Environmental Factors Affecting Methoprene Concentrations for West Nile Virus Control in a Storm Sewer System

James Y. Li,* Ching Lo, Peter D. Luciani, Angelune Des Lauriers, Kevin Sze, Jiang Shao, Wayne Komer, Ken Wilkinson, David Truen, and Rod Anderton

Department of Civil Engineering, Ryerson University, 350 Victoria Street, Toronto, Ontario, Canada M5B 2K3

To address vector-borne West Nile virus in Canada, chemical larvicides (methoprene) are applied to storm sewer system catch basins (CBs) to control mosquitoes. This study assessed the fate and transport of methoprene in such systems over time relative to precipitation. Rainfall and methoprene concentration patterns revealed the effect of dilution, dissolution, and flushing of the larvicide. In the summer and fall of 2003 to 2005, field monitoring studies were conducted in Toronto, Ontario on two CBs, each treated with a control dose of methoprene, supplied in pellet or ingot formulation. Furthermore, in 2005, concentrations at the storm sewer outfall were measured during nine rainfall events. Based on daily monitoring, findings indicate that (1) the methoprene concentration at the CBs fell below the minimum lethal concentration or LC$_{50}$ one or two weeks after treatment, and remained below LC$_{50}$ concentrations over 70% of the time; (2) rainfall flushed methoprene from the CBs to the storm sewer outfall at concentrations higher than the levels specified by Ministry of Environment, which may cause ecosystem damage; (3) based on the number of cycles per diem within each CB in each study period, there was no conclusive pattern in the flushing susceptibility of pellets versus ingots; (4) the mean concentration of methoprene increased with reduced CB sump volume; (5) less total precipitation resulted in higher average methoprene concentrations and a higher number of days above the LC$_{50}$ based on ingot-dosed CBs; (6) counter-intuitive to (4) and (5), larger sump water volumes and greater rainfall resulted in lower mean concentrations and fewer days above the LC$_{50}$; and (7) a single ingot dosage was comparable in performance to a three pellet dosage.

Key words: West Nile virus, methoprene, larvicides, rainfall

Introduction

The West Nile virus, transmitted to humans by mosquitoes, is established in Ontario, Canada (MOHLTC 2008). According to the City of Toronto, 98 humans tested positive for West Nile virus between 2003 and 2007 (Toronto Public Health 2007). Catch basins (CBs) were identified as being important breeding grounds of mosquitoes, and in Toronto it was confirmed that mosquito larvae of species likely to carry West Nile virus were present in most CBs sampled (City of Toronto 2008). The decision to larvicide CBs in the city was due to the large number of reported cases of infections in 2002. Since the larviciding programs in 2003, the number of reported infections have dropped significantly.

The City of Toronto undertook larviciding programs to control mosquitoes in the summer months of 2003 to 2005 during the peak reproduction cycle of *Culex pipiens*. In 2005 a total of 197,052 CBs were treated. The larvicide, methoprene, commercially known as Altosid in pellet formulation, Registration #21809 under the Pest Control Products Act, Canada, contains approximately 4.25% active ingredient. The ingot is a slow release formulation. Methoprene (isopropyl-11-methoxy-3,7,11-trimethyl-2-4-dodecadienoate) kills mosquitoes by preventing the natural maturation of larvae, and has a LC$_{50}$ of 0.3 to 2.3 μg/L for *Culex pipiens* (Amin and White 1984; Ali et al. 1995). Methoprene is considered by the U.S. Environmental Protection Agency (U.S. EPA) as a ‘least toxic’ insecticide (U.S. EPA 2000). Spiegel and Novak (1999) found that methoprene was effective in Illinois CBs for one month, despite physical variations and differing water depth in the CBs.

