Report of Mahoning River chronic sublethal sediment evaluations with *Chironomus tentans* and *Hyalella azteca*

For Rosemary Reilly

US Army Corps of Engineers

Pittsburgh District

Prepared by

John D Farrar

US Army Engineer Research and Development Center

November 2003

Introduction

At the request of the Pittsburgh District, scientist at the US Army ERDC conducted chronic sublethal sediment toxicity tests and chemistry evaluations of sediment samples collected from the Mahoning River (Pennsylvania, USA). Experimentation was conducted in the last quarter of 2002. Chemistry evaluations were completed in January 2003. The following is a compendium of the procedures, methods and results of these evaluations.

Materials and Methods

Sediment sample nomenclature

In an effort to collect sediments that would produce the widest range of toxic response, sediments were collected from the Mahoning River in areas where toxicity was expected to be low (4MAO327; 0 to 5 feet bank), moderate (4MAO327; 0 to 5 river) and high (4MAO327; 2 to 7 bank). A reference sediment (4MAO345), representative of a natural uncontaminated site of the Mahoning River, was also provided for statistical comparisons. Sediment sample classifications are outlined in Table 1.

Sediment handling and processing

Sediment samples were collected by the Pittsburgh district and provided to the ERDC for experimentation and chemical evaluation. A control sediment was provided by the ERDC for performance evaluation of the toxicity assessments. Mahoning River sediments were placed in glass jars and shipped in coolers to the ERDC via overnight delivery. Ice packs were placed in the coolers to maintain temperature during shipment. Upon arrival, sediment samples were placed in cold storage at 4 °C. After 3 days in cold storage, sediment samples were removed for processing. The low-level contaminated sediment was, in reality, dry river bank soil. In order to perform sediment toxicity testing on the sample, it was saturated with dechlorinated tap water and mixed thoroughly to form a sediment. The soil (~ 6 liters) was mixed for 30 minutes. Water was added initially and during the mixing process. Enough water was added to the soil to completely hydrate the soil particles. A two inch layer of water was left on the sediment surface after mixing in case additional water was absorbed during storage. All samples were mixed then pressed through a 1 mm sieve to remove any large debris. After processing, samples were returned to cold storage. Sediments were allowed to equilibrate for 8 days prior to experimentation.

Test animals

Hyalella azteca were obtained from in-house laboratory cultures. Animals were maintained, under flow-through conditions, in 10 gallon aquaria containing maple leaf substrate and were fed Tetramin® (Tetrasales, Blacksburg, VA, USA) 3 times weekly. *Chironomus tentans* were obtained from Environmental Testing and Consulting (Superior, Wisconsin, USA). *Chironomus tentans* arrived as an egg mass. Egg masses were placed in crystallizing dishes in de-chlorinated tap water and the dishes were placed in a temperature controlled water bath at 23 °C. Animals emerged approximately three days after arrival. Animals were placed directly into the test from the crystallizing dishes within 24 hours of emergence.

Experimental Design and Testing Procedures

The 20-d *Chironomus tentans* and 28-d *Hyalella azteca* experiments were conducted following the guidelines outlined in Methods for Measuring Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates (USEPA, 2000). The only exceptions were that beakers were aerated and the reproductive endpoint was not measured. Experimental conditions for the *Chironomus tentans* and *Hyalella azteca* chronic experiments are similar and are outlined in Table 1.

The day prior to test initiation, treatment sediments were removed from cold storage and mixed for 15 minutes with a laboratory impeller mixer. Approximately 75 mL of each treatment sediment was added to 6 replicate 300 mL beakers to obtain the required depth of 2 centimeters. One liter of sediment was also collected from each mixing vessel for chemistry analyses. Beakers were placed in an exposure module under gentle aeration. Temperature was maintained at 23 °C and light cycle was set at 16:8 light:darkness. Beakers were allowed to undergo one water exchange prior to addition of animals. Twice daily water exchanges were conducted using a modified Zumwalt water delivery system coupled with a dilutor board and timer.

At test initiation twelve <24-hour old *Chironomus tentans* larvae were counted directly into each beaker. Unlike *Chironomus tentans,* ten 7-8 day old H*yalella azteca* were first placed in counting chambers prior to addition to beakers. The number of animals in each counting chamber was verified then each chamber was gently rinsed into a treatment beaker (1 counting chamber/beaker). Water quality measurements (Dissolved oxygen, hardness, alkalinity, conductivity, pH and ammonia) were determined at day 0 and prior to test termination. Temperature was monitored daily, conductivity weekly, and dissolved oxygen and pH three times weekly in one replicate of each treatment. Each *Chironomus tentans* beaker received 6 milligrams of Tetrafin® and each *Hyalella azteca* beaker received 1 mL of YCT daily. Daily observations of each beaker were conducted. On day 20 for *Chironomus tentans* and day 28 for *Hyalella azteca* the sediment in each treatment beaker was gently sieved (425 µm sieve) and surviving animals recovered. Survival was enumerated and animals from each replicate beaker were placed on pre-weighed pans for final weight determination. Ash-free dry weight was measured for *Chironomus tentans* and dry weight was determined for *Hyalella azteca*.

