Assessing contaminant sensitivity of federally endangered and threatened freshwater fish and mussels

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ABSTRACT

A series of acute or chronic early life-stage toxicity tests were conducted with several organic or inorganic toxicants and with 12 federally-listed fishes, 11 mussels (including 4 listed species), and 6 commonly tested surrogate fishes and aquatic invertebrates. Results of 96-h fish tests indicated that the sensitivity of the listed species to copper, 4-nonylphenol, permethrin, carbaryl, or pentachlorophenol (PCP) was generally similar to that of the surrogate species, and EC50s for tested fish were above USEPA water quality criteria (WQC). However, in 28-d chronic tests, one of two listed fish tested was more sensitive to copper or PCP than two surrogate fishes, and chronic effect concentrations for the listed species were at or below the WQC. Results of acute tests with glochidia (24- or 48-h exposure) and juvenile mussels (96-h exposure) indicated that the early life stages of mussels were generally more sensitive to copper and ammonia than the surrogate fishes, daphnids, and amphipods. Acute and chronic (28-d exposure) effect concentrations for mussels were above the WQC for lead, cadmium, and chlorine, but were at or below the WQC for copper, zinc, and ammonia. The results of these studies indicate that (1) acute WQC for chemicals tested are protective of listed fish species, but may not adequately protect mussels tested, and (2) chronic WQC for some of chemicals tested may not adequately protect listed fish and mussels tested.

INTRODUCTION

➢The USEPA water quality criteria (WQC) are primarily based on responses of species routinely cultured and tested in the laboratory as surrogates for untested species.

➢Limited information is available about the chemical sensitivity of endangered or threatened (listed) species compared to surrogate species.

➢Toxicity data for freshwater mussels have not been routinely used to establish the WQC, although about 70% of mussel species are listed as endangered, threatened, or of special concern in the US (Williams et al 1993).

➢The objective of the studies was to assessing contaminant sensitivity of listed fish and mussels in acute and chronic laboratory exposures.

MATERIALS AND METHODS

Conditions for acute toxicity tests with fish (USEPA 1993; ASTM 2006a)

Fig.1. Test chambers

Test type: **Renewal (Fig. 1)**
Chemicals: **Carbaryl, copper sulfate, 4-nonylphenol, pentachlorophenol (PCP), or ammonia chloride**
Test duration: **96 h**
Temperature: **12, 20, or 25ºC (depending on species)**
Solution volume: **0.5 L (larvae) to 15 L (juveniles)**
Renewal of solution: **After 48 h**
Age of organism: **Larvae or juveniles**
organisms/chamber: **7 to 10**
replicates/concentration: **2 or 3**
Dilution: **Control and 5 concentrations**
Dilution water: **ASTM hard (170 mg/L as $CaCO_3$)**
Endpoint: **Survival**
Test acceptability criterion: **>90% survival in control**

Conditions for chronic toxicity tests with fish (USEPA 1994; ASTM 2006b)

Fig. 2. Flow-through diluter system.

Test type: Flow-through (Fig. 2)
Chemicals: Copper sulfate or PCP
Test duration: 30 to 60 d
Temperature: 12 or 25ºC
Test solution volume: 5 L
Age of organism: eyed embryos or larvae
organisms/chamber: 10
replicates/concentration: 4
Dilution water: ASTM hard (170 mg/L as $CaCO_3$)
Dilution: Control and 5 concentrations
Endpoint: Survival and growth
Test acceptability criterion: >70% in control

Conditions for acute tests with daphnids, amphipod, and larval (glochidia) and juvenile mussels (USEPA 1993; ASTM 2006a,c)

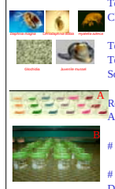

Fig. 3 Test chambers for toxicity tests with glochidia (A) and juvenile mussels (B).

Test type: Static or renewal (Fig. 3)
Chemicals: Copper sulfate, zinc sulfate, cadmium nitrate, lead nitrate, or ammonia chloride
Test duration: 48 h or 96 h
Temperature: 20ºC
Solution volume: 100 mL (glochidia); 40 mL (others)
Renewal of solution: After 48 h
Age of organism: <24 h (daphnids and glochidia), 8 d (amphipod), 5 or 60 d (juvenile mussels)
organisms/chamber: About 1000 (glochidia); 5 (others)
replicates/concentration: 3 (glochidia); 4 (others)
Dilution water: ASTM soft (50 mg/L; pH 7.8) or hard (170 mg/L; pH 8.1-8.3)
Dilution: Control and 5 concentrations
Endpoint: Survival
Test acceptability criterion: >90% survival in control

Conditions for flow-through tests with glochidia and juvenile mussels (ASTM 2006c)

Fig. 4. Flow-through diluter system.

Test type: **Flow-through (Fig. 4)**
Chemicals: **Sodium hypochlorite, ammonia chloride, copper sulfate, zinc sulfate, cadmium nitrate, or lead nitrate**
Test duration: **2 d (glochidia); 28 d (juveniles)**
organisms/chamber: **about 1000 glochidia; 10 juveniles**
replicates/concentration: **3 or 4**
Temperature: **20ºC**
Test solution volume: **200 mL**
Addition of solution: **125 mL/20 min (chlorine test) or 4 h (other chemicals)**
Dilution water: **ASTM soft (50 mg/L; pH 7.8) or hard (170 mg/L; pH 8.2)**
Feeding: **None for 2- or 4-d tests; twice/d with non-viable algae mixture for 28-d test**
Dilution: **Control and 5 concentrations**
Endpoint: **Survival; shell length (28-d test)**
Test acceptability criterion: **>90% survival in control (2-d test); >80% (28-d test)**

Data analysis: LC50 or EC50 for acute tests; chronic value (ChV, geometric mean of NOEC and LOEC) and 10% inhibition concentration (IC10) were calculated using Toxstat software (West Inc. 1996).

