Chapter 6

Environmental Concentrations of Urban Pesticides

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In 1991 a study of two urban streams in Hamilton and two urban stormwater detention ponds in Guelph was initiated to determine the degree of pesticide contamination in these systems. Water was tested for phenoxy acid herbicides (i.e. 2,4-D, mecoprop, dicamba, MCPA), for neutral herbicides (i.e. trifluralin, atrazine, metolachlor), and for organophosphorus insecticides (i.e. diazinon, dimethoate, chlorpyrifos), during base flow and during runoff events. Sediment was collected and analyzed for persistent organochlorine compounds and for selected pesticides. A questionnaire was circulated to the residents of two Guelph subdivisions to determine the types and amounts of pesticide used by householders.

Canadian Water Quality Guidelines (CWQG) for Drinking Water were not exceeded for any of the pesticides. Concentrations of 2,4-D did exceed the

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CWQG for the Protection of Freshwater Aquatic Life in 10% of the samples collected. The maximum observed concentration of 2,4-D was $14.6\mu\text{g/L}$, more than three times the CWQG for the Protection of Freshwater Aquatic Life ($4\mu\text{g/L}$). Eight other phenoxy acid herbicides were also detected. The organophosphorus (OP) insecticides diazinon, dimethoate, and chlorpyrifos, were detected in water. Although provincial (Ontario) water quality objectives exist for some of the OPs there are no CWQGs for the Protection of Freshwater Aquatic Life for OPs. The neutral herbicides atrazine, metolachlor, and trifluralin, were also detected in water. Eight persistent organochlorines and atrazine were detected in sediment samples.

Survey results indicated that in 1991 over twenty different pesticide compounds were used in the study areas. 66% of the lawns and/or gardens in the two subdivisions received at least one pesticide application and 36% of the homes used a professional lawn care service.

6.1 Introduction

The flow of contaminants into the Great Lakes originates from a diversity of point, and non-point sources. The lack of data on the types, and amounts of contaminants from non-point source urban activities, hinders the conservation and protection of the Great Lakes.

Due to a greater awareness of environmental issues, public concern has grown recently regarding the use of pesticides in urban environments. Most pesticides used now are non-persistent and non-bioaccumulating. These compounds are generally very water soluble and have a low affinity for sediment. They generally do not bioaccumulate but are very toxic and can impact non-target organisms in aquatic and terrestrial ecosystems. This is in contrast to the banned or restricted organochlorine pesticides (e.g. DDT) which had very low water solubility and a high affinity for sediment and biota, and a potential to bioaccumulate in fish and fish-eating birds.

Environmental concentrations of these compounds would be expected to be at their highest during rain events immediately following application periods. Although ecosystem damage to the open water sections of the Great Lakes from these compounds would not be expected, tributary streams and near shore areas may be adversely affected.

This study had two main parts:

- 1) a survey designed to estimate the types, and amounts of pesticides applied to lawns and gardens in two urban subdivisions, and
- 2) a field sampling program to determine the concentrations of pesticides in urban streams, and in urban stormwater detention ponds in southern Ontario.

The inclusion of the stormwater detention ponds provided an opportunity to investigate pesticide runoff within an in-line storage system. The streams were selected because they represented a variety of land-use practices common to partially urbanized watersheds in Southern Ontario.

6.2 Pesticide Questionnaire

In August 1991, a questionnaire was circulated to each home in two Guelph subdivisions. One third of the homes were visited for an oral interview, to serve as a control for judging the accuracy of the written responses. Householders were asked what types and amounts of pesticides they applied, and if they used professional lawn care service. Results from the control group gave no indication that the oral interviews were more complete than the mailed-in responses. The overall response rate to the survey was 43%. The physical details of each subdivision are available in more detail (Licsko, 1992).

