Characteristics of urban chemical spills in Southern Ontario
Weihua Cao, James Li and Darko Joksimovic

ABSTRACT

Thousands of chemical spills occur as a result of accidents or natural disasters each year worldwide and have the potential to harm human health and the environment. More than 700 recorded chemical spills involving more than 1,000 types of chemical occur every year in Southern Ontario, resulting in multiple environmental impacts. This paper presents characteristics of urban chemical spills (1988–2007) and an ArcGIS-based spatial distribution in Southern Ontario. Eleven regions involving 77 municipalities had experienced chemical spills during the study period. Industrial plants accounted for the majority of occurred spills. The St Clair River and the Humber River were the two major rivers encompassing higher spill areas owing to the high density of industry surrounding them. Pipe/hose leaks both accounted for the highest proportion of total chemical spills and resulted in a largest portion of chemical spills causing surface water impacts. The analysis results will provide information for a further study to develop a comprehensive urban chemical spill management strategy, which emphasizes spill prevention, control and emergency response. The strategy could also be used to assist both municipalities and industries to minimize the potential spill impacts to the environment and public health and to better protect water resources.

Key words | spill causes, spill characteristics, spill distribution, spill prevention and management, surface water impacts, urban chemical spill

INTRODUCTION

Thousands of oil and chemical spills occur each year worldwide through accidents or natural disasters and bring great potential to harm human health and impact water, air and land and their associated terrestrial and aquatic species, which has been well documented by Tagatz (1961), Hutchinson et al. (1974), McKinley et al. (1982) and Shales et al. (1989). As defined by several environmental legislations, a spill is a form of ‘discharge’ (Ontario Water Resources Act s. 1(1) & s. 1(3)(b) 1990; Ontario Environmental Protection Act s. 91(1) 1990; Environmental Protection Act, Ontario Regulation 675/98 Part I), ‘deposit’ (Canadian Fisheries Act s. 34 1985), ‘release’ (Canadian Environmental Protection Act s. 3(1) 1999), or ‘an uncontrolled, unplanned or accidental release’ (Canadian Environmental Protection Act s. 193 1999). It enters the environment ‘from or out of a structure, vehicle or other container’ (Ontario Environmental Protection Act s. 91 (1)(b) 1990). Spills are characterized as harmful in terms of their ‘deleterious’ effects (Canadian Fisheries Act s. 34 1985), ‘impairment’ to water quality (Ontario Water Resources Act s. 1(5) 1990), and ‘adverse effects’ (Ontario Environmental Protection Act s. 1(1) 1990; Environmental Protection Act, Ontario Regulation 675/98 Part I). A spill occurrence is ‘abnormal in quality or quantity in light of all the circumstances’ (Ontario Environmental Protection Act s. 91(1)(c) 1990) and represents a failure in system, education, engineering, regulation, enforcement or packaging (Castle 1999).

Urban spills have been identified as one of the major sources of pollution of the Great Lakes (Cheng 2005). Unlike tanker spills in oceans, urban spills originate from industrial and municipal lands (Li 2005), including production sites, local product stores and transportation corridors. They can occur for a number of reasons and situations, such as equipment failure or human error, and may cause impairment of drinking water quality, contamination of surface water and...
groundwater, destruction of freshwater invertebrates and vertebrates, and disturbance of fish habitats and wildlife populations, especially in spawning areas (Li & McAteer 2000). The types of spill that are of most concern are those of toxic substances which can directly or indirectly deposit into watercourses through several different routes, such as air, leaking (e.g. ground/underground tank and landfills), discharge, overflow, etc. (Environment Canada 1997). Spills in large quantity could acutely elevate certain toxic chemicals at water intakes (Cheng 2010). Even in small quantities spills could affect the long-term toxicity levels in ambient waters. The Ontario Clean Water Act was enacted to ensure water sources are protected from non-point sources of pollution, such as spills. Municipal drinking water quality standards are set out in the Ontario Drinking Water Quality Standards (Ontario MOE 2002) under the Safe Drinking Water Act. The enactment of the Safe Drinking Water Act also forces industries to be more attentive to spill management resulting in a decreasing trend of spill frequency over the last 20 years. The chemical concentrations under the maximum acceptable concentration (MAC) are deemed safe for lifelong human consumption of drinking water (Health Canada 1996).