Chemistry analyses

Chemical analyses of the Mahoning River sediments were conducted at the ERDC by personnel from the Environmental Chemistry Branch (ECB) of the Environmental Laboratory. Chemical classes likely to be encountered in the Mahoning River were identified by the Pittsburgh District. These chemical classes included polycyclic aromatic hydrocarbons (PAHs), metals, polychlorinated benzenes (PCBs), pesticides and total recoverable hydrocarbons (TRPH). All analyses were conducted according to standard EPA methods (Tables 2-7).

Statistical analysis

All measurement values are expressed as mean ± 1 standard deviation. Survival and growth data were analyzed using a completely randomized one-way analysis of variance (ANOVA). Dunnett's mean comparison test was used for treatment mean comparisons with the reference mean. Survival data were analyzed following an arc-sine square root transformation. Significance level for all tests was set at $\alpha = 0.05$. All data were analyzed using Toxstat Statistical Software (West, Inc., Cheyenne, WY, USA).

Results and Discussion

Chemistry analyses

Detection limits for all analyses are expressed as laboratory reporting limits (LRLs). The LRL normally corresponds to the lowest standard used in calibration. The laboratory reporting limits for PAHs, PCBs, pesticides and TRPH varied in each sediment sample due to differences in moisture content between sediments (Tables 3-7). Since sediments were dried prior to metal analyses, the LRL values varied according to the metal analyzed rather than sediment sample (Table 8). Matrix interference was encountered in the PCB analysis of the moderate-level and high-level contaminated sediment samples. The interference may have been due to the presence of high PAH concentrations in those samples. To reduce interference and allow for PCB quantification, 1:20 and 1:2 dilutions were conducted on the moderate-level and high-level contaminated sediments, respectively. The dilution resulted in high detection limits for these two samples (Table 4).

Relative to the reference and the low-level contaminated sediment, much higher concentrations of PAHs, PCBs, TRPH and metals were observed in the moderate-level and high-level contaminated sediments. Analysis of the low-level contaminated sediment revealed higher concentrations of PAHs, pesticides and metals compared to the reference sediment. Pesticide contamination was not as prevalent as observed for other chemical classes. Although an attempt was made to identify sediments with varying levels of contamination, the moderate-level and high-level contaminated sediment samples were similar in their levels of contaminant burden (Tables 2-8).

Comparison to Sediment Quality Guidelines

In order to provide guidance regarding the potential of the observed contaminants to elicit a biological effect, sediment contaminant concentrations were compared to the sediment quality guidelines presented in "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario" (MOE, 1993). The guidelines were developed using the screening level approach and define three levels of ecotoxic effects for a given contaminant based on its chronic, long tem effects on benthic organisms. According to the narrative intent of these guidelines the "no effect level" (NEL) is the level at which no toxic effects have been observed on aquatic organisms and is the level in at which no biomagnification through the food chain is expected. The "lowest effect level" (LEL) is defined as the level of contamination that can be tolerated by the majority of benthic organisms. The "severe effect level" (SEL) is the level at which deleterious effects on the benthic community would be expected. This level of contamination would be expected to be toxic to the majority of benthic species. If all contaminant levels for a given sediment are below the NEL then no adverse effect would be expected. If a sediment contaminant concentration exceeds the NEL but is below the LEL, it would be considered to have a negligible potential to illicit a toxic effect on the benthos. If a sediment contaminant concentration exceeds the LEL it would be anticipated that some biological resources may be impaired. If a sediment contaminant concentration is at or exceeds the SEL then a sediment is considered highly contaminated, according to the narrative intent of the Ontario guidelines, and would likely have a significant adverse effect on benthic biological resources.

Sediment quality guidelines are not available for all compounds encountered in the Mahoning River sediment. The lack of guideline values for all compounds is a source of uncertainty associated with the used of sediment quality guidelines. For contaminants where NEL, LEL and SEL values exist, guideline values are presented in tables 3, 5, 6, and 8. The SEL guideline values for PAHs, PCBs and pesticides have been adjusted for each sediment according to the sediments organic carbon content. The total organic carbon content of each sediment is presented in table 9. The correct SEL value is obtained by multiplying the fractional organic carbon content of the sediment by the SEL value reported in the guideline document. No effect level concentrations are not available for all compounds.

Due to interferences observed during the chemistry analysis for most pesticides and PCBs, a comparison of the observed concentration to the LEL or SEL is not possible since the LRL exceeds the guideline concentration. This was the case to a varying degree for all sediments analyzed. Results are presented only for those cases where the observed concentrations were greater than the LRL. Although the relationship of pesticide and PCB concentrations below the LRL to their respective LEL or SELs is unknown, there was no detection of compounds between the instrument detection limit and the LRL in most cases. Since biological effects are not generally expected at concentrations below the LEL, discussions of contaminant concentrations in Mahoning River sediments will only focus on instances where the LEL or SEL is exceeded.

For the reference sediment (4MAO345) exceedence of the LEL was observed for arsenic, cadmium, chromium, iron and nickel. Since the reference sediment is representative of localized background sediment conditions, the metal concentrations observed may be close to the natural background concentrations and may represent the practical lower limit for management decisions. The pesticides 4'4' DDD, 4'4' DDE exceeded the SEL guideline values for these compounds.

