Trace Metals Contamination of Urban Streams and Stormwater Detention Ponds

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In 1991, trace metal levels were monitored over a nine month period in two urban creeks in the Hamilton Harbour watershed and in two urban stormwater detention ponds in Guelph, Ontario. Samples were collected both during dry or non-event periods and immediately after wet weather events. Both water and surficial sediment samples were tested for cadmium, copper, lead, mercury, nickel and zinc. In almost all cases wet weather concentrations of lead, copper and zinc in the water collected from the two urban streams exceeded the Canadian Water Quality Guidelines (CWQGs) for the protection of freshwater aquatic life. While not designed for water quality improvement, both stormwater ponds reduced the levels of metals in discharged water, but in the process trace metals accumulated in sediment to levels above the lowest effect level guideline for the protection and management of aquatic sediment in Ontario, and in the case of zinc above the severe effect level guideline. Although these levels are above guidelines, further investigation is needed to establish a relationship between metal contamination and biological impacts. This is particularly important for ponds intended for the dual purposes of stormwater treatment and as habitat for biota.

17.1 Introduction

In order to characterize water quality from two streams whose watersheds have been partially urbanized (10-40%) and two urban residential stormwater detention ponds, a sampling program involving both baseline (dry weather) and

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event (wet weather) sampling was undertaken over nine months in 1991. While neither pond was specifically designed to impact on water quality, detention and vegetative features of these ponds did result in significant reductions in many conventional pollutants (Licisko, 1992). Measured removal efficiencies for many pollutants were similar to those reported for other stormwater detention ponds in Ontario (MOE, 1991).

Sampling the water discharged from two different types of stormwater detention ponds provides information on the possible use of these structures for improving stormwater discharged to streams of the type also sampled in this study. While some sampling focused on conventional parameters (Licisko, 1992) also of particular concern were the levels and fate of toxins such as trace metals and trace organics. The trace organics analysis focused on persistent organochlorine compounds and in-use pesticides in both sediment and water and has been reported on elsewhere (Struger et. al., 1993). This report focuses on the trace metals levels in water and surficial sediment in both ponds and in the two streams.

17.2 Water and Sediment Sampling Methodology

Water samples were collected on an event basis from the outlets of both stormwater detention ponds which receive stormwater from upstream residential land-uses. Samples were collected during or after rain events from April, 1991 to December of 1991. Samples were collected from the outlets of both detention ponds approximately two hours after the start of a rainfall event. Base-line or non-event samples were also collected in both ponds.

During the same period both streams were sampled between one to three hours after the start of moderate to heavy rainfall. In order to obtain baseline or non-event levels for trace metals in water, dry weather samples were also collected at each of the sample sites.

Analyses completed on water samples included six heavy metals (cadmium, copper, lead, mercury, nickel, zinc) nutrients (total phosphorus, ortho-phosphorus, total kjeldahl nitrogen, ammonia, nitrate), selected ions (sodium, potassium), dissolved organic and inorganic carbon, pH, conductivity and turbidity. The levels of cadmium, copper, lead, mercury, nickel and zinc were also determined in the surficial sediment samples.

Surficial sediment (top 1 to 2 cm of sediment) samples were collected from four samples sites between April to December of 1991 (spring, summer and fall). Stream sediment samples were collected as close as possible to their outlets into Hamilton Harbour while avoiding backwater effects. Samples collected in the dry pond were collected from a perennial low flow channel in the pond.

To avoid contamination, sample bottle preparation and handling adhered to procedures outlined by McCrea and Fischer (1993). All analyses were completed

by the methods outlined in the National Water Quality Laboratory Manual (Environment Canada, 1995).

17.3 Results and Discussion

Sample results have been summarized using the following format. Mean baseline or non-event (dry) and wet-weather or event (wet) results from the two streams are shown separately while both wet and dry values for each pond are combined. The combining of wet and dry weather data for the two ponds was felt to be justified on the basis that both ponds, the dry pond to a lesser extent, retain some water between events, consequently the water flowing from the pond during a rain event may in fact represent water from a prior rain event. The small data set (four samples) for each pond site also provided justification for combining the sampling results for these two sample locations. The distinction made earlier between baseline and wet-weather or event sampling worked well for the analysis of data from the stream sampling portion of this study.

