

Full Length Research Paper

# Health of Brockport creek following removal of contaminated sediment from an upstream tributary

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**After removing contaminated sediments from a toxic waste site's outlet stream into Brockport creek, PCB concentrations in the outlet stream dropped from 1,730 to 34,900 µg/kg in 2002 to 288 to 432 µg/kg in 2003. Concentrations are now below water quality criteria for aquatic organisms and human health. Concentrations of eight metals (Arsenic, Barium, Cadmium, Chromium, Copper, Lead, Nickel and Zinc) also decreased greatly but because of naturally high background levels several remain above water quality criteria. The benthic macroinvertebrate community at the remediated site was severely degraded by dredging but showed signs of recovery the next year. All but one of the other sites sampled above and below the outlet stream from the toxic waste site had moderately polluted or disturbed benthic macroinvertebrate communities typical of the region. No patterns of sediment toxicity (survival, growth, reproduction) were observed for *Daphnia magna*, *Hyalella azteca* and *Pimephales promelas* in relation to sampling locations in the waste site's outlet stream and Brockport creek. The cleanup of the contaminated outlet stream appears to have been successful.**

**Key words:** Toxicity testing, PCBs, metals, benthic macro invertebrates.

## INTRODUCTION

Contaminants accumulate in sediments following their introduction into aquatic ecosystems and may adversely affect benthic organisms. Through bioaccumulation and trophic interactions, contaminants may also magnify in food webs and threaten top predators, including humans. A number of contaminants, including heavy metals and polychlorinated biphenyls (PCB), are found in sediments from the Great Lakes region due to industrial activity (Sly, 1983; Fallon and Horvath, 1985; Hamdy and Post, 1985; Lum and Gammon, 1985; Maguire et al., 1985; Chau et al., 1985; Pranckevicius, 1986; Sierra Legal, 2006; Teach

Great Lakes, 2007).

PCBs are found in fish and wildlife around the world at concentrations that may adversely affect their health (Holmes et al., 1967; Risebrough et al., 1968; Jensen et al., 1969; Manny and Kenaga, 1991a; Pearson et al., 1997; Gale et al., 1997; Geisy et al., 1997). PCBs were used in dielectrics, vacuum pumps, heat transformer liquids, lubricants, and plasticizers (Walker et al., 2001). Due to their persistence in nature and detrimental effects on humans and animals, they were banned in the U.S. in 1976. Major sources of PCB pollution included manufacturing waste and careless disposal practices (EIP Associates, 1997; Landis and Yu, 1998; UNEP Chemicals, 1999). Their distributions and toxicological affects have been reviewed by Gustafson (1970), Peakall

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and Lincer (1970), Risebrough (1970), Veith and Lee (1970), BNS (1999), ATSDR (2000), Schantz et al. (2003), and Heidtke et al. (2006).

Heavy metals, like PCBs, accumulate in the sediment of lakes and rivers. Once in contact with the sediment, metals easily adsorb to organic molecules and biota within the sediment in depositional regions (Manny et al., 1991b; Nichols et al., 1991; Goncalves et al., 1992; Landis and Yu, 1998; Walker et al., 2001; Hatje et al., 2003; Jain and Ram, 1997; Saeedi et al., 2004; Fan et al., 2007; Saeedi et al., 2011). Once in the benthos, metals are transported up the food web into fish and other predators. Accumulation of large concentrations of heavy metals causes gill, liver, kidney, and hematological damage in fish and invertebrates (Delvalls et al., 1998; Rasmussen and Anderson 2000; Usha Rani, 2000; Adami et al., 2002; Farkas et al., 2002; Basa and Rani, 2003; Olaifa et al., 2004; Ashraj, 2005; Vosyliene and Jankaite 2006; Waqar, 2006; Farombi et al., 2007; Vinodhini and Narayanan, 2008).

The objective of this study was to:

- (1) Compare the concentrations of total PCBs and eight metals in Brockport Creek and Tributary #3 before and after remediation of Tributary #3.
- 2) Assess the health of the aquatic invertebrate community in Brockport Creek and Tributary #3 after remediation.
- (3) Determine the toxicity to three standard test organisms of sediments remaining in Brockport Creek and Tributary #3 following remediation.

## MATERIALS AND METHODS

Brockport Creek is small, shallow and drains a 21.5 km<sup>2</sup> watershed that flows into south-central Lake Ontario (Figure 1). It receives water from Tributary #3, a 1.7 km-long manmade stream that drains storm water runoff and sludge pit (43.21268°N, 77.92950°W) effluent from the former Dyna Color-3M, General Electric, and Black and Decker facilities that operated from 1940 to 1986. In 2002, the New York State Department of Environmental Conservation (NYSDEC) began removing contaminated sediment from Tributary #3, a NYS superfund site.

Approximately 2,140 metric tons of contaminated sediment was removed from the start of Tributary #3 at the Industrial site downstream to Site #6 and a new tributary bed was constructed (Figure 1).

### Sample collection and analysis

Composite sediment samples were collected from seven sites, one in Tributary #3 and six in Brockport Creek, on October 30, 2003 (Figure 1). At each site, sediment was removed from the slowest moving section where fine sediment accumulated and presumably contained the highest concentrations of contaminants. Approximately 4 L of sediment was collected at each site with a 1 L hexane-rinsed stainless steel cup. Sediment samples were placed in 4 L hexane-rinsed plastic containers and stored at 4°C until used. Sites 3 to 6, which encompass the remediation site in Tributary #3, the confluence of Tributary #3 and Brockport Creek, and two sites

in Brockport Creek immediately downstream from Tributary #3 (Figure 1), were analyzed for PCBs following USEPA (1996a) and for heavy metal presence following USEPA (1996b). One concentration value was provided for composited samples from each site before (Ecology and Environment, 2001) and after (Ecology and Environment, 2004) remediation.