Anaylsis of the low contaminant level (4MAO; 0 to 1.5 bank) sediment revealed exceedences of the LEL guideline for all PAHs except for flourene. Sediment concentrations of the pesticide dieldrin, exceeded the LEL guideline value. Endrin, heptachlor epoxide and gamma-clordane concentrations exceeded the SEL guideline values. All metal concentrations exceeded the LEL guideline values with chromium, copper, iron nickel, and zinc exceeding the SEL guideline value.

For the moderate contaminant level (MAO327; 0 to 5 river) sediment, concentrations exceeding the LEL were observed for all the PAHs and metals analyzed. All metals except cadmium, and mercury exceeded the SEL guideline values. Concentrations of the pesticides aldrin, 4'4' DDE, and endrin and PCB-1248 exceeded the SEL guideline values.

Analysis of the high contaminant level (4MAO327; 2 to 7 bank) sediment revealed that all PAH and metal concentrations exceeded the LEL guideline values. As observed with the moderate contaminant level sediment, all metals except cadmium, and mercury exceed the SEL guideline values. Also, as observed in the moderate contaminant level sediment, the SEL guideline value was exceeded by PCB-1248. Due to interferences encountered during sediment analysis all pesticide and most PCB detection limits were above the SQG guideline values for the high contaminant level sediment.

Chironomus tentans 20-day and Hyalella azteca 28-d experiments

Survival in the performance control sediment met or exceeded method requirements for both *Chironomus tentans* and *Hyalella azteca*. Measured water quality parameters were within acceptable ranges for both studies. Survival effects for both species are were broadly correlated with increasing contaminant burden. Significant effects on *Chironomus tentans* survival were observed following the 20-d exposure to the moderate-level and high-level contaminated sediments (Table 10 and Figure 1A). No significant survival effect was observed for the low-level contaminated sediment (Figure 1A). No significant effects on *Chironomus tentans* growth were observed for any of the sediments (Table 11 and Figure 2B).

Similar results were obtained in the *Hyalella azteca 28-d experiment. Hyalella azteca* survival was significantly reduced following 28-d exposure to the moderate-level and high-level contaminated sediment with no survival effects observed in the low-level contaminated sediment (Table 12 and Figure 2A). As observed in the *Chironomus tentans* study, no significant effect on *Hyalella azteca* growth was detected (Table 13 and Figure 2B). Survival effects observed in both species correspond to sediment samples where relatively high and similar concentrations of PAHs, PCBs, TRPH and metals were identified (Tables 3-8).

As expected, the toxicity observed occurred in sediments where the majority of the SQG SEL guideline values were exceeded (Tables 3, 5, 6, and 8). Yet, no toxicity was observed in the reference and low contaminant level sediments where pesticide and metal SEL concentrations were exceeded. Failure to observe toxicity may be the result of higher than usual levels of organic carbon, acid volatile sulfide or other partitioning phase that reduces contaminant bioavailability. The lack of observed toxicity in some cases where SEL values were exceeded speaks directly to the uncertainty associated with using chemistry data alone to make predictions about potential for impact. These observations emphasize the need for using toxicity tests as a definitive tool in the evaluation of contaminated sediments.

References

Ontario Ministry of the Environment (1993). Guidelines for the Protection and Management of Aquatic Sediemtn Quality in Ontario. ISBN 0-7729-9248-7.

U.S. Environmental protection Agency. (2000). Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates-second edition. EPA/600/R-99/064. Office of Science and Technology, Washington, D.C.

Table 1. Mahoning River sediment sample contaminant level classification.

Sample ID	**Contaminant Level Classification**
4MAO345	Reference
MAO327 (0 to 1.5 bank)	Low-level
MAO327 (0 to 5 river)	Moderate-level
MAO327 (2 to 7 bank)	High-level

Table 2. Experimental conditions for the *Chironomus tentans 20-d* and *Hyalella azteca* 28-d experiments.

	Organism	
Parameter	***Chironomus tentans***	***Hyalella azteca***
Test duration	20 days	28days
Temperature	23 °C	23 °C
Light Quality	Wide-spectrum fluorescent lights (100 to 1000 lux)	Wide–spectrum fluorescent lights (100 to 1000 lux)
Photoperiod	16:8 Light:Darkness	16:8 Light:Darkness
Test Chamber	300 mL tall-form lipless beaker	300 mL tall-form lipless beaker
Overlying water	de-chlorinated tap water	de-chlorinated tap water
Overlying Water Volume	125 mL	125 mL
Renewal of Overlying Water	2 intermittent volume additions/day	2 intermittent volume additions/day
Age of Organism	< 24 hour old larvae	7-8 days old
Number of Organisms per Beaker	12	10
Number of Replicate Beakers/Treatment	8 (2 for sediment chemistry)	8 (2 for sediment chemistry)
Feeding	Tetrafin®, 6mg daily to each beaker	YCT, 1 mL/beaker/day (1800 mg/L stock)
Aeration	1 bubble/sec	1 bubble/sec
Overlying Water Quality Measurements	hardness, alkalinity, conductivity, pH and ammonia at the beginning and end of the test for each beaker and dissolved oxygen and pH three times weekly and Conductivity weekly in 1 replicate per treatment Temperature daily.	hardness, alkalinity, conductivity, pH and ammonia at the beginning and end of the test for each beaker and dissolved oxygen and pH three times weekly and Conductivity weekly in 1 replicate per treatment Temperature daily.
Endpoints	survival and growth (dry weight) sediment (TOC, total zinc, SEM-zinc, and AVS) interstitial water (total zinc)	survival and growth (dry weight) sediment (TOC, total zinc, SEM-zinc, and AVS) interstitial water (total zinc)
Test acceptability	Minimum control survival of 83% and minimum mean control weight 0.6 mg dry weight/animal	Minimum control survival of 80%