The fate and transport of methoprene formulations from stormwater sewer systems to watersheds in Canada is largely unknown. In 2003, Struger et al. (2007) conducted a field study on the occurrence and fate of methoprene and its metabolites in CBs and receiving water in Hamilton Harbour and Cootes Paradise in Ontario. They concluded that dissolved methoprene and its derivatives are quickly flushed from CBs during rainfall events. However, concentrations at the outfalls fell quickly and were mostly undetectable in the receiving waters. The half-life of methoprene in the environment is four weeks for hydrolysis, 10 hours for photolysis, and 10 days in soil, and its water solubility is <200 μg/L (Wellmark International 2004). Although methoprene toxicity to fish is low (LC$_{50}$ for bluegill trout is 760 μg/L), levels in excess of 10 μg/L could have detrimental effects on nontarget invertebrates that are important sources of food for fish (Ross et al. 1994). Fish and frog deformities may be attributed to the metabolite methoprenoic acid, which mimics retinoic acid (Kleiner 1997; LaClair et al. 1998; Sea Technology 1999). Methoprene and its
metabolites may also have unknown effects downstream from where it is applied.

Former research at Ryerson University has evaluated methoprene concentrations relative to rainfall and CB sump volumes within three discrete periods in 2003 to 2005. This paper presents the fate of methoprene at the CBs and the storm sewer outfall, and a multidimensional factor analysis of methoprene concentrations with respect to the methoprene formulation (i.e., ingot versus pellet), water levels at the CBs, and rainfall over the three years. To our knowledge, this is the first multiyear analysis of the fate, transport, and critical environmental factors affecting methoprene in a storm sewer system in North America. It is hoped that the findings may improve program efficacy and cost-effectiveness for reducing human infection rates of West Nile virus while balancing negative ecological impacts. The scope of the research was limited to field study monitoring and water sample analysis.

Methods

Field Study Method

The study site consisted of two CBs on Silverview Drive near the intersection of Willowdale Avenue within the Newtonbrook sewershed in Toronto. The streets service medium- to low-density residential land that includes trees and lawns. One of the CBs is shallow (11.5-cm sump water depth) and the other deep (106-cm sump water depth). The storm sewer outfall is 50 m southeast of the Willowdale Avenue / Silverview Drive Intersection, and becomes the origin of Newtonbrook Creek which joins the East Don River. The East Don River is part of the Don River, which flows into Lake Ontario via the Toronto Harbour. The storm sewer system drains an approximately 360 hectare basin.

In 2003, three separate gauges recorded rainfall data: Earl Bales station at Bathurst Street and Sheppard Avenue (approximately 3.75 km to the southwest); Mitchell field station at Church Avenue (approximately 1.13 km to the south); and a local station at Willowdale Avenue and Silverview Drive to the northeast. In 2004 and 2005, precipitation records used in the assessment came solely from the local gauge operating within the monitoring site. Through a field monitoring program, larvicide dosages were applied either as pellets (0.7g per CB) or a single ingot (45.33g per CB) as per Table 1.