Benthic macroinvertebrate samples were collected at Sites 1 to 7 (Figure 1) using a D-ring kick net (32 × 25 cm) following the method of Bode et al. (1996) and preserved in 70% ethanol. We identified organisms to order and calculated a biotic index for each site following the method of Hilsenhoff (1975) modified by Beck (2005).

### Toxicity testing

To generate test organisms, laboratory cultures of the cladoceran (*Daphnia magna*), the isopod (*Hyalella azteca*), and the fathead minnow (*Pimephales promelas*) were established according to protocols of Neuderfer (2000) and USEPA (2002). Acute 48 h tests with *D. magna* were conducted according to USEPA (1994). Ten newly hatched neonates (<24 h old) were placed in 130 ml beakers with 50 ml sediment and 50 ml water from each site. Four replicates were tested for each site, and survival was recorded at 24- and 48 h. A chronic 10-day test with *D. magna* was conducted in the same manner as the acute test except for the following conditions: one newly hatched neonate was placed in each 130 ml beaker, two replicates were tested for each site, and survival and offspring produced were recorded every other day.

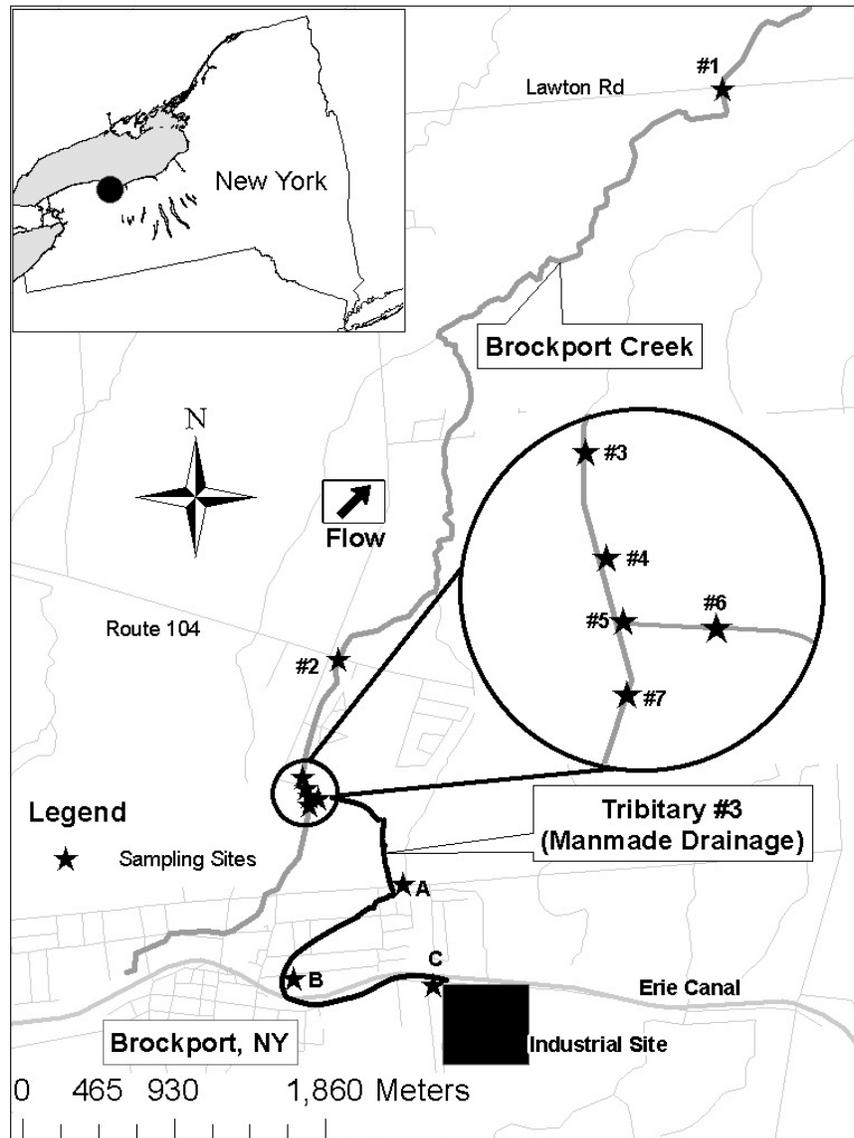
Acute 10-day tests with *H. azteca* were conducted according to USEPA (2000). Ten 7 to 10 day old amphipods were placed in 130 ml beakers with 50 ml sediment and 50 ml water in five replicates from each site. Survival and growth in length and weight were recorded after 10 days. Chronic 42-day tests with *Hyalella* were conducted in the same manner except for the following conditions. Four replicates were evaluated for changes in weight and length after 28 days.

On day 35, five replicates were viewed for offspring production. Five additional replicates were evaluated for survival, offspring production and changes in weight and length through 42 days.

Acute 96 h tests with *P. promelas* followed USEPA (1994). An Ace Diluter system was connected to a 500 L tank containing 3 L of sediment and 100 L of water from each site. Ten adult fathead minnows were placed in 10 L jars and connected to the diluter system. Two replicates at four diluent: effluent concentrations (3:1, 1:1, 1:0, and control) were tested for each site. Survival was recorded daily. Chronic 7-day tests with larval fathead minnows were conducted in the same manner except for the following conditions. Ten newly hatched larvae (<24 h) were placed in 1-L beakers with 200 ml sediment and 800 ml water from each site. Two replicates were tested for each site. Survival and change in length were recorded at the end of 7 days.

### Statistical analysis

Potential differences in sediment toxicity among the seven sites and their controls were determined following statistical flow diagrams provided with each toxicity protocol (USEPA, 1994, 2000, 2002). A probability level  $P < 0.05$  was considered significant. Normality of data was determined using the Shapiro-Wilks test. Normally distributed data were analyzed using one-way analysis of variance (ANOVA) to determine significance (Statistix 8.0, Analytical Software, Tallahassee, FL). When significance was detected, we used Turkey's pairwise comparison test to determine which sites differed. Non-normal data were assessed using the Kruskal-Wallis non-parametric ANOVA and the same pair-wise comparison test was used when a significant difference was detected.