Recognizing the severity of urban chemical spills in the Great Lakes areas, several levels of Canadian government have commissioned spill analysis studies in their jurisdictions (Li 2002a, 2002b, 2002c, 2002d, 2002e, 2003, 2005). The characteristics of spills in various municipalities in terms of frequency, volume and cause were analyzed. For instance, the most frequent chemical spills which impact on surface water were found to be ethylene glycol (antifreeze) while the primary cause of chemical spills was container leaks in the Greater Toronto Area (GTA). Similarly, Ontario Ministry of the Environment (Ontario MOE 2005) analyzed the occurrences of industrial spills in Ontario in the 2003–2004 period in terms of their number, quantities (volume and mass) released, environment impacts, industrial sectors and WTP (water treatment plant) notifications and intake closures. In particular, it was reported that a number of significant spills in the City of Sarnia occurred and entered the St Clair River from petrochemical facilities, resulting in direct impacts to surrounding communities and the environment.

This paper presents the statistical and spatial analysis of urban chemical spill characteristics in Southern Ontario based on the spill data collected by the Ontario Spills Action Centre (SAC) and the Sarnia-Lambton Environmental Association (SLEA) for the 1988–2007 period. The statistical and spatial analysis of the characteristics of urban chemical spill events, which caused surface water quality impact, will provide information for a further study to develop a comprehensive urban chemical spill management strategy, which emphasizes spill prevention, spill control and emergency response to spill events. The framework of this strategy is presented in this paper and could be used to assist both municipalities and industries to minimize the spills’ potential threats to human health and/or the environment (i.e. air, water and soil).

**URBAN CHEMICAL SPILLS IN SOUTHERN ONTARIO**

The urban chemical spill records for Southern Ontario were originally provided by the SAC and updated by Ryerson University (e.g. assignment of longitude and latitude of spills, spill locations, etc.). The SAC database records the majority of spill events and other urgent environmental events. Chemical spills as defined by the SAC include releases of acids, bases, solvents, pesticides, other organic and inorganic chemicals, liquid industrial waste, sewage, and liquid hazardous wastes, smoke, dust/particulates, nitrous oxide, natural gas, and others. The major spill attributes in the updated SAC database include date, geo-coding, region/municipality, chemical type, volume/mass (estimated), location, corporation, source, sector, cause and environmental impact. As recorded in the SAC database, Southern Ontario experienced 13,682 chemical spills involving more than 1,000 chemicals between 1988 and 2007, resulting in multiple environmental impacts such as air, water and land contamination. The attributes of spill date, quantities and corporation with location are the most important information for a further study to investigate the probabilistic occurrences of a certain type of urban chemical spill (mass and time) characterized by NAICS (North American Industry Classification System)-based locations. Spills from industrial facilities with the same NAICS code will be assumed to have similar spill properties (e.g. probability distributions of spill occurrence times and spilled mass) and will be used for a further study on the risk-based analysis of surface water quality violation caused by chemical spills.

In addition to the SAC database, the SLEA provided industrial chemical spills records between 1986 and 2005 in
the Sarnia-Lambton Area, some of which had caused WTP shutdowns in the St Clair River Area of Concern (AOC) (Cheng 2010). Differing from those in the SAC database, the major attributes in the SLEA database only include spill date, chemical type, estimated quantity, discharge classification and shutdown records. As recorded, the SLEA industrial spill database contains 801 chemical spills involving more than 280 chemicals. While some spill events are recorded in both databases, there are discrepancies between the two recording systems. This may be attributed to the definition of spill events and the use of spill information between the SAC and the SLEA. The SAC is a provincial agency which collects and coordinates spill response. Its mandate addresses provincial priorities and fulfills the requirements of reporting and cleaning up spills immediately and restoring the environment promptly by the owner of the spilled material and the person causing/permitting the spill and the person controlling a material when it was spilled under the Environmental Protection Act (Ontario MOE 2007a, 2012). The spill data are analyzed annually to identify spill occurrences and types in various regional municipalities and industries. The SLEA is an industrial association which focuses on local industrial cooperation and sharing of technical information. It is understandable that the data collected by each agency are not consistent. After the SAC and the SLEA databases are synchronized in terms of spill date, chemical type and region, a total of 14,174 chemical spills were compiled for the regions of Toronto, Hamilton, Peel, Niagara, Lambton, Essex, York, Halton, Durham, Guelph and London between 1988 and 2007. This combined database indicates an annual average of 709 chemical spills, or about two spills per day in Southern Ontario.