66% of householders applied or had someone else apply pesticides on their property during 1991 (see Table 6.1). In comparing pesticide use in Guelph to a recent national survey by Statistics Canada, the Guelph subdivision usage is

Table 6.1
Results of pesticide use survey

Total Number of Householders Surveyed	367
Total Responses (%)	43
Average Lot Size (m ²)	771
Householders with Professional Lawn Care (%)	36
Householders Applying and/or Receiving a Pesticide Application (%)	66

more than twice the national average of 31 percent for households in large urban areas (Statistics Canada, 1991). Householders who responded to the national survey may not have been aware that some fertilizer formulations contain pesticides. It is also likely that the national survey included households that do not live in single-family detached housing.

Based on the survey results at least 22 different pesticides were applied to lawns and gardens in the two subdivisions (Table 6.2). All but three of the pesticides (bensulide, bromacil and insecticidal soap) were also used in agricultural areas in Ontario during 1988 (Moxley, 1989). Survey responses were generally not detailed enough to accurately estimate the total amounts of each compound

Table 6.2
Pesticides used by house- holders and lawn care
companies

Herbicides	Insecticides
2,4-D/ Mecoprop/Dicamba mixtures	Diazinon
MCPA	Chlorpyrifos
Chlorthal dimethyl	Phosalone
Fenoxaprop ethyl	Methoxychlor
Bensulide	Malathion
Glyphosate	Carbaryl
Bromacil	Insecticidal soap
Sethoxydim	

Fungicides	
Chlorothalonil	Captan
Benomyl	Sulphur
Maneb	

used in the two urban areas. This was particularly true for householders who had arranged for a professional lawn care service, and who, although aware that a pesticide was applied to their lawns, were unaware of the type and the amounts. This coupled with the large variety of pesticide products available for use by the householder, and professional lawn care companies, made it difficult to compare use patterns, and to calculate application amounts.

In order to provide estimates of professional lawn care pesticide loading on an annual areal basis, the following procedure was used: 1) spraying frequencies for herbicides (2.4 applications per year), insecticides (1 application per year) and fungicides (0.7 applications per year) were based on a lawn care company survey completed by the Turfgrass Institute, University of Guelph (1992), and 2) if the pesticide used during the spraying could not be determined from survey data, recommendations as to the type and amounts of pesticide used were based on the Ontario Ministry of Agriculture and Food publication 384: Recommendations for Turfgrass Management (OMAF, 1990). The lawn area sprayed is based on survey results for lot size and an urban lawn area conversion factor of 0.6.

Using this method a comparison of application rates between householders and professional lawn care indicates that lawn care companies apply more compounds than the householder, and at a greater frequency (Table 6.3).

Table 6.3
Householder and lawn care application rates for commonly applied
pesticides in Guelph subdivisions

Pesticide	Householder Applied (kg ha ⁻¹ yr ⁻¹)	Professional Lawn Care (kg ha ⁻¹ yr ⁻¹)
Broadleaf Weed Control (herbicides)		
2,4-D	0.122	0.453
Dicamba	0.012	0.238
Mecoprop	0.064	0.043
Crabgrass Control¹ (herbicides)		
Chlorthal dimethyl	-	1.002 to 1.754 ³
Fenoxaprop ethyl	-	0.017
Bensulide	-	0.950 to 1.526
Insect Control¹ (insecticides)		
Diazinon	0.009	1.026 to 2.117
Chlorpyrifos	0.022	0.208 to 0.467
Fungi Control (fungicides)		
Chlorothalonil ²	-	1.361 to 2.720

¹ In the case of crabgrass control and insect control by professionals the applications are based on the assumption that only one of the listed compounds is used exclusively for the respective pest control.

² Assumed to be the most commonly used fungicide.

³ Range of recommended application rates (OMAF, 1990).