17.3.1 Conventional Water Quality Parameters

Baseline values for several conventional parameters were similar for both streams (Table 17.1). Differences in the amount of urban land-use between the two streams did not appear to cause large differences in the baseline values between these two streams. Red Hill Creek baseline samples had, however, slightly higher concentrations for all nutrients and for sodium. For both streams large increases during wet weather were observed for total and ortho-phosphorus, and turbidity. Concentrations of dissolved organic carbon and total kjeldahl nitrogen also increased during wet weather sampling of the two streams.

Mixing of stream baseflow, originating mainly from groundwater, with surface runoff during wet weather resulted in the concentration of several measured parameters being lower during wet weather (sodium, potassium, conductivity). Clear differences between baseline and wet weather sampling of the two streams were not evident for pH, nitrate, ammonia or dissolved inorganic carbon.

Water discharged from the two ponds was in some respects similar to the quality of baseflow in the two streams. Total phosphorus and ortho-phosphorus concentrations as well as turbidity levels in the water from the wet pond were, however, slightly higher than the water sampled from the dry pond and both streams. Since the two ponds receive primarily surface flows, concentrations of dissolved ions were also different from those seen in the two streams.

Table 17.1 Water quality characteristics at sampling sites.

Sample Site	Spencer	Red Hill	Spencer (% increase or decrease)	Red Hill (% increase or decrease)	Wet Pond	Dry Pond
Number of samples	5	4	10	11	4	4
Type of Sample	Dry ¹	Dry	Wet ²	Wet	Both	Both
Dissolved organic carbon (mg/L)	4.8	3.6	6.2 (+ 29 %)	5.7 (+ 59 %)	6.1	3.3
Dissolved inorganic carbon (mg/L)	35.8	25.2	38.9 (+ 8 %)	26.3 (+ 4 %)	12.8	34.9
Total Phosphorus (mg/L)	0.039	0.07	0.404 (+ 942 %)	0.427 (+ 538 %)	0.202	0.016
Ortho-phosphorus (mg/L)	0.016	0.038	0.097 (+ 506 %)	0.0674 (+ 79 %)	0.140	0.006
Total Kjeldahl Nitrogen as N (mg/L)	0.607	1.000	1.298 (+ 114 %)	1.51 (+ 51 %)	1.477	0.224
Nitrate as N (mg/L)	1.10	1.553	0.932 (- 16 %)	1.957 (+ 26 %)	0.417	1.77
Ammonia as N (mg/L)	0.19	0.397	0.200 (+ 4 %)	0.150 (- 62 %)	0.302	0.019
pH	7.85	7.64	7.67 (- 2 %)	7.52 (- 1 %)	7.83	7.61
Specific Conductance (μ S/cm)	1212	1439	724 (- 40 %)	847 (- 41 %)	332	509
Turbidity (NTU)	0.61	0.81	26.6 (+ 4236 %)	132 (+ 16196 %)	4.57	1.78
Sodium (mg/L)	41.7	121	30.9 (- 26 %)	84.9 (- 30 %)	16.8	31.6
Potassium (mg/L)	6.4	7.2	3.9 (- 39 %)	6.13 (- 15 %)	4.30	1.35

1. Dry weather sampling

2. Wet weather sampling

17.3.2 Trace Metals Levels in Water

Dry weather flow metal concentrations were lower than the CWQGs (Environment Canada, 1992) for the protection of aquatic life at an assumed best case scenario (water hardness greater than 180mg/L CaCO₃; Table 17.2). For both streams wet weather concentrations of copper, lead and zinc exceeded the Canadian guidelines for the protection of freshwater aquatic life. Water discharged from both the wet and dry pond were generally at or below the guidelines for the protection of freshwater aquatic life. Water discharged from the dry pond had lower metals concentrations than did the wet pond for all metals except zinc. Roof leaders in the catchment which had the dry pond are directly connected to the storm sewer system while the roof leaders in the wet pond's catchment generally

Table 17.2 Dry and wet weather metal concentrations in water samples.

