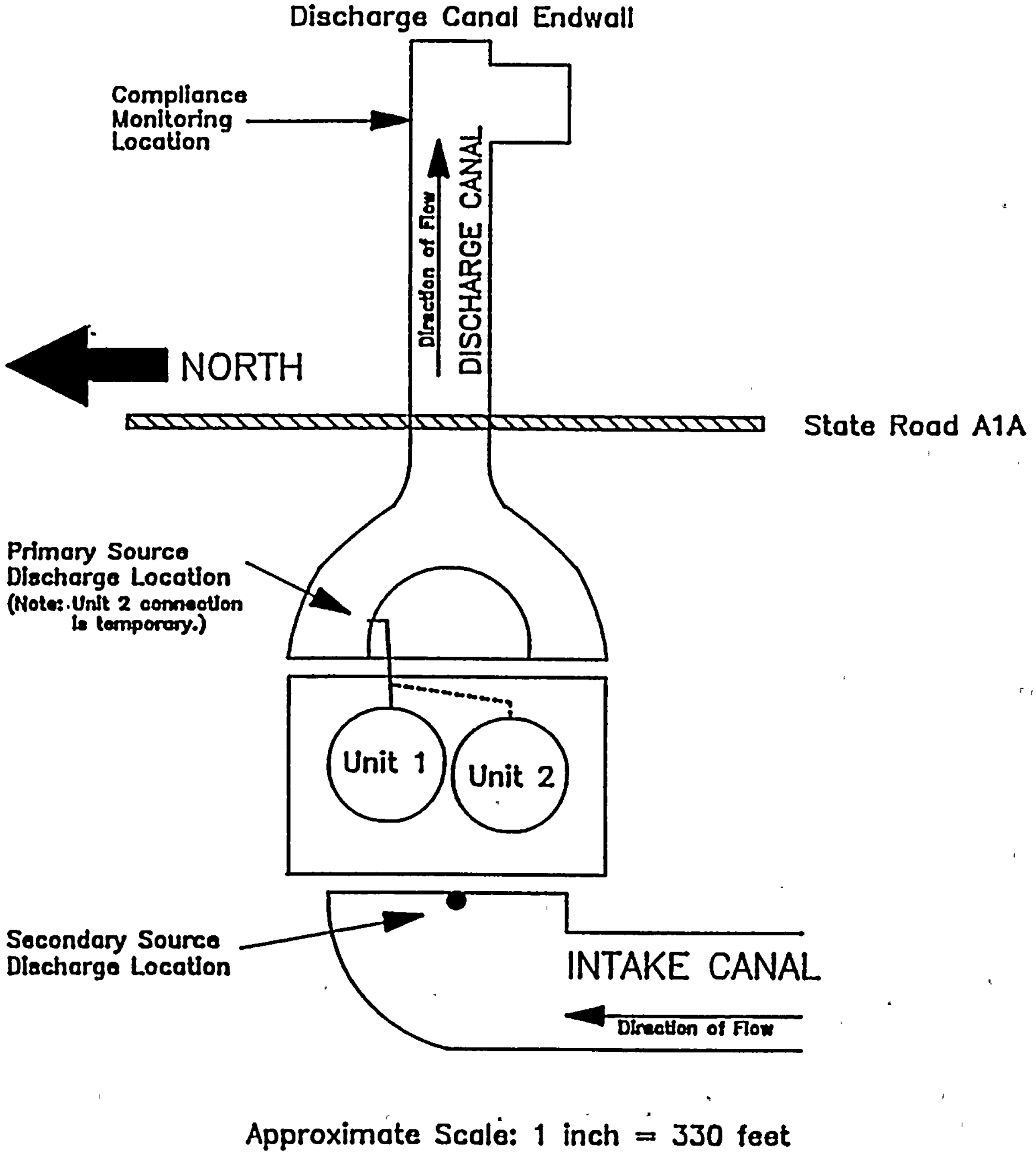

Figure 1. Schematic Layout of the Discharge Canal at FPL's St. Lucie Power Plant

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Table 1. Summary of Flow Characteristics in the St. Lucie Power Plant Discharge Canal