Table 3. Selected polycyclic aromatic hydrocarbon concentrations (µg/kg) in Mahoning River sediments analyzed according to EPA SW-846 method 8270C with modification for GC/MS detection by selected ion monitoring.

PAH	(A) 4MA0345 (Reference) LRL = 13 µg/kg	(B) 4MA0327 (0-1.5 Bank) LRL = 27 µg/kg	(C) 4MA0327 (0 to 5 River) LRL = 33 µg/kg	(D) 4MA0327 (2-7 Bank) LRL = 28 µg/kg	NEL	LEL	*SEL µg/kg organic carbon
Total PAH	2,148.9	17,128.50	35,067	33,850	N/A	4,000	(A) 350,000 (B) 590,000 (C) 810,000 (D) 800,000
Acenaphthene	15.2	56.7	518	443	N/A	N/A	N/A
Acenapthylene	6.0 J	36.8	143	112	N/A	N/A	N/A
Anthracene	51	331	1,420	1,470	N/A	220	(A) 12,950 (B) 21,830 (C) 29,970 (D) 29,600
Benzo(a)anthracene	144	1470	2,610	2,530	N/A	320	(A) 51,800 (B) 87,320 (C) 119,880 (D) 118,400
Benzo(a)pyrene	128	1,470	1,620	1,660	N/A	370	(A) 46,900 (B) 79,060 (C) 108,540 (D) 107,200
Benzo(b)fluoranthene	313	1,330	1,630	1,590	N/A	N/A	N/A
Benzo(G,H,I)perylene	101	969	1,060	1,070	N/A	170	(A) 11,200 (B) 18,880 (C) 25,920 (D) 25,600
Benzo(K)fluoranthene	127	1,250	1,300	1,190	N/A	240	(A) 46,900 (B) 79,060 (C) 108,540 (D) 107,200
Chrysene	180	1,520	3,530	3,210	N/A	340	(A) 16,100 (B) 27,140 (C) 37,260 (D) 36,800

LRL=Laboratory Reporting Limit
J = sample concentration below LRL but above instrument detection limit
*Severe Effects Guideline values converted to bulk sediment values based on TOC content of sediment (i.e., SEL X fractional OC)

Table 3 (continued). Selected polycyclic aromatic hydrocarbon concentrations (µg/kg) in Mahoning River sediments analyzed according to EPA SW-846 method 8270C with modification for GC/MS detection by selected ion monitoring.

PAH	(A) 4MA0345 (Reference) LRL = 13 µg/kg	(B) 4MA0327 (0-1.5 Bank) LRL = 27 µg/kg	(C) 4MA0327 (0 to 5 River) LRL = 33 µg/kg	(D) 4MA0327 (2-7 Bank) LRL = 28 µg/kg	NEL	LEL	*SEL µg/kg organic carbon
2-Methylnaphthalene	44.4	321	679	576	N/A	N/A	N/A
Dibenzo(A,H)anthracene	15.9	188	274	250	N/A	60	(A) 4,550 (B) 7,670 (C) 10,530 (D) 10,400
Fluoranthene	384	3,010	5,840	5,530	N/A	750	(A) 35,700 (B) 60,180 (C) 82,620 (D) 81,600
Fluorene	36.4	123	1,600	1,590	N/A	190	(A) 5,600 (B) 9,440 (C) 12,960 (D) 12,800
Indeno(1,2,3-C,D)pyrene	110	1,300	1,310	1,270	N/A	200	(A) 11,200 (B) 18,880 (C) 25,920 (D) 25,600
Naphthalene	44.4	414	442	385	N/A	N/A	N/A
Phenanthrene	196	1,430	5,300	5,490	N/A	560	(A) 33,250 (B) 56,050 (C) 76,950 (D) 76,000
Pyrene	297	2,230	6,470	6,060	N/A	490	(A) 29,750 (B) 50,150 (C) 68,850 (D) 68,000

LRL=Laboratory Reporting Limit
J = sample concentration below LRL but above instrument detection limit
*SEL values converted to bulk sediment values based on TOC content of sediment (i.e., SEL X fractional OC)

Table 4. Selected semi-volatile polycyclic aromatic hydrocarbon concentrations (µg/kg) in Mahoning River sediments analyzed according to EPA SW-846 Method 8270C.

