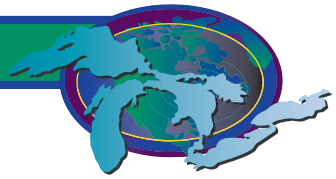

Wastewater Treatment and Pollution

Indicator # 7065

Note: This is a progress report towards implementation of this indicator.

Overall Assessment

Status:	**Not Assessed**
Trend:	**Undetermined**
Rationale:	**Data to support this indicator have not been summarized according to quality control standards. Compilation of a comprehensive report on wastewater treatment and pollution in the Great Lakes will require a substantial amount of additional time and effort.**

Lake-by-Lake Assessment

Data summarization is incomplete and unavailable for analysis and assessment on an individual lake basin scale at this time.

Purpose

- To measure the proportion of the population served by municipal sewage treatment facilities
- To evaluate the level of municipal treatment provided
- To measure the percent of collected wastewater that is treated
- To assess the loadings of phosphorus, biochemical oxygen demand (BOD), ammonia and solids (and organic chemicals and metals, when possible) released by wastewater treatment plants into the water courses of the Great Lakes basin

Ecosystem Objective

The quality of wastewater treatment determines the potential adverse impacts to human and ecosystem health as a result of the loadings of pollutants discharged into the Great Lakes basin. The main objectives for assessing and reporting this indicator are to foster (1) reductions in the pressures induced on the ecosystem by insufficient wastewater treatment networks and procedures, and (2) the progression of wastewater treatment towards sustainable levels. Adequate maintenance of facilities and operational procedures are required to meet the objectives. This indicator supports Great Lakes Water Quality Agreement Annexes 1, 2, 3, 11 and 12 (United States and Canada 1987).

State of the Ecosystem

Background

Wastewater refers to the contents of sewage systems drawing liquid wastes from a variety of sources, including municipalities, institutions, industry and stormwater discharges. After treatment, wastewater is released as effluent into receiving waters such as lakes, ponds, rivers, streams and estuaries.

Wastewater contains a large number of potentially harmful pollutants, both biological and chemical. Wastewater systems are designed to collect and remove many of the pollutants using various levels of treatment, ranging from simple to very sophisticated. Effluents released from wastewater systems can still contain pollutants of concern, since even advanced treatment systems do not necessarily remove all pathogens and chemicals.

The following constituents, although not necessarily routinely monitored, are mostly associated with human waste and are present in all sewage effluent to some degree:

- biodegradable oxygen-consuming organic matter (measured as biochemical oxygen demand or BOD)
- suspended solids (measured as total suspended solids or TSS)
- nutrients, such as phosphorus (usually measured as total phosphorus) and nitrogen-based compounds (nitrate, nitrite, ammonia, and ammonium, which are measured either separately or in combination as total nitrogen)
- microorganisms (which are usually measured in terms of the quantity of representative groups of bacteria, such as fecal coliforms or fecal streptococci, found in human wastes)
- sulphides
- assorted heavy metals

- trace amounts of other toxins and chemicals of emerging concern that have yet to be consistently monitored for in wastewater effluents

Municipal wastewater effluent is one of the largest sources of pollution, by volume, discharged to surface water bodies in Canada (CCME 2006). Reducing the discharge of pollution through wastewater effluent requires a number of interventions ranging from source control to end of pipe measures.

The concentration and type of effluent released into a receiving body of water depends heavily on the type of sewage treatment used. As a result, information regarding the level of wastewater treatment is integral in assessments of potential impacts on water quality. In both the United States and Canada, the main levels of wastewater treatment used include primary, secondary, and advanced or tertiary.

In the U.S., *pretreatment* of industrial wastewater may be required to reduce levels of contaminants and to remove large debris before the waters are released to municipal treatment systems for regular treatment. U.S. federal regulations require that Publicly Owned Treatment Works (POTW) pretreatment programs include the development of local pretreatment limits for industrial pollutants that could potentially interfere with municipal treatment facility operations or contaminate sewage sludge. The U.S. Environmental Protection Agency (U.S. EPA) can authorize the states to implement their own pretreatment programs as well. Of the eight states that are part of the Great Lakes basin, Michigan, Minnesota, Ohio and Wisconsin currently hold an approved State Pretreatment Program (U.S. EPA 2006b).

In *primary* wastewater treatment, solids are removed from raw sewage primarily through processes involving sedimentation. This process typically removes about 25% to 35% of solids and related organic matter (U.S. EPA 2000).

Secondary wastewater treatment includes an additional biological component in which oxygen-demanding organic materials are removed through bacterial synthesis enhanced with oxygen injections. About 85% of organic matter in sewage is removed through this process, after which the excess bacteria are removed (U.S. EPA 1998). Effluent can then be disinfected with chlorine prior to discharge to kill potentially harmful bacteria. Subsequent dechlorination is also often required to remove excess chlorine that may be harmful to aquatic life.