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Year</th>
<th>Date (day-month)</th>
<th>Shallow CB</th>
<th>Deep CB</th>
</tr>
</thead>
<tbody>
<tr>
<td>pellet</td>
<td>2003</td>
<td>4-July</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9-August</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9-September</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ingot</td>
<td>2004</td>
<td>16-July</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ingot</td>
<td>2005</td>
<td>2-July</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Methoprene prevents emergence from the pupal stage with no effect on larvae. Altosid cylindrical pellets or chalk-like ingots are designed to inhibit mosquito emergence and be effective for up to 30 or 120 days, respectively, according to the manufacturer and field trials by Floore et al. (1991) and Spiegel and Novak (1999). Water was sampled daily from each CB using a small mechanical pump fitted with a long stainless steel tube. The outfall water was sampled during study-period rain events in 2003 to 2005 using an automatic wastewater sampler. Daily water samples were analyzed by the City of Toronto's Wastewater Laboratory for methoprene using the United States Geological Survey method of liquid-liquid extraction, and gas chromatography/mass spectrometry (GC/MS) (Zimmerman et al. 2001). The United States Geological Survey's method of analysis and quality assurance practice were developed for the determination of four mosquito insecticides (malathion, methoprene, phenothrin, and resmethrin) and one synergist (piperonyl butoxide) in water. The analytical method requires liquid-liquid extraction and GC/MS. Water samples were collected in glass-fibre bottles. At the laboratory, each bottle was assigned an identification number. A surrogate compound was added and a small volume of sample was removed from the bottle; the remaining sample in the bottle was mixed with hexane. The hexane extract was then removed and evaporated under nitrogen within the internal standard. The sample components were separated, identified, and measured by injecting an aliquot of the concentrated extract into a high-resolution, fused-silica capillary column of a GC/MS system under selected-ion mode (SIM). The compounds eluted from the GC column were subsequently identified by comparing their measured ions and retention times with the reference ions and retention times obtained by the measurement of control standards under the same conditions used for the water samples. The concentration of each identified compound was measured by assessing the mass spectrophotometer response of the quantitation ion produced by each compound in relation to the mass spectrophotometer response of the quantitation produced by the surrogate standard. The United States Geological Survey method detection limit ranged from 0.02 to 0.05 μg/L. The recovery factor for the methoprene ranged from 0.56 to 0.58.

Method of Analysis

Using the primary data collected from the field study, multidimensional factor comparisons were made through descriptive indicators that used basic statistical measures such as mean, standard deviation, percentage, and relative frequency. In Table 2, the indicators are grouped into the following categories: overall study; yearly overall; CB versus yearly; and CB overall. Notations below Table 2 define yearly rainfall and less obvious indicators.

A residual concentration spike which returns to a baseline value is considered a cycle. The multidimensional comparisons made in the next section include: overall dry versus wet weather years; deep versus shallow CBs; deep...
versus shallow CBs in dry versus wet ingot dosage years; and pellet versus ingot formulations in maintaining LC$_{50}$. In this manner, the general relationships and patterns between the factors of precipitation, CB sump volume, and methoprene formulation and concentrations are empirically described across the three study periods to aid in improving treatment efficiency. With these relationships and patterns highlighted, continued and refined field monitoring are needed to develop a more robust dataset to enable statistical analysis to be performed. Such analysis can ascertain if statistically valid correlations exist between those factors which can then be deemed most pertinent to improving the effectiveness of West Nile virus treatment programs.

**TABLE 2.** Methoprene monitoring results of CBs within study period in a letter by number matrix $^a$

<table>
<thead>
<tr>
<th>Year (rainfall): $^b$</th>
<th>2003 (wet)</th>
<th>2004 (dry)</th>
<th>2005 (wettest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sump water depth :</td>
<td>Shallow</td>
<td>Deep</td>
<td>Shallow</td>
</tr>
<tr>
<td>A</td>
<td>No. of study days</td>
<td>96</td>
<td>96</td>
</tr>
<tr>
<td>B</td>
<td>No. of doses</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>Dosage formulation (0.7g/CB)</td>
<td>Pellet</td>
<td>Pellet</td>
</tr>
<tr>
<td>D $^c$</td>
<td>Mean precip./dien (mm)</td>
<td>2.7</td>
<td>1.5</td>
</tr>
<tr>
<td>E</td>
<td>No. of rainfall events &gt; 5mm</td>
<td>13</td>
<td>8</td>
</tr>
</tbody>
</table>

**OVERALL STUDY**

| F                    | % of sample dates > LC$_{50}$/year | 12       | 22           | 8    |
| G                    | Mean meth. conc./year (µg/L) | 0.29     | 0.28         | 0.19 |
| H                    | SD of meth. conc./year | 1.41     | 0.47         | 0.74 |