Semi-volatile PAH	4MA0345 (Reference) LRL = 660 µg/kg	4MA0327 (0-1.5 Bank) LRL = 680 µg/kg	4MA0327 (0 to 5 River) LRL = 820 µg/kg	4MA0327 (2-7 Bank) LRL = 720 µg/kg
2-Methylnaphthalene	44.4	321	679	576
Dibenzofuran	<660	<680	900	799
Carbazole	<660	<680	500 J	460 J
2,4,5-Trichlorophenol	<660	<680	<820	<720
2-Methylphenol	<660	<680	<820	<720
3-Methylphenol/4-Methyphenol	<660	<680	1140	722

LRL=Laboratory Reporting Limit
J = sample concentration below LRL but above instrument detection limit

Table 5. Selected polychlorinated biphenyl (arochlor) concentrations (mg/kg) in Mahoning River sediments analyzed according to EPA SW-486 Method 8082.

PCB (arochlor)	(A) 4MA0345 (Reference) LRL = 32.4 mg/kg	(A) 4MA0327 (0-1.5 Bank) LRL = 33.2 mg/kg	(B) 4MA0327 (0 to 5 River) LRL = 798 mg/kg	(C) 4MA0327 (2-7 Bank) LRL = 69.1 mg/kg	NEL	LEL	*SEL µg/g organic carbon
1016	<32.4	<33.2	<798	<69.1	N/A	0.007	(A) 1.85 (B) 3.12 (C) 4.29 (D) 4.24
1221	<32.4	<33.2	<798	<69.1	N/A	N/A	N/A
1232	<32.4	<33.2	<798	<69.1	N/A	N/A	N/A
1242	<32.4	<33.2	<798	<69.1	N/A	N/A	N/A
1248	<32.4	<33.2	15200	1470	N/A	0.03	(A) 5.25 (B) 8.85 (C) 12.15 (D) 12.00

LRL=Laboratory Reporting Limit
*SEL values converted to bulk sediment values based on TOC content of sediment (i.e., SEL X fractional OC)

Table 5 (continued). Selected polychlorinated biphenyl (arochlor) concentrations (mg/kg) in Mahoning River sediments analyzed according to EPA SW-486 Method 8082.

PCB (arochlor)	(A) 4MA0345 (Reference) LRL = 32.4 mg/kg	(D) 4MA0327 (0-1.5 Bank) LRL = 33.2 mg/kg	(E) 4MA0327 (0 to 5 River) LRL = 798 mg/kg	(F) 4MA0327 (2-7 Bank) LRL = 69.1 mg/kg	NEL	LEL	*SEL µg/g organic carbon
1254	<32.4	<33.2	<798	<69.1	N/A	0.06	(A) 1.19 (B) 2.01 (C) 2.75 (D) 2.72
1260	<32.4	<33.2	<798	<69.1	N/A	0.005	(A) 0.84 (B) 1.41 (C) 1.94 (D) 1.92

LRL=Laboratory Reporting Limit

*Severe Effects Guideline values converted to bulk sediment values based on TOC content of sediment (i.e., SEL X fractional OC)

Table 6. Selected pesticide concentrations (mg/kg) in Mahoning River sediments analyzed following EPA SW-846 Method 8081A.

Pesticide	(A) 4MA0345 (Reference) LRL = 3.24 mg/kg	(B) 4MA0327 (0-1.5 Bank) LRL = 3.32 mg/kg	(C) 4MA0327 (0 to 5 River) LRL = 3.99 mg/kg	(D) 4MA0327 (2-7 Bank) LRL = 3.45 mg/kg	NEL	LEL	*SEL µg/g organic carbon
Aldrin	<3.24	<3.32	20.1	<3.45	N/A	0.002	(A) 0.28 (B) 0.47 (C) 0.65 (D) 0.64
A-BHC	<3.24	<3.32	<3.99	<3.45	N/A	0.006	(A) 0.42 (B) 0.71 (C) 0.97 (D) 0.96
B-BHC	<3.24	<3.32	<3.99	<3.45	N/A	0.005	(A) 0.35 (B) 0.59 (C) 0.81 (D) 0.80
G-BHC	<3.24	<3.32	<3.99	<3.45	0.0002	0.003	(A) 0.74 (B) 1.24 (C) 1.70 (D) 1.68
D-BHC	<3.24	4.01	<3.99	<3.45	N/A	N/A	N/A
4'4' DDD	5.42	<3.32	<3.99	<3.45	N/A	0.008	(A) 0.21 (B) 0.35 (C) 0.49 (D) 048
4'4' DDE	1.92 J	<3.32	44.8	<3.45	N/A	0.008	(A) 0.66 (B) 1.12 (C) 1.54 (D) 1.52
4'4' DDT	<3.24	<3.32	<3.99	<3.45	N/A	0.007	(A) 2.48 (B) 4.18 (C) 5.75 (D) 5.68
Heptachlor	<3.24	<3.32	<3.99	<3.45	N/A	N/A	N/A
Dieldrin	<3.24	1.73 J	<3.99	<3.45	N/A	0.002	(A) 3.18 (B) 5.36 (C) 7.37 (D) 7.28

LRL=Laboratory Reporting Limit
J = sample concentration below lowest standard but above instrument detection limit
*Severe Effects Guideline values converted to bulk sediment values based on TOC content of sediment (i.e., SEL X fractional OC)

