The Effect of Increased Temperature Upon the Acute Toxicity of Some Heavy Metal Ions

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The discharge of heat into a water body can have direct and indirect effects on aquatic life. If the heat input is within the tolerance limit for the organism a metabolic rate increase can be seen, and if the organism is a fish this will increase its oxygen demand while at the same time decreasing the solubility of oxygen in water.

In addition to direct effects upon the metabolism, indirect effects such as increased solubility and diffusion rates of substances that control water quality can be observed.

The effect of temperature on the toxicity of water soluble toxins is difficult to predict. The published data for heavy metal ions tends at first to be conflicting. For example, Cairns has shown that a 10°C increase in water temperature does not increase the toxicity of zinc to the common bluegill sunfish (1) while others have reported that a 10°C rise in temperature may halve the survival rate for fish in the presence of metal ions (2,3,4).

These apparent discrepancies may be somewhat explainable if the exact toxic mechanism were known. If the mechanism were intercellular and involved a biochemical reaction one might predict an increase in water temperature would increase toxicity. If, however, the mechanism were to involve the deposit of a gelatinous metal hydrous oxide precipitate on the gill membranes, (5) water parameters such as hardness would be more important than temperature.

This laboratory has been engaged in the investigation of the toxicity of six metal ions to several Hudson River fish species at 28°C. This temperature was chosen as it represents the ambient temperature of the thermal plume of the Danskammer Point power station in the town of Newburgh. While both the plume temperature and the ambient river temperature can vary as much as 10°C during a six month period (6), the plume temperature never exceeded the ambient river temperature by more than 6°C during this investigation.

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The geography of Danskammer Point is interesting in that the heat discharge is in a small cove-like area, which could create a warm lake that could lure fish into the plume, especially in the colder months of the year.

The purpose of this investigation was to establish the mean toxicity limit for 50% survival (TLm) for representative Hudson River fish species at 28°C and to compare these values to the limits established at 15°C by this laboratory (7) and other published data. The data are expressed in analytical concentration of metal ion (ppm) as well as multiples of background concentrations.

METHODS - All methods of collecting, analysis and data processing were the same as indicated in the initial phases of this project (7), with the exception of the addition of temperature control to the bioassay tanks.

Temperature control was maintained through the use of standard aquaria tank heaters. The air pump inlets were placed close to the heaters so the turbulence would help in the circulation of water within the tank.

Results & Discussion

Table I contains the water quality parameters measured and maintained during the course of an experiment.

TABLE I

Temperature 28°C	pH 8.0
Hardness 55 mg/l	D.O. 6.9 mg/l

Table II contains the results of the TLm experiments in terms of analytical concentration (ppm) of metal ion in the water.

Table III relates the TLm values to the existing ambient background concentrations for the same metal ions measured in the river during the course of the investigation. This yields the magnitude of change that would have to occur to the receiving waters in order to produce a fish kill.

TABLE II

Species	Metal	TLm 24hr	TLm 48hr	TLm * 96hr
banded killifish (Fundulus diaphanus)	Cu^{++}	1.3	0.98	0.84
	Zn^{++}	23.0	20.4	19.2
	Ni^{++}	63.1	50.0	46.1
	Cd^{++}	0.30	0.21	0.11
	Hg^{++}	0.27	0.16	0.11
	Cr^{+++}	26.3	20.8	16.9
striped bass (Roccus saxatilis)	Cu^{++}	8.4	6.6	4.0
	Zn^{++}	11.3	10.0	6.8
	Ni^{++}	10.0	8.5	6.3
	Cd^{++}	1.9	1.5	1.1
	Hg^{++}	0.22	0.14	0.09
	Cr^{+++}	19.3	18.8	17.7
pumpkinseed (Lepomis gibbosus)	Cu^{++}	3.5	2.9	2.7
	Zn^{++}	25.1	21.9	20.1
	Ni^{++}	16.4	12.1	8.0
	Cd^{++}	2.8	2.2	1.5
	Hg^{++}	0.41	0.39	0.30
	Cr^{+++}	19.1	17.8	17.0
white perch (Roccus americanus)	Cu^{++}	11.5	7.9	6.4
	Zn^{++}	13.5	10.1	14.4
	Ni^{++}	18.4	16.0	13.7
	Cd^{++}	1.6	1.1	8.4
	Hg^{++}	0.42	0.34	0.22
	Cr^{+++}	17.5	16.0	14.4
American eel (Anguilla rostrata)	Cu^{++}	10.6	8.1	6.0
	Zn^{++}	21.4	20.1	14.5
	Ni^{++}	14.1	13.1	13.0
	Cd^{++}	1.5	1.1	0.82
	Hg^{++}	0.25	0.19	0.14
	Cr^{+++}	19.5	16.3	13.9
carp (Cyprinus carpio)	Cu^{++}	1.9	1.2	0.80
	Zn^{++}	14.4	9.2	7.8
	Ni^{++}	38.3	28.9	10.4
	Cd^{++}	0.45	0.3	0.24
	Hg^{++}	0.33	0.21	0.18
	Cr^{+++}	21.2	18.4	14.3