**Figure 1.** Composited sediment sampling sites in Brockport Creek and Tributary #3. Before remediation: Site A = 690 m upstream in Tributary #3, Site B = 1.29 km upstream in Tributary #3, Site C = 1.46 km upstream in Tributary #3. After remediation: Site 1 = 5.7 km downstream in Brockport Creek, Site 2 = 610 m downstream in Brockport Creek, Site 3 = 120 m downstream in Brockport Creek, Site 4 = 46 m downstream in Brockport Creek, Site 5 = confluence of Tributary #3 and Brockport Creek, Site 6 = Remediation Site, Site 7 = 61 m upstream of confluence of Tributary #3 and Brockport Creek.

## RESULTS AND DISCUSSION

### Contaminant concentrations in sediments

Sediments were analyzed for total PCBs and heavy metal presence before (Sites A-C, Ecology and Environment, 2001) and after (Sites 3 to 6, Ecology and Environment, 2004) remediation in Tributary #3 (Figure 1). Three Arochlors were detected, with total PCB concentrations

ranging from 2,317 to 52,778  $\mu\text{g}/\text{kg}$  ( $20.248 \pm 16.293$   $\mu\text{g}/\text{kg}$ , mean  $\pm$  SE) before and 288 to 432  $\mu\text{g}/\text{kg}$  ( $342.9 \pm 34$   $\mu\text{g}/\text{kg}$ ) after remediation (Table 1, Figure 2A). All PCB concentrations after remediation were below human hazard limits (AAP, 1999; ATSDR, 2000; USEPA, 1986, 2001).

Excluding non-detects, low concentrations of metals in Tributary #3 ranged from 2.86 mg/kg (Arsenic, Site A) before to 0.14 mg/kg (Cadmium, Site 6) after

**Table 1.** Concentrations of total PCB and metals in sediments at six sites in Brockport Creek (1-5, 7) and three sites (6, A-C) in Tributary #3 near an abandoned industrial site before and after removal of contaminated sediments. (ns = not sampled, nd = not detected; HHL = human hazard limit)

PCB ( µg/kg )	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	HHL	Site A	Site B	Site C
Total	ns	ns	288.3	361	431.7	290.5	ns	795	5650	52778	2317
<b>Metals (mg/kg)</b>											
Arsenic	1.1	3.5	3.4	2	5.46	2.45	5.1	1.25	6.49	2.86	5.29
Barium	73	134.9	115.4	104.2	77	60.3	132.8	2.5	146	54.1	1630
Cadmium	0.7	0.9	0.9	0.8	0.43	0.14	1.4	0.625	1.23	355	9.64
Chromium	19.8	19.5	22.7	24.1	19.2	6.6	38.6	1.25	72.6	19.5	511
Copper	16.1	15.5	22.2	28.2	nd	nd	20.4	2.5	64.5	24.6	47.6
Lead	64.3	18.8	21.9	29.5	25.4	7.3	30	0.625	124	64.4	2240
Nickel	17	19	23.5	17.1	nd	nd	32.1	2.5	28.1	39.2	769
Zinc	nd	114.4	117	nd	nd	nd	172.4	12.5	626	205	2530

remediation. High concentrations of metals in Tributary #3 ranged from 2,350 mg/kg (Zinc, Site C) before to 60.3 mg/kg (Barium, Site 6) after remediation.

Before remediation, concentrations of the eight metals analyzed from sediments in Tributary #3 were all well above human hazard limits (HHL). After remediation, four metals (Arsenic, Barium, Chromium, Lead) remained above their HHLs and four were below (Cadmium, Copper, Chromium and Lead were non-detects) (Table 1, Figure 2B).

After remediation, metal concentrations upstream in Brockport Creek (Site 7), at the confluence of Brockport Creek and Tributary #3 (Site 5), and downstream in Brockport Creek (Sites 1 to 4) were mostly above their HHLs (Table 1, Figure 2B). Since relatively high metal concentrations are natural for the area (pers. comm., Kelly Cloyd, NYS Department of Environmental Conservation), and post-remediation metal concentrations upstream (Site 7) and downstream (Sites 1 to 4) in Brockport