In order to compare urban pesticide use with agricultural use in the Canadian portion of the Lake Ontario drainage basin, in the three general categories of herbicides, insecticides and fungicides, the lowest application rate recommended for commercial lawn care in each of these categories were summed. In the case of herbicides used for crab grass control, and for insecticides (Table 6.3) it was assumed that only the compounds listed in Table 6.3 were used. The value used for these categories reflected the lowest average application rate of the compounds listed. For example, the urban insecticide loading was estimated to be 50 % due to diazinon and 50% due to chlorpyrifos resulting in an urban insecticide use estimate of 0.62 kg/ha. The residential area (78300 ha) in the Canadian Lake Ontario drainage basin estimated by Schroeter (1992) was used in the final calculation. Use of pesticides in industrial, commercial or open lands in urban areas was not included in the estimates. Agricultural estimates of the amounts of pesticides used on field, fruit and vegetable crops for the Canadian Lake Ontario drainage basin were obtained from Moxley (1988).

Table 6.4
Estimated pesticide use in three categories
for the Lake Ontario drainage basin

Pesticide	Urban Residential (kg)	Agricultural (kg)
Herbicides	135,459	528,520
Insecticides	48,546	99,920
Fungicides	106,566	274,450

The results shown in Table 6.4 indicate that residential urban pesticide use is appreciable even when compared to that used in surrounding agricultural areas in the same drainage basin.

6.3 Field Sampling

6.3.1 Study Area - Watershed Description

Two sites were located in stormwater detention ponds in Guelph, Ontario; two additional sample sites were located in streams that are part of the Hamilton Harbour watershed of Lake Ontario.

6.3.1.1 Detention Ponds

The two detention ponds sampled drain catchments typical of residential development within the City of Guelph. The Fieldstone residential catchment, was constructed in 1986-87, and is 14.2 ha in area, with a density of twelve single-family detached houses/ha (gross catchment area). A grass-surfaced park with an area of about 1.5 ha forms part of this catchment. Roof downpipes drain directly onto lawns in most instances, and streets, backyards, and the park area, are all drained by catch basins. Stormwater from the entire catchment flows into a stormwater detention wet pond which was designed to limit outflow rates from the catchment to pre-development rates.

The Brandt catchment, in Guelph, covers 18 ha, and has a single-family detached housing density of 11 houses/ha (gross catchment area). The area was developed in 1971, and a school and park area (mostly grassed), encompasses approximately 4 ha of the catchment. Roof downpipes are connected directly to the stormwater sewer drainage system, and the catchment drains into a dry

stormwater detention pond.

The surface area of the wet pond at Fieldstone is 0.16 ha (1570 m² or 1.1% of the catchment area) with an average depth of approximately 30 cm giving the pond a total volume of approximately 500 m³. Outflow rates based on the drop in water level and the pond surface area ranged from a high of 314 m³/hr (24.2 mm storm with a two hour duration) to a low of 16 m³/hr (a 8.6 mm storm with a four hour duration). The pond is well protected from wind with houses surrounding the pond on three sides, consequently wind-induced re-suspension of settled material would not be expected.

The dry pond at Brandt encompasses 1.1 ha (6.1 percent of the catchment area) and is part of a natural wetland covered by grasses and cattails. A field on the south and east sides of the pond and a wooded area on the pond's west side also occasionally contribute flows to the pond. During spring and wet periods during the summer a dry-weather base flow due to groundwater infiltration into the storm sewer pipe network also contributes some flow. Overflow rates were not monitored for this pond. An estimated stormwater detention time for this pond is approximately two to four hours. Additional information on both the residential catchments and on the detention ponds can be found in a thesis (Licisko, 1992).

6.3.1.2 Urban Streams

Hamilton Harbour comprises three distinct bodies of water: the main Harbour (central), Cootes Paradise (west), and Windermere Basin (south-east). Spencer Creek flows to Cootes Paradise, and Red Hill Creek discharges to Windermere Basin. Both creeks were sampled downstream of points directly influenced by urban runoff and upstream of the point of discharge to the Harbour.