**YEARLY OVERALL**

| I $^d$               | % of cycles > LC$_{50}$/CB/year | 75       | 0           | 64    | 50    | 50   | 33  |
| J $^e$               | % of sample dates > LC$_{50}$/CB/year | 24      | 0           | 17    | 28    | 13   | 4   |
| K $^f$               | Mean meth. conc./CB/year (µg/L) | 0.55     | 0.03        | 0.23  | 0.31  | 0.33 | 0.05 |
| L                    | SD of meth. conc./CB/year (µg/L) | 1.97     | 0.01        | 0.43  | 0.49  | 1.02 | 0.1 |
| M                    | Range of meth. conc. (µg/L) | 0.03–15.00 | 0.03–0.14 | 0.03–0.60 | 0.03–3.00 | 0.00–6.00 | 0.00–0.51 |
| N $^g$               | No. of cycles/dien | 0.13     | 0.04        | 0.11  | 0.12  | 0.07 | 0.07 |

**CB OVERALL**

| O $^b$               | 3-year mean of peak meth . conc./CB(µg/L) | 7.87     | 1.22         |       |
| P $^i$               | Mean no. of cycles/dien/CB | 0.1      | 0.08         |       |
| Q                    | Mean meth. conc./CB(µg/L) | 0.39     | 0.13         |       |
| R                    | SD of meth. conc./CB(µg/L) | 1.38     | 0.31         |       |
| S $^k$               | Absolute mean conc. dif. (deep vs shallow CB/year) (µg/L) | Year 2003 = 0.08 | Year 2005 = 0.28 |
| T $^m$               | Absolute mean conc. dif. (from 2004–2005/CB) (µg/L) | 0.10     | 0.26         |       |

$^a$ Abbreviations and acronyms: CB = catch basin; No. = number; precip. = precipitation; meth. = methoprene; conc. = concentration; SD = standard deviation; vs = versus.

$^b$ Rainfall in years 2003, 2004, and 2005 was 238.8 mm (wet), 143.2 mm (dry), and 253.3 mm (wettest), respectively.

$^c$ Mean precip./dien (mm) = average rainfall per day.

$^d$ % of cycles > LC$_{50}$/CB/year = percentage of cycles which exceed LC$_{50}$ concentration per catch basin per year.

$^e$ % of sample dates > LC$_{50}$/year = percentage of entire catch basin sump water sample dates that exceed LC$_{50}$ concentration in a study year’s period.

$^f$ Mean meth. conc./CB/year = average methoprene concentration per catch basin per year.

$^g$ No. of cycles/dien = average number of cycles per day.

$^h$ 3-year mean of peak meth. conc./CB = average of peak methoprene concentration over 3 study period years per catch basin.

$^i$ Mean no. of cycles/dien/ CB = average number of cycles per day per catch basin.

$^j$ Absolute mean conc. dif. (deep versus shallow CB/year) = cell (K,3) – cell (K,4) versus cell (K,5) – cell (K,6).

$^k$ Absolute mean conc. dif. (from 2004–2005/CB) = cell (K,5) – cell (K,3) versus cell (K,6) – (K,4).

TBA
Results and Discussion

Catch Basin Results

Results are summarized and referred to in Table 2 using row identifiers. Study years are classified as wet or dry noting a benchmark average annual rainfall in Toronto, Ontario, Canada at the Downsview station, 6158443 (Adams and Papa 2000). Normalized to 88.7 days (the minimum study period), the station’s average annual rainfall was 140.5 mm [(average volume/event (4.7mm) x average number of events (93.3)] at an inter-event time definition of 2 hours. Inter-event time definition is the minimum temporal spacing without rainfall to consider two rainfalls as belonging to different events for statistical analysis.