Table 6 (continued). Selected pesticide concentrations (mg/kg) in Mahoning River sediments analyzed following EPA SW-846 Method 8081A

Pesticide	(A) 4MA0345 (Reference) LRL = 3.24 mg/kg	(B) 4MA0327 (0-1.5 Bank) LRL = 3.32 mg/kg	(C) 4MA0327 (0 to 5 River) LRL = 3.99 mg/kg	(D) 4MA0327 (2-7 Bank) LRL = 3.45 mg/kg	NEL	LEL	*SEL µg/g organic carbon
A-Endosulfan	<3.24	<3.32	<3.99	<3.45	N/A	N/A	N/A
B-Endosulfan	2.17 J	<3.32	<3.99	<3.45	N/A	N/A	N/A
Endosulfan sulfate	<3.24	<3.32	<3.99	<3.45	N/A	N/A	N/A
Endrin	<3.24	10.5	30.9	<3.45	0.01	0.003	(A) 4.55 (B) 7.67 (C) 10.53 (D) 10.40
Endrin aldehyde	<3.24	<3.32	<3.99	<3.45	N/A	N/A	N/A
Heptachlor epoxide	<3.24	38.0	<3.99	<3.45	0.0003	0.005	(A) 0.17 (B) 0.29 (C) 0.49 (D) 0.48
Methoxychlor	<32.4	19.1 J	<39.9	<34.5	N/A	N/A	N/A
Toxaphene	<64.9	<66.4	<79.9	<69.1	N/A	N/A	N/A
Alpha-chlordane	<3.24	<3.32	<3.99	<3.45	0.005	0.007	(A) 0.2 (B) 0.4 (C) 0.5 (D) 0.5
Gamma-chlordane	<3.24	7.29	<3.99	<3.45	0.005	0.007	(A) 0.2 (B) 0.4 (C) 0.5 (D) 0.5

LRL=Laboratory Reporting Limit
J = sample concentration below lowest standard but above instrument detection limit
*SEL values converted to bulk sediment values based on TOC content of sediment (i.e., SEL X fractional OC)

Table 7. Total recoverable petroleum hydrocarbon concentrations (mg/kg) in Mahoning River sediments analyzed following EPA Method 418.1 and method described in EPA-600/4-79-020. Extractions were conducted following EPA SW-486 Method 9071A.

TRPH	4MA0345 (Reference) LRL = 69.0 mg/kg	4MA0327 (0-1.5 Bank) LRL = 71.3 mg/kg	4MA0327 (0 to 5 River) LRL = 85.8 mg/kg	4MA0327 (2-7 Bank) LRL = 74.2 mg/kg
	197	120	18700	7910

LRL=Laboratory Reporting Limit

Table 8. Selected metal concentrations (mg/kg) in Mahoning River sediments analyzed following +EPA SW-846 Method 6020 (Sb, As, Be, Cd, Se, Ag, Tl), ++EPA SW-846 Method 6010 (Cr, Cu, Pb, Ni, Zn, Fe) and +++EPA SW-846 Method 7471 (Hg).

Metal	Metal Specific LRL	4MA0345 (Reference)	4MA0327 (0-1.5 Bank)	4MA0327 (0 to 5 River)	4MA0327 (2-7 Bank)	NEL	LEL	SEL
+Antimony	0.300	<0.300	<0.300	<0.300	0.3	N/A	N/A	N/A
+Arsenic	0.200	9.09	19.5	48.4	47.3	N/A	6	33
+Beryllium	0.100	0.5	1.1	1.0	0.899	N/A	N/A	N/A
+Cadmium	0.020	0.679	1.83	5.49	5.29	N/A	0.6	10
++Chromium	0.200	43.7	177	914	679	N/A	26	110
++Copper	2.0	32	143	580	609	N/A	16	110
++Iron (%)	5.0	2.15	9.02	23.1	27.5	N/A	2	4
++Lead	1.0	26.4	150	495	433	N/A	31	250
+++Mercury	0.005	0.0744	0.362	1.1	0.859	N/A	0.2	2
++Nickel	0.50	66.6	108	351	291	N/A	16	75
+Selenium	0.200	0.999	1.9	2.5	1.7	N/A	N/A	N/A
+Silver	0.100	<0.100	1.6	7.2	4.2	N/A	N/A	N/A
+Thallium	0.200	<0.200	1.1	1.8	1.3	N/A	N/A	N/A
++Zinc	1.0	109	829	3060	2250	*65	120	820

LRL=Laboratory Reporting Limit

Table 9. Total organic carbon content of Mahoning river sediment in (PPM) and (%).