Item	Value	Units
DISCHARGE CANAL DIMENSIONS:		
Nominal Operational Capacity of Canal	48,000,000	Gallons
	6,417,100	Cubic Feet
Length of Canal "Arm" from Unit 1	480	Feet
Length of Canal "Arm" from Unit 2	480	Feet
Length of Straight Canal Section	1,550	Feet
Total Length of Discharge Canal	2,510	Feet
Maximum Travel Distance from Either Unit	2,030	Feet
Canal Top Width	165	Feet
Canal Depth	24.5	Feet
Estimated Canal Side Slope	2.5 : 1	
Estimated Canal Bottom Width	42.5	Feet
Estimated Canal Cross Sectional Area	2,540	Ft Squared
FLOW CHARACTERISTICS		
Flow in Canal	125,000	Gal/Min
	279	Cubic Ft/Sec
Average Flow Depth	15.4	Feet
Estimated Average Flow Velocity	0.11	Feet/Sec
Estimated Average Travel Time	5.14	Hours
Estimated Transverse Mixing Coefficient	0.068	Ft Sq/Sec

Table 2. Estimated Hydrazine Concentration in Discharge Canal at the St. Lucie Power Plant - Mass Balance Modeling

Item	Value	Units
Flow in Canal	125,000	Gal/Min
	279	Cubic Ft/Sec
Travel Time Through Canal	5.14	Hours
Estimated Hydrazine Decay Rate	0.184	per Day
Percent of Hydrazine Lost Through Decay at End of Canal	3.87%	
PRIMARY SOURCE RELEASE		
Discharge Rate of Release	300	Gal/Min
	0.67	Cubic Ft/Sec
Hydrazine Concentration in Released Water	250	mg/L
Hydrazine Concentration in Discharge Canal	0	mg/L
Estimated Hydrazine Concentration in Discharge Canal due to Release	0.599	mg/L
SECONDARY SOURCES RELEASE		
Discharge Rate of Release	480	Gal/Min
	1.07	Cubic Ft/Sec
Hydrazine Concentration in Released Water	50	mg/L
Hydrazine Concentration in Discharge Canal	0	mg/L
Estimated Hydrazine Concentration in Discharge Canal due to Release	0.191	mg/L
COMBINED DISCHARGE HYDRAZINE RELEASE	0.787	mg/L

Note: 1. The hydrazine releases from the primary and secondary sources would occur independently over a 4-day period. However, some overlap of the discharges could occur.

2. Due to the low hydrazine losses through decay, estimated concentrations for this case treat hydrazine as a conservative substance.

Table 3. Transverse Mixing Analysis for Primary Source Release

Average Canal Depth	15.4	Feet
Average Flow Velocity	0.11	Feet/Second
Flow Shear Velocity	0.011	Feet/Second
Canal Width	165	Feet
POD with respect to Width	0	Feet
Effluent Concentration	250	mg/L
Effluent Discharge Rate	0.67	Cubic Feet/Second
Background Concentration	0	mg/L
Background Discharge Rate	279	Cubic Feet/Second
Transverse Mixing Coefficient	0.068	Sq Feet/Second

Distance Downstream (feet)	Concentration (mg/L) versus Distance Across Canal (feet)										
	0	17	33	50	66	83	99	116	132	149	165
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
200	7.09	2.36	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
300	5.01	2.89	0.55	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	4.09	2.84	0.94	0.15	0.01	0.00	0.00	0.00	0.00	0.00	0.00
500	3.55	2.69	1.18	0.30	0.04	0.00	0.00	0.00	0.00	0.00	0.00
600	3.17	2.54	1.31	0.44	0.09	0.01	0.00	0.00	0.00	0.00	0.00
700	2.89	2.41	1.39	0.56	0.15	0.03	0.00	0.00	0.00	0.00	0.00
800	2.68	2.29	1.43	0.65	0.22	0.05	0.01	0.00	0.00	0.00	0.00
900	2.51	2.18	1.45	0.73	0.28	0.08	0.02	0.00	0.00	0.00	0.00
1000	2.36	2.09	1.45	0.79	0.33	0.11	0.03	0.01	0.00	0.00	0.00
1100	2.24	2.01	1.44	0.83	0.39	0.14	0.04	0.01	0.00	0.00	0.00
1200	2.14	1.93	1.43	0.87	0.43	0.18	0.06	0.02	0.00	0.00	0.00
1300	2.05	1.87	1.42	0.90	0.47	0.21	0.08	0.02	0.01	0.00	0.00
1400	1.97	1.81	1.40	0.92	0.51	0.24	0.09	0.03	0.01	0.00	0.00
1500	1.90	1.75	1.38	0.93	0.54	0.27	0.11	0.04	0.01	0.00	0.00
1600	1.83	1.70	1.37	0.95	0.57	0.29	0.13	0.05	0.02	0.01	0.00
1700	1.77	1.65	1.35	0.95	0.59	0.32	0.15	0.06	0.02	0.01	0.00
1800	1.72	1.61	1.33	0.96	0.61	0.34	0.17	0.07	0.03	0.01	0.01
1900	1.67	1.57	1.31	0.96	0.63	0.36	0.18	0.08	0.03	0.01	0.01
2000	1.63	1.54	1.29	0.97	0.64	0.38	0.20	0.10	0.04	0.02	0.01