General trends. In general, within both CBs, rainfall diluted and flushed the methoprene, resulting in residual concentrations below the LC50 (0.3 μg/L) over 70% of the time. The highest percentage of sample dates exceeding the LC50 (28%) occurred in the dry year 2004 within the deep CB (row J, Table 2). The overall pattern observed was a concentration peak above the LC50 after the initial dosage, a flush and/or dilution during heavy rainfalls, and a slow recovery with a peak again (Fig. 1–5). Residual concentration spikes that return to a baseline value are considered cycles. In this study, such a cycle caused by a rainfall event was considered an indicator of a flushing event. The frequency of cycles tended to decrease over time as the formulation was dissolved, diluted, degraded, and flushed. During some extended dry weather periods, concentrations did peak above initial dosage concentrations over three- to five-day periods within the deep CB in 2004 and 2005 (Fig. 3 and 5). This may be due to the ingot’s slow-release formulation. Sump temperatures in the CBs were stable and permissive for mosquito reproduction at around 18.0 to 25°C throughout the study periods. Results were further analyzed below by the multidimensional comparisons.

Dry versus wet weather—ingot dosage study years. As indicated in Table 2, less precipitation across both basins resulted in a higher percentage of sample dates with concentrations above the LC50 (row F), and a higher mean concentration of methoprene (row G). Overall, this was likely caused by less volumetric dilution within the

![Fig. 1.](image) Hydrodynamics of a three-pellet methoprene dosage (application time indicated as “dose”) at the shallow catch basin in 2003; rainfall represented as bars from the top, and methoprene concentration as discrete points joined by a line after dosage points; the disconnections of plotted points are associated with missing data.
**Fig. 2.** Hydrodynamics of a single-ingot methoprene dosage (application time indicated as “dose”) at the shallow catch basin in 2004; rainfall represented as bars from the top, and methoprene concentration as discrete points, some connected by a line; the disconnections of plotted points are associated with missing data.

**Fig. 3.** Hydrodynamics of a single-ingot methoprene dosage (application time indicated as “dose”) at the deep catch basin in 2004; rainfall represented as bars from the top, and methoprene concentration as discrete points, some connected by a line; the disconnections of plotted points are associated with missing data.
Fig. 4. Hydrodynamics of a single-ingot methoprene dosage (application time indicated as “dose”) at the shallow catch basin in 2005; rainfall represented as bars from the top, and methoprene concentration as discrete points, some connected by a line; the disconnections of plotted points are associated with missing data.

Fig. 5. Hydrodynamics of a single-ingot methoprene dosage (application time indicated as “dose”) at the deep catch basin in 2005; rainfall represented as bars from the top, and methoprene concentration as discrete points, some connected by a line; the disconnections of plotted points are associated with missing data.
CBs, associated with a lower number of rainfall events (row E) and mean precipitation/diem (row D). Flushing (represented by the number of cycles per diem within each CB over the three study periods [row N]) displayed no identifiable pattern, and the mean number of cycles/diem/CB were separated by a value of 0.02 (row P) in the deep versus shallow CB.

**Deep versus shallow CB—overall.** In all study years, the shallow CB compared with the deep CB was subject to a higher percentage of cycles that had concentrations above the LC50 (row J) and the mean concentration (row Q). Based on this data, we concluded that as the CB sump water depth increased, the mean concentration of methoprene and the percentage of cycles that had concentrations above the LC50 were reduced. This relationship may be due to reduced volumetric dilution and not necessarily flushing based on cycling observations noted in Fig. 1 to 5.

**Deep versus shallow CB—dry versus wet study periods using ingots.** Based on the two relationships, established above, between rainfall and concentration and CB sump water depth and concentration, it would be expected that the shallow CB compared with the deep CB would achieve, in dry years, higher mean methoprene concentrations and a higher percentage of sample dates with levels over the LC50 and lower concentrations and percentage in the wet year. However, for the dry year (2004), the deep CB had a higher percentage of sample dates with concentrations over the LC50 (row J), and higher mean (row K) and peak (row M) methoprene concentrations compared with the shallow CB. In the wet year (2005), the shallow CB exhibited higher values, notwithstanding a short-term methoprene concentration response to the hydrodynamic characteristics of the deep and shallow CBs, as evident in Fig. 1 to 6. In 2003 (the other wet year), pellet dosages in the shallow CB versus the deep CB also exhibited similar results (row J; row K; and row M). Accordingly, it appears that as sump volume and rainfall increase, the mean concentration and days with concentrations above the LC50 decrease. These observations hint that methoprene in the shallow CB may be subject to an elevated degradation, perhaps due to (1) elevated biological activity associated with higher temperatures and less dilution, and (2) elevated photolytic degradation since light penetrates more readily through lower sump water volumes.