Total Organic Carbon	4MA0345 (Reference)	4MA0327 (0-1.5 Bank)	4MA0327 (0-5 River)	4MA0327 (2-7 Bank)
PPM	35000	59000	81000	80000
%	3.5	5.9	8.1	8.0

Table 10. *Chironomus tentans* percent survival following 20-day exposure to Mahoning River sediments

Treatment		Mean	S.D.	S.E.	C.V.	Min	Max	n
Control		81.9%	16.2%	6.6%	19.7%	58.3%	100.0%	6
Reference		72.2%	12.5%	5.1%	17.4%	58.3%	91.7%	6
Low-level		79.2%	11.5%	4.7%	14.5%	66.7%	91.7%	6
moderate-level	*	0.0%	0.0%	0.0%	N/A	0.0%	0.0%	6
hig-level	*	0.0%	0.0%	0.0%	N/A	0.0%	0.0%	6

Table 11. *Chironomus tentans* mass following 20-day exposure to Mahoning River sediments

Treatment		Mean	S.D.	S.E.	C.V.	Min	Max	n
Control		0.95	0.24	0.10	25.2%	0.71	1.31	6
Reference		1.02	0.30	0.12	29.4%	0.79	1.55	6
Low-level		0.81	0.21	0.09	26.6%	0.45	1.00	6
moderate-level		N/A	N/A	N/A	N/A	N/A	N/A	0
hig-level		N/A	N/A	N/A	N/A	N/A	N/A	0

* Statistically different from Reference sediment (MAO345 0 to 5 feet river; Dunnett's Test p=0.05)

Table 12. *Hyalella azteca* percent survival following 28-day exposure to Mahoning River sediments

Treatment		Mean	S.D.	S.E.	C.V.	Min	Max	n
Control		90.0%	16.7%	6.8%	18.6%	60.0%	100.0%	6
Reference		78.3%	14.7%	6.0%	18.8%	60.0%	100.0%	6
Low-level		90.0%	16.7%	6.8%	18.6%	60.0%	100.0%	6
moderate-level	*	0.0%	0.0%	0.0%	N/A	0.0%	0.0%	6
hig-level	*	0.0%	0.0%	0.0%	N/A	0.0%	0.0%	6

Table 13. *Hyalella azteca* mass following 28-day exposure to Mahoning River sediments

Treatment		Mean	S.D.	S.E.	C.V.	Min	Max	n
Control		0.14	0.05	0.02	36.4%	0.07	0.22	6
Reference		0.19	0.05	0.02	26.1%	0.13	0.25	6
Low-level		0.10	0.04	0.02	39.8%	0.05	0.14	5
moderate-level		N/A	N/A	N/A	N/A	N/A	N/A	0
hig-level		N/A	N/A	N/A	N/A	N/A	N/A	0

* Statistically different from Reference sediment (MAO345 0 to 5 feet river; Dunnett's Test p=0.05)