Sample Site	Spencer	Red Hill	Spencer (% increase or decrease)	Red Hill (% increase or decrease)	Wet Pond	Dry Pond	CWQG Freshwater aquatic life, water hardness > 180 mg/L (CaCO ₃)
Number of samples	4	4	10	11	8	7	
Type of Sample	Dry	Dry	Wet	Wet	Both	Both	
Cadmium (µg/L)	0.2	0.3	0.3 (+ 65 %)	0.5 (+ 85 %)	0.2	0.2	1.8
Copper (µg/L)	1.9	3.4	20.4 (+ 990 %)	28.2 (+ 728 %)	4.5	1.5	4
Lead (µg/L)	0.9	1.1	11.8 (+ 1288 %)	17.6 (+ 1467 %)	3.6	0.3	7
Mercury (µg/L)	.025	.05	.12 (+ 380 %)	.045 (- 9 %)	.025	nd	0.1
Nickel (µg/L)	6.6	5.2	10.8 (+ 64 %)	12.9 (+ 150 %)	1.7	0.9	150
Zinc (µg/L)	10.7	13.4	84.9 (+ 695 %)	108.9 (+ 711 %)	15.2	51.4	30

drained onto lawns. Corroding of leaders may account for the elevated zinc concentrations discharged from the dry pond.

To gage the frequency with which the two streams sampled could be expected to have elevated levels of trace metals, stream flows corresponding to the time of sample collection were plotted with respect to the long-term flow duration curve for one of the streams (Spencer Creek). Although historical flow records are available for the second stream (Red Hill) flows were not recorded in 1991. The results shown in Figure 17.1 for Spencer Creek indicate that for the most part the sampling program focused, in relation to historical flows, on a number of small events which had a limited hydrologic impact on the stream, but which had a significant impact on trace metal levels. Conversely sampling of some medium sized flows, which corresponded to spring or winter baseflow conditions, had low metal concentrations.

Figure 17.1 Sampling in relation to the annual flow duration curve for Spencer Creek.

17.3.3 Trace Metals in Sediment

Sediment collected from each of the sample locations reflected the pattern of concentration measured in water samples (Table 17.3). Both stormwater ponds and streams accumulated trace metals (copper, lead, nickel and zinc) to levels

Table 17.3 Trace metal levels in surficial sediment samples.
Concentration of selected heavy metals in sediment (all concentrations in $\mu\text{g/g}$ of dried surface sediment)

Sample Site	Spencer	Red Hill	Wet Pond	Dry Pond	Interim freshwater quality assessment values, and incidence (%) of adverse biological effects in concentration ranges defined by these values (Environment Canada, 1994).			Guidelines for the Protection and Management of Aquatic Sediments in Ontario (Persaud et al., 1992)	
Number of samples	3	3	3	3	Threshold effect level (TEL)	Probable effect level (PEL)	% =>PEL	Lowest Effect Level	Severe Effect Level
Cadmium	nd	nd	0.38	2.25	0.596	3.53	47	0.6	10
Copper	39.5	41.2	44.9	99.9	35.7	196.6	43	16	110
Lead	36.1	40.8	88.7	203.3	35.0	91.3	42	31	250
Mercury	0.07	0.08	0.07	0.11	0.174	0.486	36	0.2	2
Nickel	22.7	22.2	18.9	19.9	18.0	35.9	44	16	75
Zinc	209	204	491.7	1666.7	123.1	314.8	36	120	820

above the interim threshold effect level (TEL) (Environment Canada, 1994) and above the MOE's lowest effect level for sediment (Persaud et al., 1992). However, since natural background levels of some trace metals are above Environment Canada's TEL and/or the MOE's lowest effect level associating biological effects with these levels would require some further investigation. The interim probable effect level (PEL) (Environment Canada, 1994) was exceeded for zinc in both detention ponds and for lead in the dry pond. The MOE's severe effect level was exceeded for zinc in the dry pond. The dry pond also had higher levels of zinc, cadmium, copper and lead than did the wet pond. This in part is likely a reflection of the number of years the pond has been in operation (about twenty years for the dry pond versus about six years for the wet pond).