It is hypothesized that in a dry year, these factors seem to operate at a lesser rate than the effects of dilution in a wet year. The difference between the mean concentrations in the shallow and deep basins in the dry year (2004) is lower than that of the wet year (2005) at 0.08 μg/L versus 0.28 μg/L (Row S), respectively. Comparing the absolute change in concentration within the CBs from 2004 to 2005 (at 0.10 μg/L [shallow CB] versus 0.26 μg/L [Row T]) also lends evidence to this hypothesis. The deeper basin, aside from greater volumetric dilution, may be less susceptible to these degradation factors during the same dry period due to protection offered by a greater sump water volume. However, in a wet year, dilution rates were higher and may have had more effect upon the deeper basin. Dilution rates appear to have more effect on methoprene concentration than the rate of microbial and/or photolytic breakdown in a dry year. Further study that examines in situ sump water levels, temperature, rainfall, microbial activity, and photolytic degradation relative to methoprene concentrations may shed light on this phenomenon.

**Ingots versus pellets in both CBs under similar rainfall.** In the wet years of 2003 and 2005 (which exhibited similar mean annual volume and number of rainfall events), ingots appeared to be less prone than pellets to flushing, noting a mean number of cycles/diem to be 0.07, whereas pellets averaged 0.09 (row N, Table 2). Pellets had the highest susceptibility to flushing in wet years with lower sump water volumes (row N). Ingots exhibited a higher mean percentage of cycles with concentrations over the LC50 (derived from cell I, 5 – 6; and cell I, 1 – 2), notably due to increases observed within the deep CB. Nonetheless, in both CBs pellets do exceed ingots for the percentage of sample dates with concentrations over the LC50 (row F) and the mean methoprene concentration (row G) both by magnitudes of 1.5. Presumably, methoprene from a single ingot dosage is subject to increased photolytic, hydrolytic, and/or microbial degradation sitting in a CB sump, more so than a three-dosage pellet regime. Taken together, the data above indicate there is no substantive difference in performance between pellets and ingots. The result may be greater cost-effectiveness of a single ingot dosage regime in a given jurisdiction, acknowledging other cost factors such as labour.

Referring to Fig. 1 and 6, in 2003, rainfall data emanated from gauges outside of the sampling site. This may explain why the small methoprene peaks did not correspond well with rainfall events. After the rain gauge was installed in the monitoring site in 2004, the inverse correlation between rain events and residual methoprene concentrations became more readily observed (i.e., days 2, 10, 15 in Fig. 2).

In the deep CB (Fig. 3 and 5), methoprene concentrations peaked immediately after ingot application, and quickly fell below the LC50 and remained there except for the occasional one or two peaks. In 2004, residual concentrations were above the LC50 for 12 days. The drier season resulted in higher overall concentrations. However, in 2003 and 2005, the wet study years, the deep CB maintained very few sampling dates at or above LC50 concentrations.