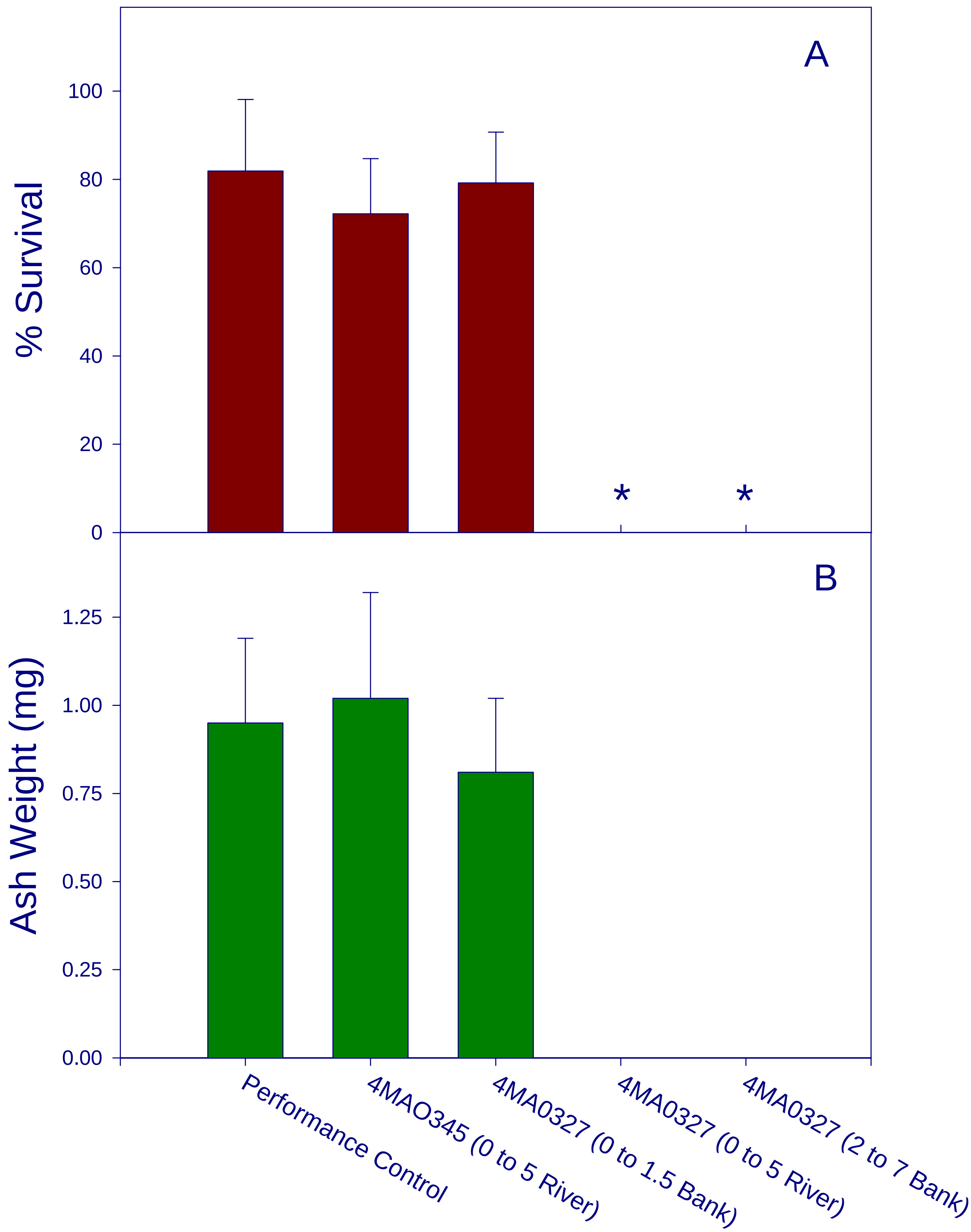

Figure 1. Survival (A) and mass (B) of *C. tentans* following 20-day exposure to Mahoning River sediments. *Indicates the value is significantly different from the reference (4MA0345 (0 to 5 River)).

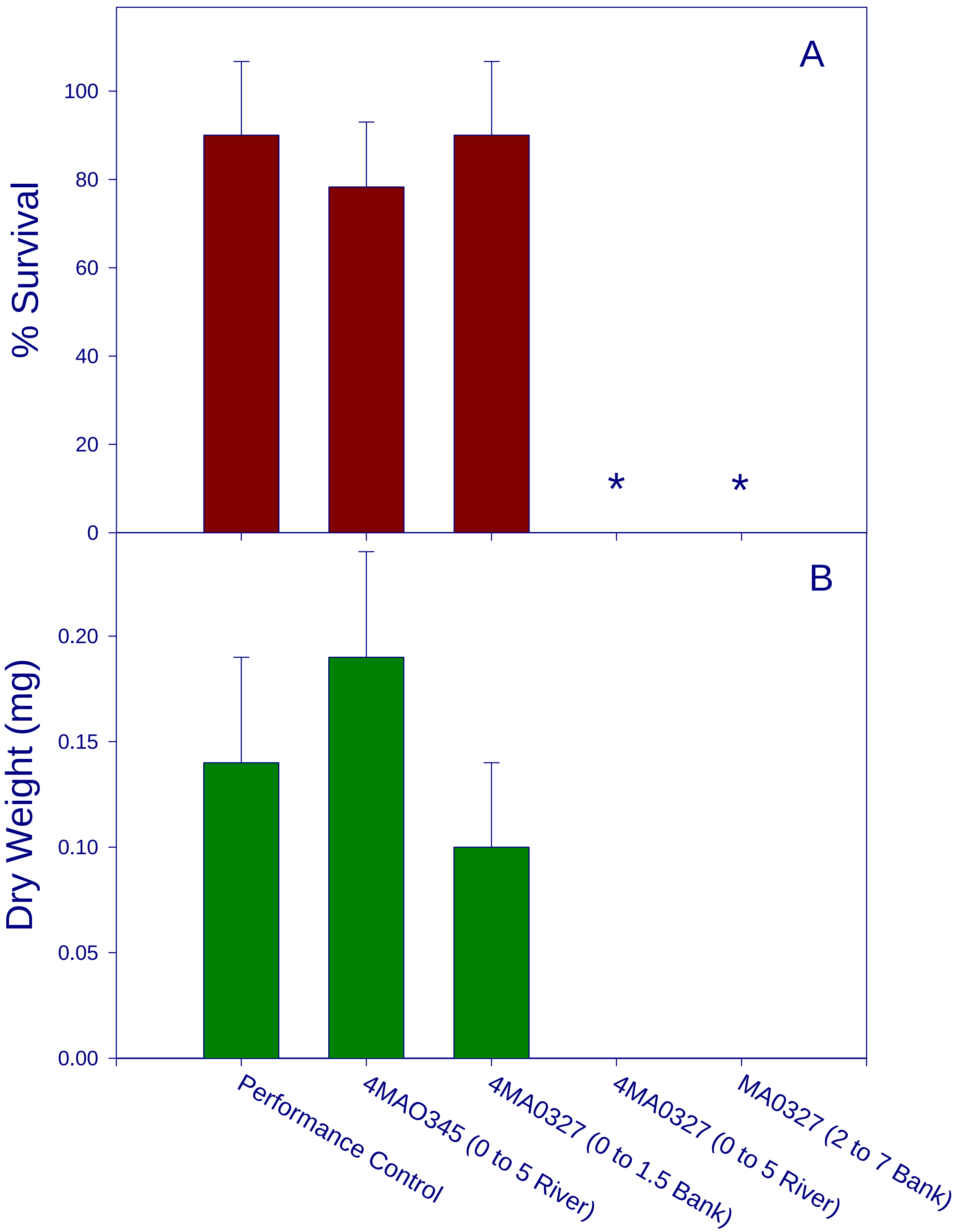

Figure 2. Survival (A) and mass (B) of *H. azteca* following 28-day exposure to Mahoning River sediments. *Indicates the value is significantly different from the reference (4MA0345 (0 to 5 River)).