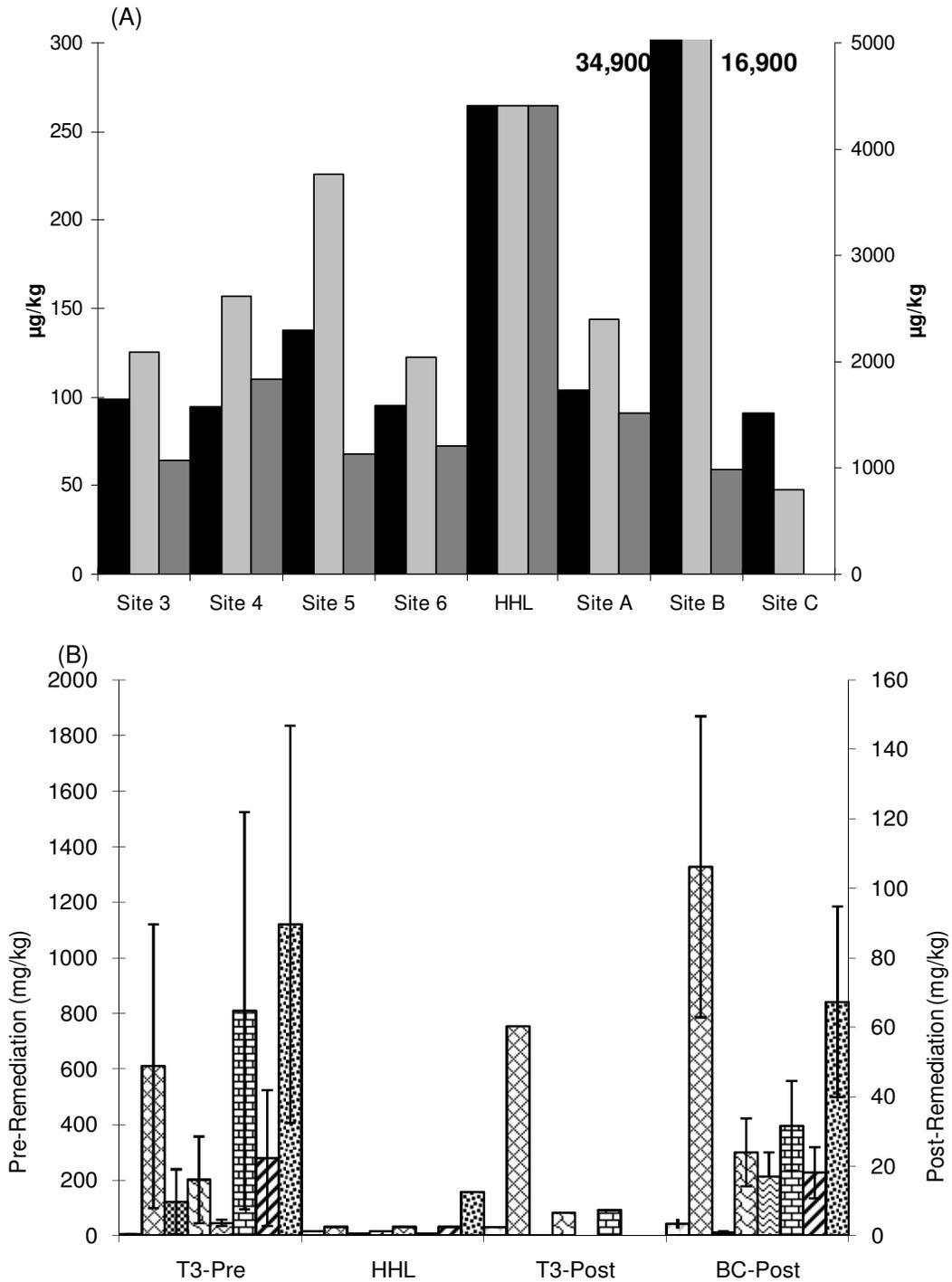
Creek were generally higher than pre-remediation concentrations at sites A and B in Tributary #3 (the pre-remediation sampling sites farthest from the industrial contamination source), the data indicate that metals from the superfund site have not contaminated Brockport Creek.

#### **Benthic macroinvertebrate community biotic index values**

Dipteran larvae (Chironomidae) were the most prevalent invertebrate taxon at the sites sampled ( $47.3 \pm 8.2\%$ ). Chironomid larvae are common in benthic samples across North America, tolerate a wide range of contaminant conditions, and are preferred prey of fish (Rehwoldt et al., 1973). Other sampled taxa included Isopoda ( $15.7 \pm 4.5\%$ ), Amphipoda ( $13.7 \pm 5.6\%$ ), Oligochaeta ( $10.9 \pm 6.3\%$ ), Coleoptera ( $4.9 \pm 2.7\%$ ), Bivalvia ( $3.9 \pm 2.0\%$ ), Trichoptera ( $2.1 \pm 1.2\%$ ), Gastropoda ( $0.5 \pm 0.5\%$ ), Ephemeroptera ( $0.4 \pm$

$0.4\%$ ), Megaloptera ( $0.3 \pm 0.3\%$ ), and Plecoptera ( $0.1 \pm 0.1\%$ ) (Figure 3).

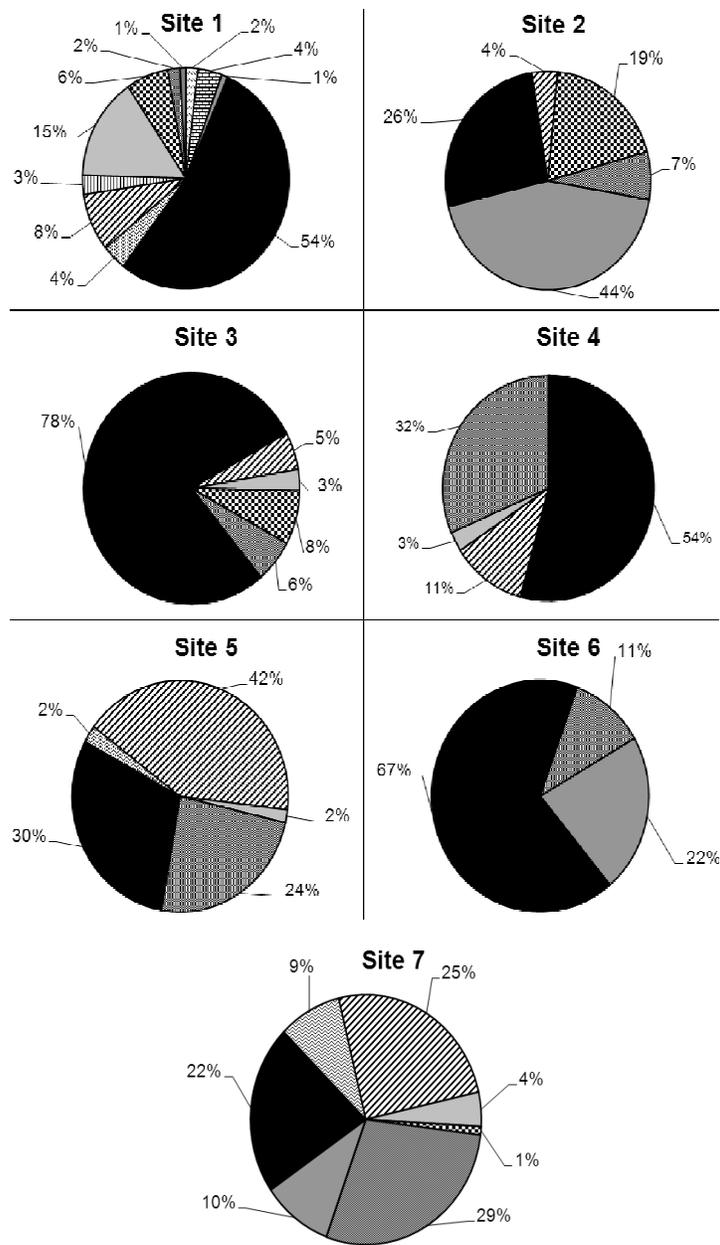
Biotic index values for Sites 3 and 6 indicated gross pollution and the index value for Site 2 was only one unit above the gross pollution value (Table 2). Site 6 in Tributary #3 was where sediment was removed less than a year before this study; its low biotic index value indicated that the benthic community had not recovered. Sites 2 and 3 are located at road crossings where bridge impacts or contaminants from traffic may adversely affect the benthic communities. The remaining sites (1, 4, 5, 7) all were categorized as moderately polluted (Table 2), suggesting that this is the general condition of benthic communities in Brockport Creek. However, Site 7 immediately upstream from the remediation site and Site 1 farthest downstream had the highest biotic index values whereas Sites 4 and 5 immediately downstream from the remediation site had intermediate values. Due to the binding of PCBs (Mayer et al. 1977; Jota and Hassett 1991;