17.4 Conclusions

- During wet weather, concentrations of zinc, lead, and copper, in both streams exceeded the CWQGs for the protection of freshwater aquatic life. The concentration of copper in water discharged from the wet pond and zinc in water discharged from the dry pond also exceeded the CWQGs.
- Stormwater treatment facilities appear to effectively prevent metals from contaminating downstream waters or sediment. The trace metals accumulating in the sediment of these ponds, however, needs to be carefully managed. The degree to which utilization of these facilities by wildlife and fish, particularly waterfowl, poses a contamination risk is not known and needs to be investigated. In the interim, strategies which deter the use of these facilities by wildlife warrants careful consideration. This is particularly true for detention ponds which receive stormwater water high in trace metals.
- Hydrologically active areas in watersheds during summer low flow periods often correspond to the urban landuses within their boundaries. During these periods not only are the flows often uncharacteristic of pre-existing hydrologic condition but trace contaminants, including trace metals and pesticides (see Struger et. al, 1993) are often present above levels reported to cause biological effects. This is particularly important since elevated temperatures, reduced oxygen concentrations and suspended sediment are all also often present in stormwater and present additional stresses.

References

- Environment Canada. 1992. Canadian Water Quality Guidelines. Water Quality Objectives Division, Water Quality Branch, Inland Waters Directorate, Environment Canada, Ottawa, Ontario, Canada, K1A 0E7.
- Environment Canada. 1994. Interim Sediment Quality Assessment Values, Manuscript Report, Guidelines Division, Evaluation and Interpretation Branch, Ecosystem Conservation Directorate, Environment Canada, Ottawa, Ontario, K1A 0H3. 8pp.
- Environment Canada. 1995. Manual of Analytical Methods, Volume 2, Trace Metals. The National Laboratory for Environment Testing, Canada Centre for Inland Waters, 867 Lakeshore Rd. P.O. Box 5050, Burlington, Ontario, L7R 4A6.
- Licsko, Z.J. 1992. Quality of Stormwater from Residential Areas in Guelph. M.Sc. Thesis, School of Engineering, University of Guelph, Guelph, Ontario N1G 4A6. 147pp.
- McCrea R.C. and J.D. Fischer. 1993. Quality Assurance and Control Considerations for the Isomet Stream Sampler. Environment Canada, Environmental Conservation, Ontario Region, 867 Lakeshore Road, P.O. Box 5050, Burlington, Ontario, L7R 4A6.
- MOE (Ontario Ministry of the Environment). 1990. Low Flow Characteristics in Ontario. Appendix D: Southwestern and West Central Region. Water Resources Branch, Environmental Services, Ontario Ministry of the Environment. Queen's Printer for Ontario, Toronto, Ontario.
- MOE (Ontario Ministry of the Environment). 1991. Stormwater Quality Best Management Practices. Queen's Printer for Ontario, Toronto, Ontario. 177pp.
- Persaud, D. R. Jaagumagi and A. Hayton. 1992. Guidelines for the Protection and Management of Aquatic Sediment in Ontario. Water Resources Branch, Ontario Ministry of the Environment, Queen's Printer, Toronto, Ontario. 23pp.
- Struger, J., D. Boyter, Z.J. Licsko and B.D. Johnson. 1993. Environmental Concentrations of Urban Pesticides. Current Practices in Modeling the Management of Stormwater Impacts, CRC Press, Boca Raton, Fl. pp85-98.

For further reading on discharge to wetlands:

- US Environmental Protection Agency, 1993. Natural Wetlands and Urban Stormwater: Potential Impacts and Management. Office of Wetlands, Oceans and Watersheds, Wetlands Division. Washington, DC. EPA# 843-R-001. 76pp.