The annual occurrences of urban chemical spills together with annual industrial gross domestic product (GDP) for the 1988–2007 period are illustrated in Figure 1. While the industrial GDP had grown in this period, the spill occurrences had not shown the same tendency, which may be attributed to the changes in both government policy and industry types from heavy, chemical-based industry to high-tech light industry. For instance, manufacturing has been reported to be struggling for some time in Ontario (CIAC 2012). In particular, the proportion of basic chemicals and resins manufactured in the province (45%) has been declining recently as a result of the closures of aging facilities and little new investment. The region of Sarnia-Lambton is experiencing a new industrial revolution involving the development of new technologies and convergence of others among the chemical, agriculture and automotive sectors (Mallay & McLaughlin 2012). Moreover, the spill trends during the two time periods of 1989–1999 and 2000–2007 are similar (i.e. the number of spills is highest at the beginning of each period and then falls to a lower level in the following years). This may be attributed to the highest industrial GDP growth rates at the beginning of both periods (8.2% in 1989 and 7.8% in 2000) and the slowdown in the following years (Statistics Canada 2012). A similar study also indicated that the number of spills reported to the
Ontario SAC and those released from industrial sources increased by approximately 5 and 24%, respectively, between 2003 and 2004 province-wide (Ontario MOE 2005). The return of higher spill occurrences in 2000 may be attributed to a strongly expanding economy between mid-1999 and mid-2000 resulting in a rapid growth of production (Thiessen 2000). Additionally, technical and product innovation and old equipment/machines replacement may have contributed to bringing down the number of spills.

The volume of Ontario imports grew from 1997 to 2007 (Ontario MOF 1995–2011). In particular, the top three international imports, motor vehicles and parts, mechanical equipment and electrical machinery, were related to industries and accounted for over 50% of the total international imports in this period. Moreover, the rapid development of computer technology and industrial automation since 2000 may have played a significant role in reducing the number of spill occurrences in the period 2000–2007. Evidence showed that the Ontario government provided strong support for research and innovation and this expenditure has increased since 1998 (Ontario MOF 1995–2011). Furthermore, government actions, such as inspection, monitoring, voluntary abatement, compliance, enforcement, penalty and prosecution, are also important impact factors in the decrease of spill occurrences. For instance, the enactment of the Safe Drinking Water Act may force industries to be more cautious in their plant operation and change their habits. The Ontario Ministry of the Environment Emergency Management Program indicates that ‘a comprehensive emergency management program is one that incorporates a risk management approach supported by the five pillars of emergency management – prevention, mitigation, preparedness, response, and recovery’ (Ontario MOE 2007b). The repeated spill trend in 2000–2007 may reflect the economic fluctuations in Ontario in the past 20 years according to the Ontario economic outlook and fiscal review (Ontario MOF 1995–2011).

The average monthly occurrences of urban chemical spills (1988–2007) together with average monthly temperature (1901–2009) are illustrated in Figure 2. As shown in this figure, the frequency of occurrence of chemical spills is the highest in the month of June (1,442 spills) and the average monthly spill occurrences and average monthly temperature are correlated. This may be attributed to an increase in transportation activities during summer months (Environment Canada 2006). Researchers said that ‘actual changes in temperature, rainfall, and other weather variables have direct effects on various economic series, such as those concerned with agricultural production, construction, and transportation, and consequent indirect effects on other series’ (Granger 1979); ‘weather is a powerful force affecting the economy’ (Niemira 2005); and ‘seasonal fluctuations are an important source of variation in all macroeconomic quantity variables, including consumption, investment, government purchases, employment and the money stock’ (Barsky & Miron 1989). Niemira (2005) also raised three basic aspects in assessing weather effects on consumer and...
business activity: the role of weather as noise in temporarily shifting the timing of purchases or production; the role of weather as a seasonal shock in possibly permanently impacting demand and output; and the potentially causal relationship between weather cycles and macroeconomic activity. He concluded that ‘weather impacts economic activity’. Consequently, the winter months may result in a total loss of demand and a decrease of production resulting in a small number of spills. Therefore, climate condition should be considered in the development of spill management plans and it is possible to implement spill management measures (i.e. inspection, monitoring and training) in accordance with seasonal cycles.