Table 4. Transverse Mixing Analysis for Secondary Source Release

Average Canal Depth	15.4	Feet
Average Flow Velocity	0.11	Feet/Second
Flow Shear Velocity	0.011	Feet/Second
Canal Width	165	Feet
POD with respect to Width	82.5	Feet
Effluent Concentration	50	mg/L
Effluent Discharge Rate	1.07	Cubic Feet/Second
Background Concentration	0	mg/L
Background Discharge Rate	279	Cubic Feet/Second
Transverse Mixing Coefficient	0.068	Sq Feet/Second

Distance Downstream (feet)	Concentration (mg/L) versus Distance Across Canal (feet)										
	0	17	33	50	66	83	99	116	132	149	165
100	0.00	0.00	0.00	0.01	0.38	1.13	0.38	0.01	0.00	0.00	0.00
200	0.00	0.00	0.01	0.09	0.46	0.80	0.46	0.09	0.01	0.00	0.00
300	0.00	0.00	0.02	0.15	0.45	0.65	0.45	0.15	0.02	0.00	0.00
400	0.00	0.01	0.05	0.19	0.43	0.57	0.43	0.19	0.05	0.01	0.00
500	0.00	0.02	0.07	0.21	0.41	0.51	0.41	0.21	0.07	0.02	0.00
600	0.01	0.03	0.09	0.22	0.38	0.46	0.38	0.22	0.09	0.03	0.01
700	0.02	0.04	0.10	0.23	0.37	0.43	0.37	0.23	0.10	0.04	0.02
800	0.03	0.05	0.12	0.23	0.35	0.40	0.35	0.23	0.12	0.05	0.03
900	0.04	0.06	0.13	0.23	0.33	0.38	0.33	0.23	0.13	0.06	0.04
1000	0.05	0.07	0.13	0.23	0.32	0.36	0.32	0.23	0.13	0.07	0.05
1100	0.06	0.08	0.14	0.23	0.31	0.34	0.31	0.23	0.14	0.08	0.06
1200	0.07	0.09	0.15	0.23	0.30	0.33	0.30	0.23	0.15	0.09	0.07
1300	0.08	0.10	0.15	0.22	0.29	0.31	0.29	0.22	0.15	0.10	0.08
1400	0.08	0.10	0.16	0.22	0.28	0.30	0.28	0.22	0.16	0.10	0.08
1500	0.09	0.11	0.16	0.22	0.27	0.29	0.27	0.22	0.16	0.11	0.09
1600	0.10	0.12	0.16	0.22	0.27	0.28	0.27	0.22	0.16	0.12	0.10
1700	0.11	0.12	0.16	0.22	0.26	0.28	0.26	0.22	0.16	0.12	0.11
1800	0.12	0.13	0.17	0.21	0.25	0.27	0.25	0.21	0.17	0.13	0.12
1900	0.12	0.13	0.17	0.21	0.25	0.26	0.25	0.21	0.17	0.13	0.12
2000	0.13	0.14	0.17	0.21	0.24	0.25	0.24	0.21	0.17	0.14	0.13

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TOXICOLOGICAL REVIEW

Prepared by Florida Power & Light Co.