**Sewer Outfall Results**

During the 2003 to 2005 study period, the storm sewer outfall was sampled during discrete rain events over the course of the field study (Fig. 7). Each study period exhibited
similar concentration to rainfall patterns. Accordingly, for brevity, 2005 has been selected as a representative year to review. The highest methoprene concentration observed in the outfall (1.20 μg/L) was below the U.S. EPA recommended environmental concentration (10 μg/L) and the ecotoxicity value for aquatic invertebrates (360 μg/L) (U.S. EPA 2001). However, this value was above the temporary Interim Provincial Water Quality Objective (IPWQO) concentration of 0.2 μg/L (MOE 2005), which is 50 times lower than the U.S. EPA concentration limit. Five out of nine water samples taken at the outfall exceeded the IPWQO.

Conclusions and Recommendations

The presence of mosquito larvae was observed in all CBs over the course of the study. Due to the statistically insufficient number of late third and fourth instar larvae present in the collected samples, no efficacy statements can be made at this time.

This field study demonstrated that key environmental and hydrodynamic factors affecting the methoprene concentration in CBs are rainfall and sump water volume. Rainfall affects the residual concentrations by diluting dissolved methoprene from the pellets or ingots. Higher total rainfall in a given season accelerates the dilutive process thereby reducing overall methoprene concentration in CBs, and increasing the influx of methoprene to the receiving waterbody through the storm sewer system. Methoprene concentrations at the sewer outfall during rain events never exceeded the U.S. EPA's limit, yet frequently exceeded the IPWQO. Cumulative impacts to water bodies and biota from methoprene metabolites originating from catch basin treatment requires further research.

Greater sump water volumes appeared to increase the methoprene dilution. Methoprene achieved a higher mean concentration and a greater number of days with concentrations above the LC₅₀ in the reduced sump water volume of the shallower CBs. Intuitively, one may expect that in drier weather, lower sump water volumes in shallower CBs would result in higher mean methoprene concentrations and a greater number of days with concentrations above the LC₅₀, and vice versa in wet weather due to dilution. However, evidence indicated the contrary. A hypothesis was drawn that methoprene in shallow CBs may be more susceptible to accelerated microbial and photolytic degradation in drier weather periods compared with the dilution and hydrolytic degradation in wet years. Greater sump water volume may protect and buffer methoprene from the former processes, which are also shown to occur at a lower rate than dilution and hydrolysis in a wet year. Further study of a longer time-series of in situ sump water levels

Fig. 6. Hydrodynamics of a three-pellet methoprene dosage (application time indicated as “dose”) at the deep catch basin in 2003; rainfall represented as bars from the top, and methoprene concentration as discrete points, some connected by a line; the disconnections of plotted points are associated with missing data.
Environmental Factors affecting Methoprene

Fig. 7. Methoprene concentrations at the Newtonbrook sewer outfall over 2005 rainfall events.

and temperature, rainfall, and microbial and photolytic activity relative to methoprene concentrations within CBs and storm sewer outfall concentrations can better test this hypothesis.

In general, ingots were comparable in performance to pellets based on data in two similar wet years. Hence, and holding other cost factors equal, this research demonstrated that a single ingot dosage may represent a more cost-effective methoprene treatment regime than multiple pellet dosages. Further studies on the efficacy of methoprene in controlling larval emergence in these CBs are warranted notwithstanding the number of days above the LC_{50} concentration revealed in this research. As well the concurrent statistical analyses of methoprene metabolites in the daily methoprene samples, the interaction between methoprene and catch basin sediments, and other factors in the degradation of methoprene (such as temperature, light, and microbial activity), would be useful in fully understanding the advantages and disadvantages of the mosquito control program.

Acknowledgments

The authors appreciate the enthusiastic support of: John Rudnickas, Manager of Water and Wastewater Services, City of Toronto; Frank Tomassini, Manager of the General Chemistry and Microbiology Laboratory Services Branch, Ontario Ministry of the Environment; a research grant from the Ontario Ministry of the Environment Standards Development Branch; and basic research support from the Natural Sciences and Engineering Research Council of Canada.

References


Sea Technology (Anonymous). 1999. Fish deformities may be linked to inhibitors. 40(6):90.


Received: 18 November 2007; accepted: 27 November 2008.