**Figure 2.** Concentrations of PCB Aroclors (A): 1242 (■), 1254 (□), 1260 (▒) and selected heavy metals (B): Arsenic (▣), Barium (▤), Cadmium (▥), Chromium (▦), Copper (▧), Lead (▨), Nickel (▩), and Zinc (▪) in composite sediment samples from Brockport Creek (BC) and Tributary #3 (T3) near an abandoned industrial site before (Sites A-C; T3-Pre) and one year after (Sites 3-5, BC-Post; Site 6, T3-Post) removal of contaminated sediments from Tributary #3. HHL = Health Hazard Limit (USEPA, 1986).

Hanberg 1996; Uhle et al., 1999; Robertson and Hansen 2001) and heavy metals (Nehring 1976; House et al 1992; Calmano et al., 1993; Salomons and Stigliani 1995;

Chen et al. 1996; Rauret 1998; Yu et al., 2001; Filgueiras et al. 2004) to organic compounds and sediment particles, the biotic index data suggest that sediment



**Figure 3.** Invertebrates collected at seven sites in Brockport Creek and Tributary #3: Megaloptera, Gastropoda, Oligochaeta, Diptera, Trichoptera, Amphipoda, Ephemeroptera, Bivalvia, Coleoptera, Isopoda, Plecoptera.

quality at Sites 4 and 5 in the past may have adversely affected the benthic communities immediately downstream from now remediated Tributary #3.

### Toxicity Testing

Using a variety of standard acute and chronic toxicity tests, *D. magna*, *H. azteca*, and *P. promelas* were

exposed to sediments from Sites 1 to 7 to evaluate their survival, growth (weight, length) or offspring production (Figures 4 to 7). Test organisms in direct contact with contaminated sediment best show relationships between concentration and survival. Sanders and Chandler (1972), Stalling and Mayer (1972), Giesy and Hoke (1989), Song and Breslin (1998), ASTM (2000), USEPA (2000), Rowe (2003), and Muscatello et al., (2006) all concluded that amphipods (example, *H. azteca*) and

**Table 2.** Scores and pollution categories at seven sites in Brockport Creek and Tributary #3 near an abandoned industrial site after removal of contaminated sediments. Biotic index =  $[2 \cdot (n \text{ in Class 1}) + (n \text{ in Class 2})]$ , where  $n$  = number of taxa in each pollution class by Order. Index score: 0-2 = grossly polluted, 3-9 = moderately polluted, >10 = clean stream.

Taxon	Pollution class	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Megaloptera	2	1	0	0	0	0	0	0
Gastropoda	3	1	0	0	0	0	0	0
Oligochaeta	3	1	1	0	0	0	1	1
Diptera	3	3	2	1	3	1	1	1
Trichoptera	2	1	0	0	0	2	0	1
Amphipoda	2	1	1	1	1	1	0	1
Ephemeroptera	1	1	0	0	0	0	0	0
Coleoptera	3	1	3	1	0	0	0	1
Isopoda	2	1	1	1	1	1	1	0
Plecoptera	1	1	0	0	0	0	0	0
	<b>Index Score</b>	8	3	2	4	4	1	5
	<b>Class</b>	<b>Mod</b>	<b>Mod</b>	<b>Gross</b>	<b>Mod</b>	<b>Mod</b>	<b>Gross</b>	<b>Mod</b>

**Table 3.** Mean ( $\pm$ SE) percent survival, change in length, and offspring production in significantly different toxicity tests for organisms exposed to sediments from six sites in Brockport Creek and one site in Tributary #3 near an abandoned industrial site one year after removal of contaminated sediments. Sites with the different letter designations (a, b, c, d) belong to statistically heterogeneous groups ( $P < 0.05$ ).