Since the SLEA database does not contain any information on the cause, environmental impact, corporation, and source/sector of spill events, the statistical and spatial analyses of spill characteristics focus on the SAC database. Chemical spills occurred in 77 municipalities including Durham, Essex, Guelph, Halton, Hamilton, Lambton, London, Niagara, Peel, Toronto, and York regions of Southern Ontario. The distributions of spills amongst the regions and municipalities are shown in Figure 3(a) and (b), respectively. Cities such as Toronto, Hamilton, Mississauga, Sarnia and Brampton accounted for 63% of all recorded spills, which may be attributed to the high density of industrial and commercial activities in these cities. Similarly, most chemical spills in the GTA were located in the industrial areas of the cities of Brampton and Mississauga (Li 2005). Approximately 23% and 27% of spills were recorded in 2003 and 2004, respectively, at industrial facilities in the City of Sarnia, which has the highest concentration of petrochemical facilities in Southern Ontario (Ontario MOE 2005). These analyses provide very important information to identify potential spill locations and may assist various levels of government in implementing management measures and allocating resources (e.g. finance, human resources, equipment and materials) for spill prevention, control and emergency response.

Twenty-six causes of chemical spills are specified in the SAC database, in addition to instances in which the cause of spills is identified as unknown. Pipe/hose leak, fuel tanks/barrels leak, process upset, discharge/bypass to watercourse, and other discharges are the top five causes recorded, as depicted in Figure 3(c), which contributed more than half of the total number of spills. Other causes shown in this figure include overflow, valve/fitting leak, tank leak and cooling system leak. Moreover, technical limitations, human errors, equipment failure and aged equipment/machines could be the impact factors causing spill occurrences. These spills could result in surface water pollution, soil contamination, air pollution and multi-media contamination, as shown in Figure 3(d). The spills may also have an impact on human health, vegetation toxicity and result in fish kills, which are included in ‘Other Impacts’ shown in Figure 3(d). Seventytwo per cent of spills are specified to have single or multiple environmental impacts. It is observed that the majority of spill impacts are surface water pollution and soil contamination. According to the SAC database, among the total 13,682 chemical spills, only up to 10% of the spills were cleaned up completely while the remaining spills were either not cleaned up or partially cleaned up. As a result, the environment of Southern Ontario may have been significantly impacted by urban chemical spills from 1988 to 2007. In order to remediate the environmental impacts of chemical spills, spill management measures such as spill preventive maintenance and operation, replacement of aging equipment/machines, improved operation technology and enhanced education and training should be considered in industrial spill management plans.

**URBAN CHEMICAL SPILLS LEADING TO SURFACE WATER IMPACT**

The chemical spills which impact surface water (surface-water-impact spills) are compiled from the SAC spill database. As indicated in Table 1, there were 4,506 spill occurrences (about 32% of the total chemical spills) involving about 680 chemicals in Southern Ontario in the 1988–2007 period. Amongst them, 1,699 spills had recorded volume and 228 spills had recorded mass. The rest of the spills were identified as unknown quantities. The total volume and mass was about 606 million liters and 634,000 kilograms, respectively. The annual occurrence of reported chemical spills fluctuated from 57 to 466, while the annual spill volume and mass had wide ranges from about 27,000 to 301 million liters and 46 kg to 262,000 kg, respectively. The average annual occurrence of chemical spills was...
about 225. Meanwhile, the average annual spill volume and mass was more than 30,000 liters and about 32,000 kg, while the maximum spill volume and mass was about 145 million liters (dirty water with suspended solid and sand caused by discharge/bypass to a watercourse from a steel filtration plant) and 200,000 kg (calcium chloride in an overflow from a chemical industry), respectively. It is noted that both annual spill volume and annual spill mass have large fluctuations.

In terms of surface water impact, 68 municipalities in the regions of Durham, Essex, Halton, Hamilton, Lambton, London, Niagara, Peel, Toronto and York in Southern Ontario have experienced chemical spills (see Figure 4(a)). Cities such as Toronto, Hamilton, Mississauga, Sarnia and Brampton have the highest proportion of chemical spill occurrences, as shown in Figure 4(b), which accounted for about 63% of the surface-water-impact spills reported. Compared with Figure 3(b), this observation is similar to that for the total spills, implying that chemical spills may also significantly impact other environmental media such as soil and air in these municipalities. Figure 5 presents the ArcGIS-based spatial distribution of the surface-water-impact spills in all reported municipalities. It is observed that the higher POI (point of interest) areas (small dots shown in the figure) have the bigger number of surface-water-impact spills in cities such as Toronto, Hamilton, Mississauga, Sarnia, and
Brampton, which might explain the higher proportion (63%) of all recorded surface-water-impact spills in these five cities as mentioned above. It is also noted that the St Clair River and the Humber River are the two major rivers which have received the most spills (i.e. Sarnia and Toronto) and may potentially suffer local water quality impairments, which may be attributed to the fact that 450 petrochemical facilities are located within a 30 km stretch of the St Clair River (Ontario MOE 2005) and 5.6% (5,760 hectares) of the total area of the Humber River watershed has industrial land use (TRCA 2008). The Humber River and the St Clair River will be selected as the study areas for a further study on the risk-based analysis of drinking water quality violation at WTP intakes caused by chemical spills.