RESULTS AND DISCUSSION

➢ LC50s of four toxicants for surrogate fish, rainbow trout, were equal or lower than LC50s for listed species over 80% of the time; USEPA (1996, 2005) acute WQC for nonylphenol, copper, or PCP were below the LC50s for all fish tested (Fig. 5).

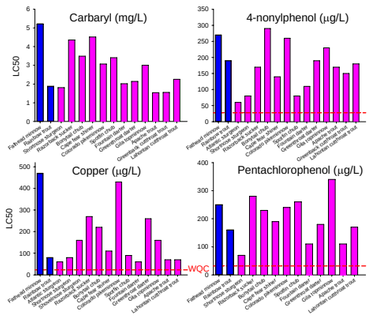

Fig. 5. The 4-d acute LC50s of 4 toxicants for 2 surrogate fish (blue bars) and 12 listed fish species (red bars; Dwyer et al. 2005). Dash line represents acute WQC (hardness 170 mg/L; no WQC for carbaryl).

➢ Copper and PCP chronic effect concentrations (ChV or IC10) for fountain darter (listed species) were lower than other fish species tested; USEPA chronic WQC were at or above the effect concentrations for all fish tested in copper exposures, and for fountain darter in PCP exposures (Fig. 6).

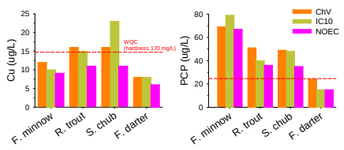

Fig. 6. The 28-d chronic value (ChV) and 10% inhibition concentration (IC10) for copper or PCP tested with common test fishes (fathead minnow and rainbow trout) and listed fishes (spotfin chub and fountain darter) (Besser et al. 2005).

➢ EC50s of copper and ammonia for surrogate species were generally higher than 24- or 48-h EC50 for glochidia and 96-h EC50s for juvenile mussels (Fig. 7); the acute WQC were below the EC50s for total residual chlorine, lead, zinc, or cadmium (Fig. 7 and 8), but were at or above the EC50s for copper or total ammonia in mussel tests (Fig. 7).

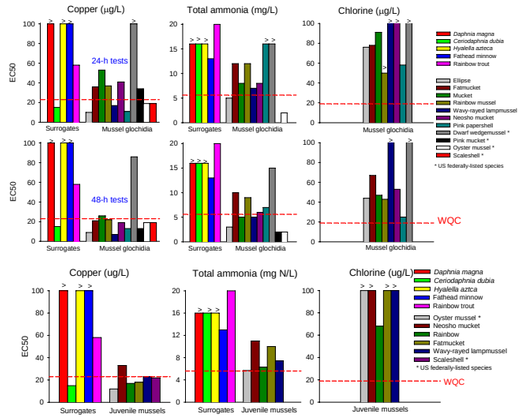

Fig. 7. The 48- or 96-h EC50s of 3 toxicants for surrogate species, 24- or 48-h EC50s for mussel larvae (glochidia), and 96-h EC50s for juvenile mussels (Wang et al. in review). Dash lines represent USEPA acute WQC (hardness 170 mg/L, pH 8.0).

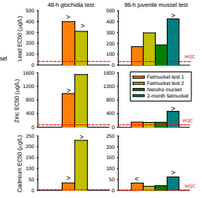

Fig. 8. Acute EC50s of lead, zinc, or cadmium for glochidia and newly-transformed or 2-month-old juvenile mussels. Dash lines represent USEPA acute WQC (hardness 50 mg/L).

The symbol ">" above bar represents the EC50s value was greater than the highest test concentration.

➢ Chronic effect concentrations (ChV and IC10) in 28-d tests with juvenile mussels were above the WQC for lead or cadmium (Fig. 9A), but were at or below the WQC for zinc, copper, or total ammonia (Figs. 9A and 9B).

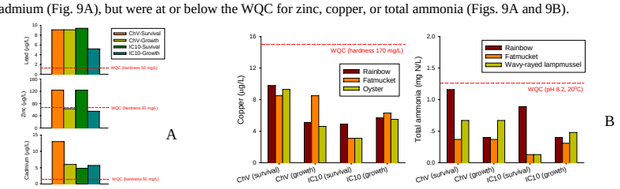

Fig. 9. The 28-d chronic values (ChV) and 10% inhibition concentration (IC10) of lead, zinc, or cadmium for juvenile mussels of fatmucket (A), and ChV and IC10 of copper or ammonia for juvenile mussels of four species (B) (Wang et al. in review).

CONCLUSIONS

➢ Rainbow trout are generally equal or more sensitive than federally-listed fish species in acute toxicity tests.

➢ Chronic WQC for copper may not adequately protect listed or unlisted fishes tested, and chronic WQC for PCP may not protect one of the two listed fish species tested.

➢ Early life stages of mussels are acutely more sensitive to copper and ammonia than commonly tested organisms.

➢ Current WQC may adequately protect mussels from chlorine, lead, or cadmium exposures, but not from copper, total ammonia, or zinc exposures.

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