The drainage area for Spencer Creek is approximately 23,100 ha. The Spencer Creek watershed contains wetlands, forests, and land use is primarily pasture, idle farm land, and rural cropland. 10% of the Spencer Creek watershed has urban land use which includes residential, commercial and industrial uses.

The drainage area for Red Hill Creek is approximately 6,600 ha. 40% of the watershed is urban, with residential, commercial, and industrial uses. Other land uses include rural cropland, forests, pasture and idle farm land.

6.3.2 Sample Collection and Analysis

Grab water samples (1 litre) were collected during moderate to heavy rain events and during dry weather conditions from each sampling location from April to December 1991. When possible, samples were collected one to three hours after the start of storms and coincided with peak flow periods. Water samples from the creeks were collected in glass bottles from mid-stream, near the out-falls at the stormwater detention ponds. Samples from the surface of the

Table 6.5
Average detected concentrations for conventional water quality parameters

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

¹ Dry weather sampling

² Wet weather sampling

sediment layer were collected on a seasonal basis using a Mini-Ponar sediment sampler at both stream and detention ponds.

Organophosphorus insecticide samples were analyzed by Gas Chromatography (GC) using a Nitrogen-Phosphorus Detector (NPD) and an Electron Capture Detector (ECD). Samples were confirmed by Mass Spectrometry

Detection (MSD). Phenoxy acid herbicide samples were analyzed on a dual column GC by ECD. Neutral herbicides which include triazine, dinitroaniline, amide, and thiocarbamate compounds were analyzed on dual column GC by ECD and NPD. Samples were confirmed by MSD. Organochlorine samples were analyzed on a dual column GC by ECD. Samples were confirmed by MSD. Complete details of the analytical methodology for the pesticides, nutrients, ions and physical parameters can be found in a manual (Environment Canada, 1992).

6.3.3 Water Quality

In summarizing the field data, baseline (dry weather) and precipitation event (wet weather), results from the two streams are shown separately. Data from wet and dry sampling for the detention ponds were combined because of small sample sizes (n=4).

For the two streams, results of the baseline (dry weather) showed concentrations for most conventional parameters to be similar (Table 6.5). A large difference in land-uses between the two streams did not appear to translate into large differences in baseline water chemistry. Red Hill Creek baseline samples had, however, slightly higher concentrations for all the nutrients and for sodium. There was a large increase in total and ortho-phosphorus, and turbidity during wet weather. 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). Large differences between dry and wet weather sampling of the two streams were not evident for pH, nitrate, ammonia or dissolved inorganic carbon.

In total, eight phenoxy acid herbicides were detected in the study (Table 6.6). Average phenoxy acid concentrations were higher during precipitation events than during dry weather for both streams sampled. Similar concentrations of phenoxy acids were measured during precipitation events in the wet pond, while the dry pond had levels below baseline values measured in the two streams. For the phenoxy acid herbicides for which CWQGs were available, concentrations measured were generally below the guidelines for the Protection of Freshwater Aquatic Life. About 10% of the 2,4-D detections were above the CWQG (4 µg/L).

Three of the eleven neutral herbicides analyzed were detected (Table 6.7). All concentrations measured were below the CWQGs for the Protection of Freshwater Aquatic Life. Although, atrazine was detected once in both ponds, and trifluralin once in the wet pond, neither the residential pesticide use survey or the OMAF Recommendations for Turfgrass Management (OMAF, 1990)

Table 6.6
Frequency of detection and average detected concentration for selected phenoxy acid herbicides¹[all concentrations µg/L in whole water samples]³