Survival test (%)	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Acute, 48-h <i>Daphnia</i>	28 $\pm$ 4.8 <sup>d</sup>	38 $\pm$ 7.5 <sup>d</sup>	40 $\pm$ 4.1 <sup>d</sup>	68 $\pm$ 4.8 <sup>c</sup>	73 $\pm$ 2.5 <sup>bc</sup>	9 $\pm$ 4.8 <sup>ab</sup>	95 $\pm$ 2.9 <sup>a</sup>
Acute, 10-d <i>Hyalella</i>	82 $\pm$ 5.8 <sup>ab</sup>	72 $\pm$ 11.6 <sup>abc</sup>	82 $\pm$ 4 <sup>ab</sup>	54 $\pm$ 4 <sup>c</sup>	86 $\pm$ 5.1 <sup>a</sup>	64 $\pm$ 6.8 <sup>bc</sup>	66 $\pm$ 10.3 <sup>abc</sup>
Acute, 7-d Larval Fathead Minnow	80 $\pm$ 3.2 <sup>a</sup>	50 $\pm$ 11.4 <sup>ab</sup>	78 $\pm$ 8 <sup>a</sup>	68 $\pm$ 3.7 <sup>ab</sup>	44 $\pm$ 6 <sup>b</sup>	76 $\pm$ 8.7 <sup>ab</sup>	70 $\pm$ 5.5 <sup>ab</sup>
<b>Growth in length (mm)</b>							
Acute, 10-d <i>Hyalella</i>	1.6 $\pm$ 0 <sup>b</sup>	1.8 $\pm$ 0.1 <sup>ab</sup>	1.9 $\pm$ 0.1 <sup>ab</sup>	1.9 $\pm$ 0.1 <sup>ab</sup>	2 $\pm$ 0.1 <sup>ab</sup>	1.7 $\pm$ 0.2 <sup>ab</sup>	2.1 $\pm$ 0 <sup>a</sup>
<b>Offspring production (#/adult)</b>							
Chronic, 10-d <i>Daphnia</i>	3 $\pm$ 0.5 <sup>c</sup>	2 $\pm$ 0 <sup>c</sup>	6 $\pm$ 0.5 <sup>bc</sup>	5 $\pm$ 0.5 <sup>c</sup>	6 $\pm$ 0 <sup>bc</sup>	11 $\pm$ 1.5 <sup>ab</sup>	12 $\pm$ 2 <sup>a</sup>

larval fish (example, *P. promelas*) accumulate substantial amounts of contaminants during contact with bottom sediment which can directly affect their survival and reproduction. These authors also mention the usefulness of *Daphnia* as another health indicator as they rapidly accumulate contaminants that are suspended in the water column.

Therefore, we believe our choices of test organisms were appropriate.

For the 28-, 35- and 42-day chronic tests for *H. azteca* and the 96-h acute test for *P. promelas* there were no significant differences in survival among Sites 1 to 7.

Three tests indicated significant differences in survival among sites (Figure 4, Table 3):

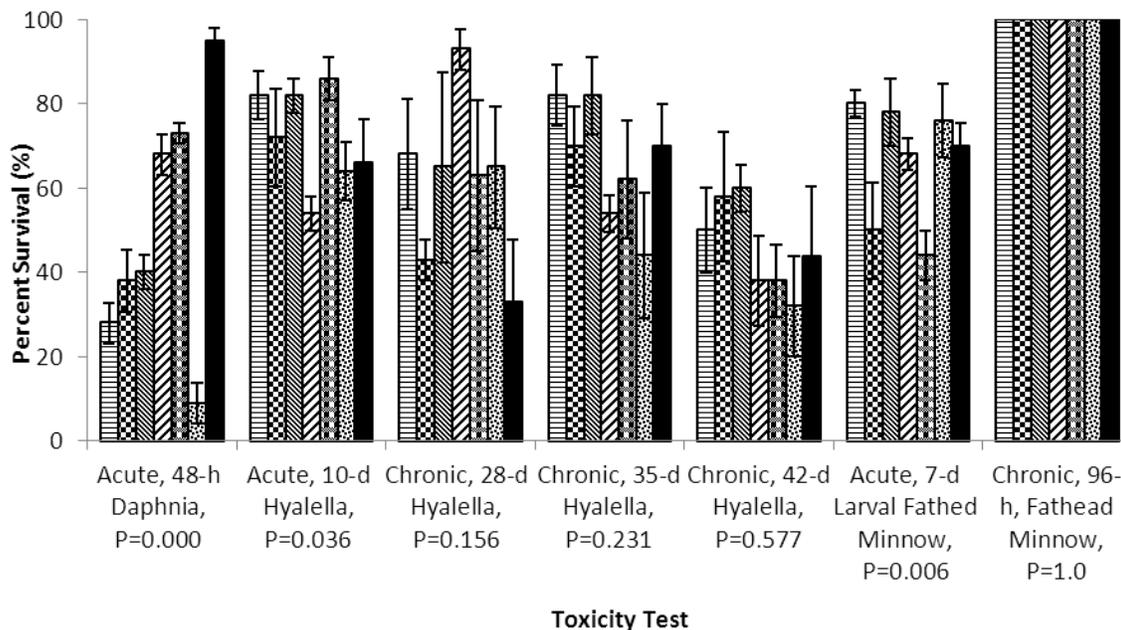
(1) *H. azteca*, 10-day acute test (1,2,3, 5 > 6,7 > 4;  $P = 0.036$ ).

(2) *D. magna*, 48-h acute test (7 > 4, 5 > 1, 2,3 > 6;  $P < 0.001$ ).