Advanced, or *tertiary*, levels of treatment often occur as well and are capable of producing high-quality water. Tertiary treatment can include the removal of nutrients, such as phosphorus and nitrogen, and essentially all suspended and organic matter from wastewater through combinations of physical and chemical processes. Additional pollutants can also be removed when processes are tailored to those purposes.

Levels of Treatment in the U.S. and Canada

In the U.S., secondary treatment effluent standards are established by the U.S. EPA and have technology-based requirements for all direct discharging facilities. These standards are expressed as a minimum level of effluent quality in terms of biochemical oxygen demand measurements over a five-day interval (BOD_5), total suspended solids (TSS) and pH. Secondary treatment of municipal wastewater is the minimum acceptable level of treatment according to U.S. federal law unless special considerations dictate otherwise (U.S. EPA 2000).

Data on the level of treatment utilized in the U.S. are available from the Clean Water Needs Survey (CWNS). This cooperative effort between the U.S. EPA and the states resulted in the creation and maintenance of a database with technical and cost information on the 16,000 POTWs in the nation. According to the results of the 2000 CWNS, the total population served by POTWs in U.S. counties fully or partially within the Great Lakes basin was 17,400,897. Of this number, 0.7% received treatment from facilities that do not discharge directly into Great Lakes waterways and dispose of wastes by other means, 14.1% received secondary treatment, and 85.3% received treatment that was greater than secondary, making advanced treatment the type used most extensively (Figure 1). These values do not include a possible additional 12,730 people who were reportedly served by facilities in New York for which watershed locations are unknown within the CWNS database.

Wastewater Treatment Plants (WWTPs) in Ontario also use primary, secondary, and tertiary treatment types. The processes are very similar, if not the same as those used in the U.S., but Canadian regulatory emphasis is placed on individual effluent quality guidelines as opposed to mandating that a specific treatment type be utilized across a province.

A complete distribution of population served according to level of treatment is not available at this time for the Great Lakes basin portion of Ontario. However, a distribution of the population served by each treatment type for all of Canada is available (Figure 2), and it may serve as a very general estimate of levels of treatment to be found in the Canadian portion of the Great Lakes basin.

Tertiary or advanced treatment is the most common type of sewage treatment across the entire Great Lakes basin, as inferred from the distribution data in both Figures 1 and 2. This indicates the potential for high effluent water quality, but that can only be verified through analysis of regulatory and monitoring programs.

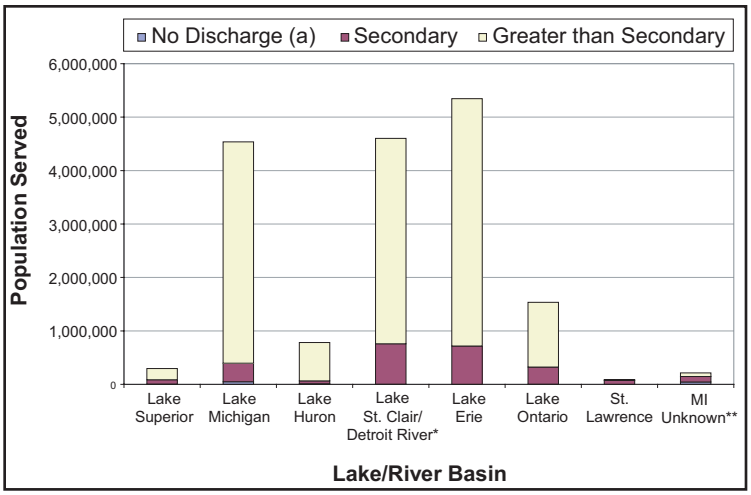

Figure 1. Population served by Publicly Owned Treatment Works (POTWs) by treatment level in the U.S. Great Lakes basin.

(a)= "No discharge" facilities do not discharge treated wastewater to the Nation's waterways. These facilities dispose of wastewater via methods such as industrial re-use, irrigation, or evaporation.

* Lake St. Clair and Detroit River watersheds are considered part of the Lake Erie basin

** MI Unknown refers to the population served by facilities in the state of Michigan for which exact watershed locations are unknown, so the data could not be grouped with a specific lake basin. Population could potentially be distributed between the Lakes Michigan, Huron, or Erie.

Source: 2000 Clean Watershed Needs Survey

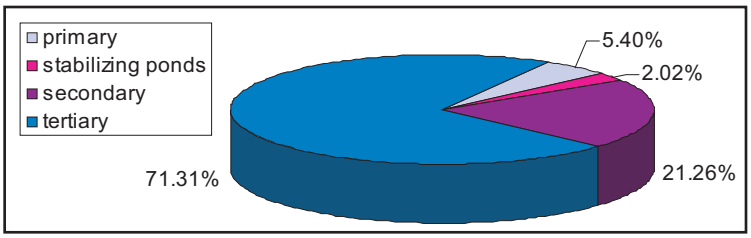

Figure 2. Percent of Population Served in Canada by Each Treatment Type in 1999.