Sampling Site	Spencer Dry	Spencer Wet	Red Hill Dry	Red Hill Wet	Wet Pond Wet & Dry	Dry Pond Wet & Dry
Number of samples	3	10	3	11	7	6
2,4-D (0.03) ²	33 % [0.45] ³	80 % [2.17]	33 % [0.19]	90 % [2.62]	71 % [3.62]	33 % [0.08]
2,4-DP (0.03)	nd ⁴	nd	nd	nd	43 % [0.48]	nd
2,4,5-T (0.05)	nd	10 % [0.01]	nd	nd	14 % [0.08]	nd
2,3,6-TBA (0.03)	nd	10 % [0.05]	nd	20 % [0.05]	nd	nd
Dicamba (0.03)	nd	20 % [0.16]	nd	10 % [0.11]	29 % [0.11]	17 % [0.19]
MCPA (0.03)	33 % [0.05]	40 % [0.47]	nd	60 % [0.24]	57 % [0.38]	33 % [0.04]
Mecoprop (0.03)	67 % [0.53]	90 % [1.18]	33 % [0.44]	80 % [1.62]	71 % [1.80]	17 % [0.07]
Picloram (0.05)	nd	nd	nd	nd	nd	33 % [0.14]

¹ 2,4-DB (0.05), Bromoxynil (0.03), and MCPB (0.050) were analyzed for but not detected. Bracketed values indicate detection limit.

² Detection limit.

³ Average detected concentration.

⁴ Not detected.

gave any indication that the compounds are used in the residential areas. Atrazine and metolachlor were both detected frequently during wet weather sampling of both streams (Table 6.7). These two compounds are the most frequently used agricultural herbicides in Ontario and made up over half of the total amount of herbicides used in the province during 1988 (Moxley, 1988). In contrast, MCPA, which was the most used phenoxy acid herbicide, only represented 4.4 % of the total agricultural use of herbicides in 1988.

Organophosphorus compounds were less frequently detected than either the phenoxy acid or neutral herbicides. Three of the thirteen OP

Table 6.7
Frequency of detection and average detected concentrations for selected neutral herbicides¹
[all concentrations µg/L in whole water samples]

Sampling Site	Spencer Dry	Spencer Wet	Red Hill Dry	Red Hill Wet	Wet Pond Wet & Dry	Dry Pond Wet & Dry
Number of samples	3	6	3	7	4	4
Atrazine (0.05) ²	67 % [0.200] ³	100 % [0.2267]	67 % [0.160]	100 % [0.621]	25 % [0.900]	25 % [0.05]
Metolachlor (0.1)	nd ⁴	67 % [0.148]	nd	57 % [0.189]	nd	nd
Trifluralin (0.005)	nd	nd	nd	43 % [0.006]	25 % [0.006]	nd

Barban (0.1), Diallate (0.1), Endaven (0.025), Hoegrass (0.050), and Triallate (0.010) were analyzed for but not detected. Bracketed values indicate detection limit.

² Detection limit. ³ Average detected concentration. ⁴ Not detected.

Table 6.8
Frequency of detection and average detected concentration for selected organophosphorus insecticides¹
[all concentrations µg/L in whole water samples]

Sampling Site	Spencer Wet	Red Hill Wet	Wet Pond Dry & Wet	Dry Pond Dry & Wet	Ontario Water Quality Objective
Number of samples	7	7	8	6	
Chlorpyrifos (0.040) ²	nd ³	nd	25 % [0.148] ⁴	nd	0.001
Diazinon (0.020)	nd	14 % [0.317]	38 % [1.041]	50 % [0.040]	0.08
Dimethoate (0.040)	nd	nd	13 % [1.405]	17 % [0.071]	-

¹ Disulfoton (0.02), Ethion (0.04), Fonofos (0.02), Azinphos-methyl (0.13), Malathion (0.03), Dibrom (0.13), Parathion (0.04), Phorate (0.02), Phosmet (0.120), Terbufos (0.03) were analyzed for but not detected. Curved bracketed values indicate detection limit.

² Detection limit.

³ Below detection limit.

⁴ Average detected concentration.