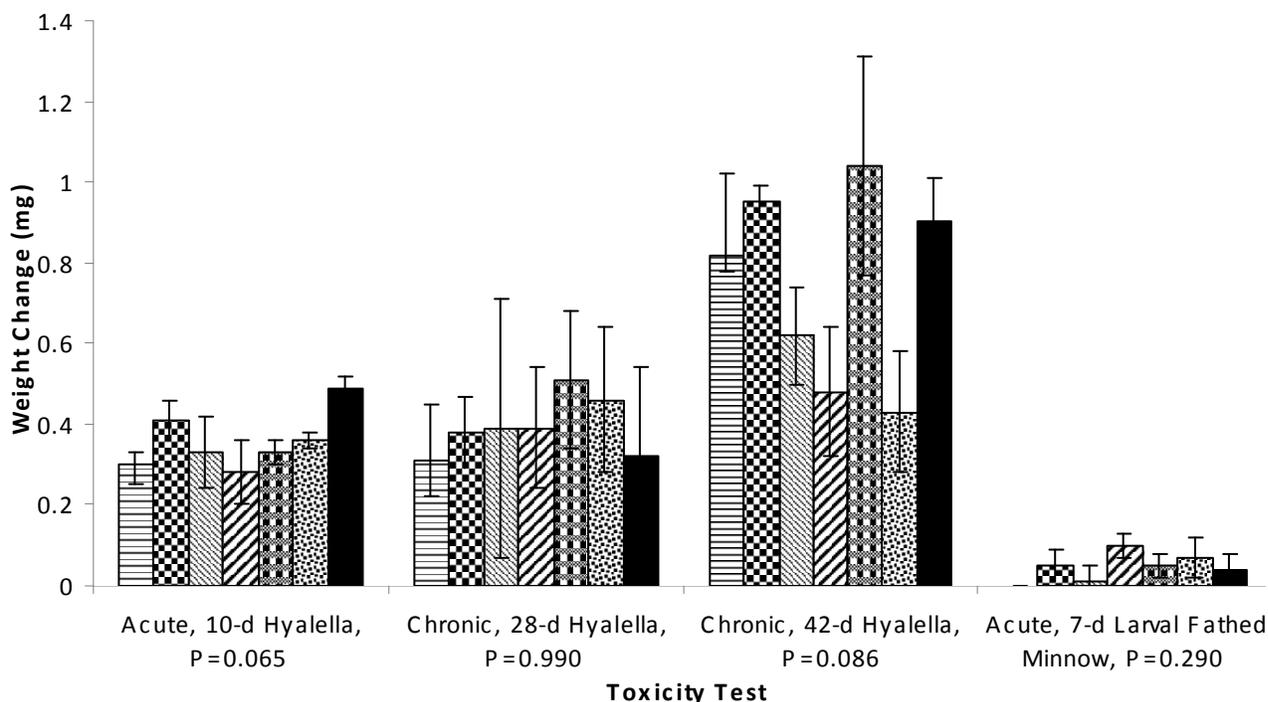
(3) *P. promelas*, 7-day acute test (7, 6, 4,3,1 > 5,2;  $P = 0.006$ ).

There were no significant changes in test organism weight (Figure 5) and only one significant change in length (Figure 6, Table 3). For the *H. azteca*, 10-day acute test, test organisms grew significantly less in length ( $P = 0.043$ ) when exposed to sediment from Site 1 than the other six sites. In the two reproduction tests (Figure 7), there was no difference in toxicity among sites for the *H. azteca*, 42-day chronic tests but there was a significant difference for the *D. magna*, 10-day chronic test (7,6 > 3,4,5 > 1,2;  $P < 0.001$  Table 3).

The removal of contaminated sediment to reduce PCB and heavy metal presence is a widely used technique. Within the Great Lakes drainage, Zarull et al. (1999) summarized success in 20 Areas of Concern (AOC) where contaminated sediment was removed and increased



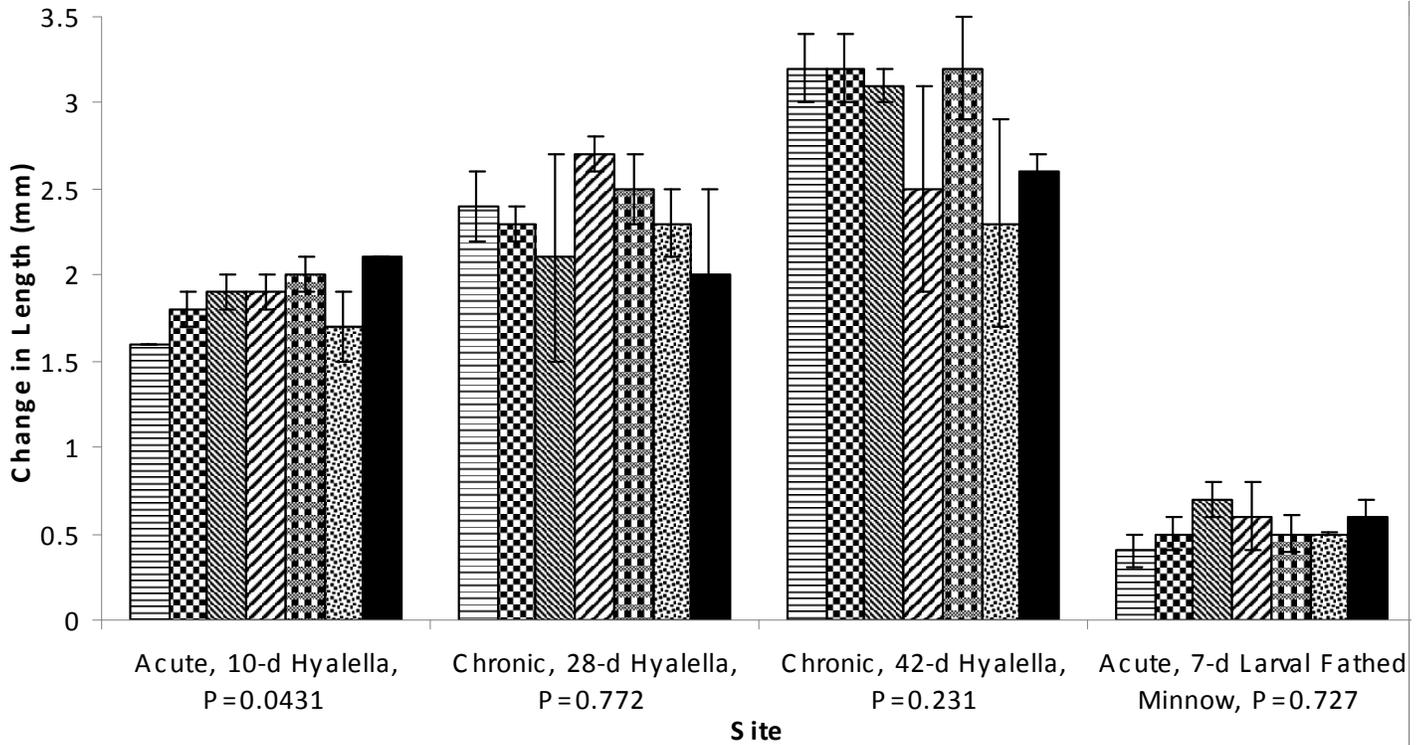
**Figure 4.** Mean percent survival (mean  $\pm$  SE) of organisms exposed to sediment from six sites in Brockport Creek: Site 1  Site 2  Site 3  Site 4  Site 5  Site 7  and one site in Tributary #3: Site 6 , near an abandoned industrial site one year after removal of contaminated sediments.