Among the surface-water-impact spills in Southern Ontario, raw unchlorinated sewage (7.7%), unknown chemicals (4.5%), ethylene glycol (3.7%) and wastewater N.O.S. (not otherwise specified, 2.4%) are the top four frequent chemical spills. However, dirty water with suspended solids/sand and calcium chloride not only have the largest total volume (301 million liters, 49.7% of total volume) and mass (250,000 kg, 39.4% of total mass) but also have the largest volume (145 million liters) and mass (200,000 kg) of a single spill, respectively. The histogram

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<th>Total volume (m³)</th>
<th>Average volume (m³)</th>
<th>Max volume (m³)</th>
<th>Min volume (10⁻³ m³)</th>
<th>No. of spills with mass</th>
<th>Total mass (kg)</th>
<th>Average mass (kg)</th>
<th>Max mass (kg)</th>
<th>Min mass (kg)</th>
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</tbody>
</table>
of the occurrences of chemical spills is depicted in Figure 6. It is noted that 88.7% of spilled chemical types occurred less than 10 times and 38.9% occurred only once while only four spilled chemicals (the top four frequent chemical spills mentioned above) occurred more than 100 times during the past 20 years (1988–2007). These results imply that the many types of chemical involved in spill events could lead to complicated and frequent surface water pollution over a wide area and bring difficulties in protecting water resources in Southern Ontario. The large number of spilled chemicals from various industries also implies that a vast number of industries or production lines are involved in chemical spill events in Southern Ontario resulting in water quality deterioration. Therefore, the comprehensive urban chemical spill management strategy should be developed province-wide jointly by governments and industries to better protect Ontario water resources. The industries that have frequent spill occurrences and high spill quantities in the past should develop comprehensive spill management plans, which address the use of chemicals in relation to their production processes to prevent spill occurrences and minimize their potential threats to human health and/or the environment in the future. Other industries would also be encouraged to prepare spill management plans for the purpose of spill prevention and emergency response.

The most frequent occurrence of surface-water-impact spills originated from industrial plants (45%) including manufacturing, processing facilities and petroleum refineries, followed by other sources which are not defined (17%), motor vehicles (5%), municipal/industrial wastewater collection system (4%) and sewage treatment plants/lagoons (3%). Unknown sources produce the third largest number of spills (16%). Industrial plants also generated a large portion of spilled chemical volume (about 498 million liters, 82% of total volume) and mass (490,000 kg, 77% of total mass). Industrial municipalities to a greater extent should develop spill management strategies in which the highly industrialized area in proximity to a surface water body is emphasized. The metallurgy, chemical and general manufacturing sectors have the highest frequency of spills in addition to instances in which the sector responsible for the spills is defined as unknown, as shown in Figure 7. ‘Other Sectors’ shown in this figure include service industries, petroleum, government municipal, food processing, pulp & paper, retail, residential/private, and other. The largest single spill volume and mass are generated from the metallurgy (478 million liters, 79% of total volume) and chemical sectors (375,000 kg, 9% of total mass). These analyses could assist both government and industries to effectively allocate resources to prevent and minimize spill occurrences which impact on the environment.

In terms of the causes of surface-water-impact spills, 23 causes including unknown were specified. Some of them had estimated reported volume, others had reported mass, while a majority had no reported volume or mass. Other
than the chemical spills with unknown causes, the cause ‘discharge/bypass to watercourse’ is the most frequent followed by causes such as ‘other discharges’, ‘container/tank/lagoon overflow’ and ‘pipe/hose leak’. The total occurrences, total volume and mass of chemical spills are presented in Table 2. It is observed that the occurrences of these five causes account for 80% of the total but occupy about 96 and 85% of the total volume and mass, respectively. This result may be able to guide not only municipalities but also industries on reporting procedure and the identification of priorities for chemical spill prevention, control and emergency response.