* ppm

TABLE III

Species	Metal	TLm 24hr	TLm 48hr	TLm * 96hr
banded killifish (Fundulus diaphanus)	Cu^{++}	54	32	31
	Zn^{++}	10535	8640	7701
	Ni^{++}	364	330	290
	Cd^{++}	50	35	19
	Hg^{++}	90	53	38
	Cr^{+++}	6575	5020	4449
striped bass (Roccus saxatilis)	Cu^{++}	294	102	61
	Zn^{++}	6001	1410	1031
	Ni^{++}	180	161	108
	Cd^{++}	315	250	190
	Hg^{++}	74	63	30
	Cr^{+++}	4870	4700	4667
pumpkinseed (Lepomis gibbosus)	Cu^{++}	134	103	87
	Zn^{++}	2730	1999	1350
	Ni^{++}	405	351	324
	Cd^{++}	466	350	250
	Hg^{++}	140	130	100
	Cr^{+++}	4868	4450	4250
white perch (Roccus americanus)	Cu^{++}	421	287	219
	Zn^{++}	3067	2709	2260
	Ni^{++}	219	166	230
	Cd^{++}	266	190	66
	Hg^{++}	140	120	74
	Cr^{+++}	4351	4000	3601
American eel (Anguilla rostrata)	Cu^{++}	371	290	231
	Zn^{++}	2330	2185	2166
	Ni^{++}	349	321	236
	Cd^{++}	250	190	134
	Hg^{++}	83	63	53
	Cr^{+++}	4875	4075	3475
carp (Cyprinus carpio)	Cu^{++}	74	38	28
	Zn^{++}	6366	4855	1766
	Ni^{++}	230	151	126
	Cd^{++}	75	50	40
	Hg^{++}	110	70	60
	Cr^{+++}	5300	4600	3561

* ratio of toxic concentration to background concentration

Table IV contains the overall ranges for TLm values up to 96hrs found for each metal studied. The ranges are not broken down to fish species since for some of the mercury, cadmium and chromium values it was necessary to use published data on fish other than the ones used in this investigation. While one could argue that it is not valid to compare TLm data if the same test species were not used, it is felt by these authors that a comparison of ranges at two different temperatures is not useless, provided the water parameters such as hardness, pH and salinity are nearly the same.

TABLE IV

Metal ion	TLm range* 15°C	TLm range 28°C
Cu^{++}	.81 - 11.8	.80 - 11.5
Zn^{++}	6.7 - 25.5	6.8 - 25.1
Ni^{++}	6.2 - 63.2	6.3 - 63.1
Hg^{++}	.37 - .74 [8]	.08 - .42
Cd^{++}	0.3 [9]	0.11 - 2.8
Cr^{+++}	10.3 - 31.6	13.9 - 26.3

* ppm

It can be seen that the TLm data at 28°C and 15°C are not significantly different for the ions studied with the exception of the mercurous ion. Computer significance analyses indicate for mercurous ion the difference in range is statistically meaningful. The 15°C data was obtained in soft water with the common goldfish, (Carassius auratus) and therefore it would appear reasonable to conclude that the toxicity of mercury is increased as the temperature increases. For carp-like fish the toxicity increase is approximately three-fold for a 10°C increase in temperature.

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