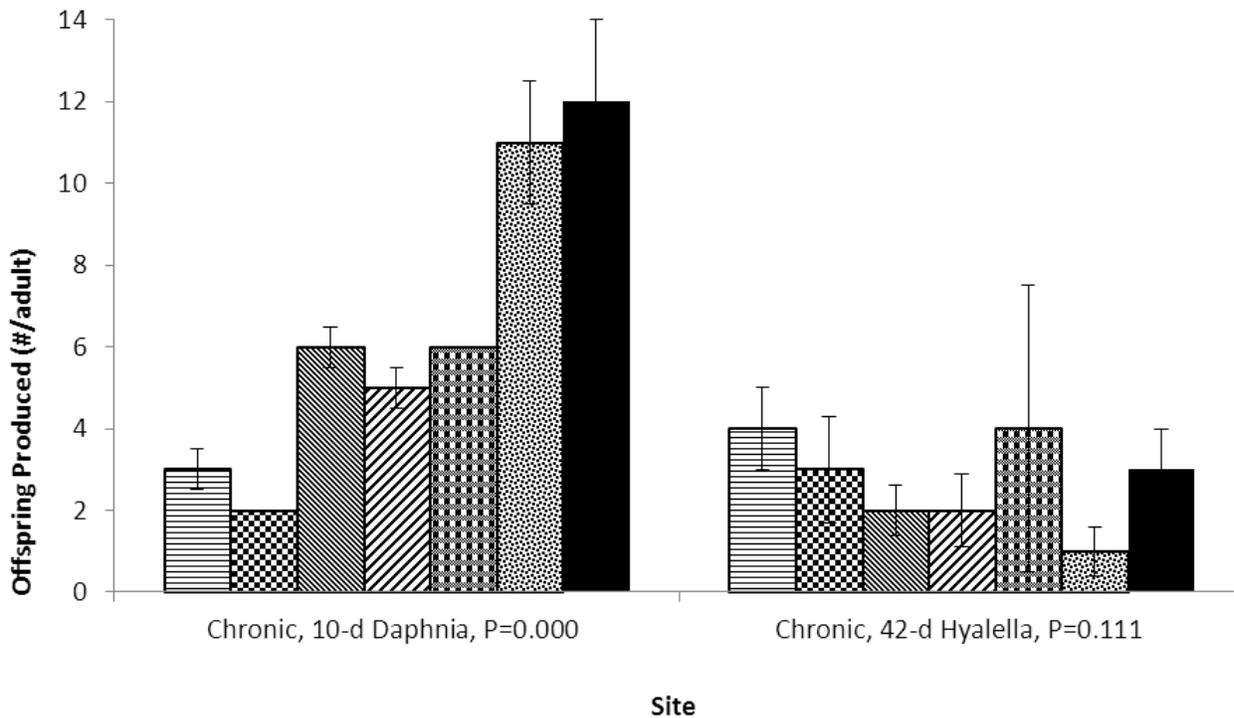
**Figure 5.** Mean change in weight (mg  $\pm$  SE) of organisms exposed to sediment from six sites in Brockport Creek: Site 1  Site 2  Site 3  Site 4  Site 5  Site 7  and one site in Tributary #3: Site 6 , near an abandoned industrial site one year after removal of contaminated sediments.

aquatic health was observed. In particular, following the removal of 5,900 and 30,000 m<sup>3</sup> of contaminated

sediment from Milwaukee Estuary and Waukegan Harbor, respectively, contaminant concentrations were



**Figure 6.** Mean change in length (mm  $\pm$  SE) of organisms exposed to sediment from six sites in Brockport Creek: Site 1 , Site 2 , Site 3 , Site 4 , Site 5 , Site 7  and one site in Tributary #3: Site 6 , near an abandoned industrial site one year after removal of contaminated sediments.



**Figure 7.** Mean offspring production ( $\pm$  SE) of organisms exposed to sediment from six sites in Brockport Creek: Site 1 , Site 2 , Site 3 , Site 4 , Site 5 , Site 7  and one site in Tributary #3: Site 6 , near an abandoned industrial site one year after removal of contaminated sediments.

below HHLs. Currently, the USEPA recognizes 43 AOC's within the Great Lakes drainage (US and Canada) with two Canadian waters (Collingwood Harbor and Severn Sound) and one U.S. water (Oswego River, NY) becoming delisted (USEPA 2011).

## Conclusion

Our data suggest that remediation of contaminated sediments in Tributary #3 was successful. Total PCB concentrations are now below the HHL at all sites sampled. The concentrations of eight metals were substantially reduced by sediment removal in Tributary #3; however, background levels of metals in the rocks of the region are naturally high and the concentrations of most metals remain above their HHLs at most of the sampled sites. The index used to assess benthic macro invertebrate health indicates moderately polluted conditions at the majority of sampled sites; sites with better or worse values are best explained by unique features of their locations rather than exposure to contaminants from Tributary #3. Finally, no consistent pattern of toxicity among test organisms was observed in relation to the locations of sediment samples taken from Brockport Creek and Tributary #3. For all of these reasons, it is reasonable to conclude that the remediation of Tributary #3 was successful. Focused studies and data collection monitoring the recovery of Brockport Creek and Tributary #3 are needed.

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