**URBAN CHEMICAL SPILL MANAGEMENT FRAMEWORK**

According to the statistical and spatial analysis of urban chemical spills in Southern Ontario for the 1988–2007 period, the receiving waters in Southern Ontario have
experienced continuous, complicated and potential impairment by many types of urban chemical spill. Therefore, comprehensive spill prevention and management are acutely needed to deal with this issue. The survey of municipal preparedness for spills in major cities in Canada between 2006 and 2007 indicated that only Toronto and Edmonton have a sewer use bylaw, spill management plan and emergency response team simultaneously (Han 2007). Spill management plans have been reported to exist for cities such as Toronto, Edmonton and Victoria, while most cities have a sewer use bylaw and some have a spill response crew. A comprehensive spill

| Course                                             | Occurrence | % of total occurrence | Occurrence with volume | Occurrence with mass | Occurrence without quantity | Volume (m^3) | % of total volume | Mass (kg) | % of total mass |
|----------------------------------------------------|------------|-----------------------|------------------------|---------------------|-----------------------------|--------------|------------------|-----------|----------------|}
| Discharge/bypass to watercourse                    | 962        | 21.3                  | 289                    | 40                  | 633                         | 380,253      | 62.7             | 68,262    | 10.8           |
| Unknown                                            | 924        | 20.5                  | 244                    | 25                  | 655                         | 19,585       | 3.2              | 30,693    | 4.8            |
| Other discharges                                   | 493        | 10.9                  | 169                    | 22                  | 302                         | 11,552       | 1.9              | 33,250    | 5.2            |
| Overflow (containers, tanks, lagoons)             | 465        | 10.3                  | 217                    | 27                  | 221                         | 153,844      | 25.4             | 256,665   | 40.5           |
| Pipe/hose leak                                     | 450        | 10.0                  | 210                    | 28                  | 212                         | 8,650        | 1.4              | 111,266   | 17.5           |
| Container (fuel tanks, barrels) leak               | 324        | 7.2                   | 249                    | 36                  | 39                          | 5,501        | 0.9              | 35,376    | 5.6            |
| Total                                              | 3,618      | 80.3                  | 1,378                  | 178                 | 2,062                       | 579,385      | 95.6             | 535,511   | 84.5           |

Table 2 | Occurrence, volume and mass of chemical spills by causes (surface water impact, 1988-2007)

Toronto and Edmonton have a sewer use bylaw, spill management plan and emergency response team simultaneously (Han 2007). Spill management plans have been reported to exist for cities such as Toronto, Edmonton and Victoria, while most cities have a sewer use bylaw and some have a spill response crew. A comprehensive spill
management framework should consist of a spill pollution prevention plan (e.g. education and preventive training), a spill control plan (e.g. spill containment and treatment facilities for long-term spill control) and an emergency response plan (e.g. fate of spills in rivers and in municipal infrastructures), as shown in Figure 8. Further research will focus on the development of planning tools involving probabilistic spill occurrence models, a spill transformation-transport model in receiving waters, and a risk-based analysis model for drinking water quality violation at WTP intakes in compliance with relevant water quality regulations and standards.

CONCLUSIONS AND RECOMMENDATION

From the urban chemical spills studies in Southern Ontario, the following conclusions can be drawn:

- Southern Ontario has experienced continuous, complicated and potential pollution by urban chemical spills.
- Many of the urban chemical spills which caused surface water pollution originated from industrial plants. The top four sectors with the most frequent spills are the metallurgy, chemical, general manufacturing and transportation sectors.
- Major causes of urban chemical spills are pipe/hose leak, fuel tanks/barrels leak, process upset, and discharge/bypass to watercourse, resulting in surface water pollution, soil contamination, air pollution and other impacts.
- The St Clair River and the Humber River are the two major rivers which have been exposed to frequent chemical spills resulting in high potential impairments of water/drinking water quality.
- Discharge/bypass to watercourse, other discharges, container/tank/lagoon overflow, pipe/hose leak and fuel tanks/barrel leak are the major causes of chemical spills leading to surface water impact.
- The majority of spilled chemicals were not cleaned up and their fates in the environment may impact on air, water and soil quality and human health.

It is clear that the analysis of the statistical and spatial characteristics of urban chemical spills will be the first step to identify the extent of the problems and the potential locations where management measures should be implemented and where resources should be effectively allocated. Also, improving the spill database reporting and recording system, such as identifying spill industrial NAICS code, geocoding spill location, estimating spill duration time, reducing unknown information on spill quantity, describing environmental impact (prediction or existence) and clean-up information in detail, are necessary for developing effective comprehensive chemical spill management plans.

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