Wet lay-up Discharges of Hydrazine to the St. Lucie Discharge Canal and Permitted NPDES Outfall

Recent data on the aquatic toxicity of hydrazine are presented in Table 5. This data base is limited to acute toxicity information (LC50) for fish and invertebrates. The LC50s range from 0.04 mg/l (ppm) to 7.7 mg/l and indicate that the acute toxicity of hydrazine to aquatic organisms is affected by the exposure conditions. Increases in temperature may increase the aquatic toxicity of hydrazine. However, it should be noted that only one temperature study with hydrazine was conducted (Hunt et al., 1981). The toxicity of hydrazine in soft water may be greater than in hardwater. This hardness-toxicity relationship has been found for several metals, however the fish species used in the hydrazine toxicity study, i.e. the common guppy, is not commonly used in toxicity tests. Furthermore, the common guppy is neither ubiquitous nor can it be considered representative of freshwater fish. Aquatic invertebrates are more sensitive to hydrazine than fish in short-term exposure studies. This is not unusual since aquatic invertebrates in general are more sensitive to chemical compounds.

Based on the LC50 values it is evident that the toxicity of hydrazine is similar for different species held under different exposure regimes. Furthermore, although the data base is limited for saltwater species, the acute toxicity of hydrazine to this group of organisms is similar to the freshwater LC50 data.

There were no long-term aquatic toxicity studies conducted with hydrazine in the literature. Hydrazine is rapidly degraded in the aquatic environment (Slonim and Gisclard, 1976). Chronic aquatic toxicity studies would therefore not represent the "typical" aquatic exposure situation <u>in situ</u>.

In order to compare the LC50s with a "potential" concentration of hydrazine in the discharge canal a mass balance model was used to define an "estimated environmental concentration". Table 2 summarizes the flow characteristics in the discharge canal used in the model. Table 3 shows that the average concentration of hydrazine in the canal is estimated to be 0.599 mg/l (ppm) from the primary source (i.e., steam generator) and 0.191 mg/l from the secondary sources (i.e., condenser and feedwater heater). The hydrazine release concentrations from the two different sources would occur independently; however, if they did overlap the combined "worst case" scenario would yield a hydrazine concentration of 0.790 mg/l (or 790 ug/l). This "worst case" estimated environmental concentration (EEC) is also based on the assumption that the hydrazine is stable over time when in fact it is known that hydrazine will degrade in the aquatic environment rapidly with a half-life from a few days to a week.

The projected "worst case" scenario of hydrazine in the St. Lucie Plant's discharge canal cannot readily be compared to the LC50 aquatic toxicity tests reported in the literature since the tests cited in the literature are based on constant, continuous exposure concentrations. (The nature of the releases at the St. Lucie Plant would not result in a constant, continuous exposure because the releases occur separately and intermitently). Furthermore, the diversity and abundance of aquatic life in the discharge canal is limited and not typical of aquatic ecosystems because of extremes in temperatures (+30°C) which are more detrimental to aquatic populations than any anticipated hydrazine exposure. In summary, the physical-chemical characteristics of hydrazine coupled with dilution is expected to preclude any significant aquatic toxicity in the canal system. As discussed in the KBN report, the actual hydrazine concentrations anticipated in the environment (canal system discharges to the ocean) will be considerably lower yet.

Table 5 Available aquatic toxicity data on hydrazine for freshwater and marine fish and invertebrates.

Test organism	Test duration(h)	LC_{50} (mg/l)	Source
Freshwater			
Fish			
Channel catfish	96	1.0	Fisher et al.(1980b)
Golden shinner	96	1.1	"
Bluegill	96	1.1	Fisher et al.(1978)
Common guppy (softwater)	24	3.3	Slonim (1977)
"	48	1.6	"
"	96	0.6	"
Common guppy (hardwater)	24	4.6	"
"	48	4.0	"
"	96	3.9	"
Crucian carp	24	1.5	Proteau et al. (1979)
Roach	24	0.9	"
Zebra danio	24	3.2	"
Fathead minnow	96	6.0	Velte (1984)
Bluegill (10C)	24	7.7	Hunt et al. (1981)
"	96	1.6	"
" (15.5C)	24	3.8	"
"	96	1.0	"
" (21C)	24	1.7	"
"	96	1.2	"
Invertebrate			
Daphnia pulex	48	[a]0.16 and 0.19	Velte (1984)
Hyalella azteca	48	0.04	Fisher et al. (1980)
Asellid isopod	72	1.3	"
Marine			
Fish			
Threespine stickleback	96	3.40	Klein & Jenkins (1979)
"	336	1.07	"
Invertebrate			
Hemgrapsus oregonensis	96	3.6	"
"	336	0.6	"
Mytilus edulis	96	5.7	"
"	336	1.7	"

[a] Reported as effect concentration (EC_{50}) where immobilization occurred.