Table 6.9
Selected organochlorine compounds in sediment¹
(all concentrations in ng/g of dried surface sediment)

Sampling Site	Spencer	Red Hill	Wet Pond	Dry Pond	Proposed sediment guidelines (MOE ² , assumes TOC @ 5%)		
Number of samples	3	3	3	3	No effect level	Lowest effect level	Severe effect Level
ΣChlordane (0.002) ³	0.6	0.2	0.13	2.27	5	7	300
Dieldrin (0.0032)	0.2	0.15	0.8	1.60	0.6	2	4550
p,p'-DDT & o,p'-DDT (0.0075) & (0.007)	2.3	nd	2.00	1.30	-	8	3550
p,p'-TDE (0.006)	0.833	nd	0.800	1.10	-	8	300
p,p'-DDE (0.0056)	19.8	1.6	40.4	2.27	-	5	950
Hexachloro-benzene (0.0063)	0.433	nd	1.000	1.5	0.2	20	1200
ΣPCBs (0.077)	25.73	nd	nd	8.03	0.2	70	26500

¹ Aldrin (0.0016), Dieldrin (0.0032), α-Endosulfan (0.0014), β-Endosulfan (0.0029), Endrin (0.0029), Heptachlor Epoxide (0.0019), α-Hexachlorocyclohexane (0.0023), γ-Hexachlorocyclohexane (0.0023), Methoxychlor (0.018) and Mirex (0.0043) were tested for but not detected. Bracketed values indicate detection limits.

² Persauld *et al.*, 1992.

³ Detection limit.

compounds analyzed were detected (Table 6.8). This is likely due to the low number of applications for pesticides, usually only once a year, and also the difficulty in determining and sampling the time period over which the application occurs. Concentrations above the detection limit were observed during precipitation events in Red Hill Creek and in the two detention ponds. The high degree of urbanization (40%) in the Red Hill Creek watershed would be expected to result in wet weather OP concentrations similar to those observed in the wet pond. All the detected values, except for Diazinon concentrations measured in the dry pond, were higher than the Provincial Water Quality Objectives for the protection of freshwater aquatic life (MOE, 1986).

Of nineteen organochlorine compounds analyzed in sediment, eight were detected (Table 6.9). In almost all cases the average concentration measured was below the Ontario Ministry of the Environment Guidelines for the Protection and Management of Aquatic Sediment Quality. Only p,p'-DDE concentrations in the wet detention pond were above the guidelines' lowest effect level.

Atrazine was the only neutral herbicide detected in sediment samples. One detection occurred in Red Hill Creek (3.5 ng/g) and the other in the dry detention pond (2.8 ng/g). No organophosphorus pesticides were detected in sediment at any of the four sampling sites.

6.4 Conclusions

Survey results indicate that, when compared to agricultural pesticide use, urban pesticide use is appreciably different both in terms of the types and in the amounts of pesticides used.

When the results of the survey are extrapolated to a drainage basin with a large urban population such as the Canadian portion of the Lake Ontario drainage basin, the total loadings from urban areas are appreciable.

Wet weather concentrations of pesticides in the two streams and in the wet pond were similar both in terms of their concentrations and in compounds detected. This observation and the normal differences between agricultural and urban areas in the amounts and types of pesticide used, suggests that the phenoxy acid herbicides and organophosphorus compounds detected in the two streams originated from the urban land-uses within their watersheds.

When detected in water, diazinon and chlorpyrifos were at concentrations above the Ontario Ministry of Environment's Water Quality Objectives for the Protection of Freshwater Aquatic Life. Concentrations of 2,4-D exceeded the CWQG for the Protection of Freshwater Aquatic Life in 10 % of the samples collected. For seven of the phenoxy acid herbicides detected and one organophosphorus insecticide (dimethoate) neither provincial (Ontario) nor federal water quality guidelines for the protection of freshwater aquatic life are available.

6.5 Recommendations

Survey results indicated that herbicides (for crabgrass control), and fungicides are used in urban areas. These two pesticide groups were not analysed in the field sampling program due to the lack of analytical capability to measure them at the time this study was undertaken. These compounds should be sampled in any future sampling programs concerned with pesticide use in urban areas.

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