Source: Municipal Water Use Database.

http://www.ec.gc.ca/water/en/manage/use/e_data.htm

Condition of Wastewater Effluent in Canada and the U.S.: Regulation, Monitoring, and Reporting

Canada

Canada sets specific limits for each individual WWTP, regardless of the type of treatment used. Effluent guidelines for wastewater from federal facilities are to be equal to or more stringent than the established standards or requirements of any federal or provincial regulatory agency (Environment Canada 2004). The guidelines indicate the degree of treatment and the effluent quality applicable to the wastewater discharged from the specific WWTP. Use of the federal guidelines is intended to promote a consistent wastewater approach towards the cleanup and prevention of water pollution and ensure that the best control technologies practicable are used (Environment Canada 2004).

Table 1 lists the pollutant effluent limits specified for all federally approved WWTPs in Ontario. In general, compliance with the numerical limits should be based on 24 hour composite samples (Environment Canada 2004).

In Ontario, wastewater treatment and effluents are monitored through a Municipal Water Use Database (MUD) by Environment Canada. This database uses a survey for all municipalities to report on wastewater treatment techniques. Unfortunately, the last complete survey is from 1999 and the data are not sufficient for use in this report. A current municipal water use survey is expected for release in 2007 and would be useful to examine treatment results within Canada.

United States

The U.S. regulates and monitors wastewater treatment systems and effluents through a variety of national programs. The U.S. EPA's Office of Wastewater Management promotes compliance with the Clean Water Act through the National

Pollutant Effluent	Limit
5 day Biochemical Oxygen Demand	20 mg/L
Suspended Solids	25 mg/L
Fecal Coliforms	400 per 100 mL (after disinfection)
Chlorine Residual	0.50 mg/L minimum after 30 minutes contact time; 1.00 mg/L maximum
pH	6 to 9
Phenols	20 micrograms/L
Oils & Greases	15 mg/L
Phosphorus (Total P)	1.0 mg/L
Temperature	Not to alter the ambient water temperature by more than one degree Centigrade (1°C)

Table 1. Canadian Pollutant Effluent Limits.

Source: Environment Canada (2004)

http://www.ec.gc.ca/etad/default.asp?lang=En&n=023194F5-1#specific

Pollutant Discharge Elimination System (NPDES) permit program. These permits regulate wastewater discharges from POTWs by setting effluent limits, monitoring, and reporting requirements, and they can lead to enforcement actions when excessive violations occur. The U.S. EPA can authorize the states to implement all or part of the NPDES program, and all U.S. states in the Great Lakes region are currently approved to do so, provided they meet minimum federal requirements (U.S. EPA 2006b). This distribution of implementation power can create difficulties, however, when specific assessments are attempted across regions spanning several states.

Large-scale, national assessments of wastewater treatment have been completed in the past using BOD and dissolved oxygen (DO) levels as indicators of water quality. Since DO levels are proven to be related to BOD output from wastewater discharges (increased BOD loadings lead to greater depletion of oxygen and therefore lower DO levels in the water) historical DO records can be a useful indicator of water quality responses to wastewater loadings. According to a national assessment of wastewater treatment completed in 2000, the U.S. Great Lakes basin had a statistically significant improvement in worst-case DO levels after implementation of the Clean Water Act (U.S. EPA 2000). The study's design estimates also showed that the national discharge of BOD_5 in POTW effluent decreased by about 45%, despite a significant increase of 35% in the population served and the influent loadings. This improving general trend supported assumptions made in the 1996 CWNS Report to Congress that the efficiency of BOD removal would increase due to the growing proportion of POTWs using advanced treatment processes across the nation.

Unfortunately, comprehensive studies such as the examples listed above have not been conducted for pollutants other than BODs, and none have been completed to an in-depth level for the Great Lakes region. However, an extensive investigation of the Permit Compliance System (PCS) database is one way an evaluation of wastewater treatment could be accomplished. This national information management system tracks NPDES data, including permit issuance, limits, self-monitoring, and compliance. The PCS database can provide the information necessary to calculate the loadings of specific chemicals present in wastewater effluent from POTWs in the U.S. portion of the Great Lakes basin, providing the relevant permits exist.

Attempted Experimental Protocol for Calculating Pollutant Loadings from Wastewater Treatment Plants to the Great Lakes

The calculation of pollutant loadings from wastewater treatment plants was attempted for both the U.S. and Canadian portions of the Great Lakes basin during the compilation of this report. Although an extensive amount of data are available and have been retrieved, their summarization to an appropriate level of quality control is substantially difficult and is not complete at this time. The protocol followed thus far is outlined below.

United States

A list of all the municipal wastewater treatment facilities located within the U.S. Great Lakes basin, and their permitted pollutants, was compiled from the PCS database. A determination was made of the most consistently permitted contaminants, and effluent data for 2000 and 2005 were then retrieved for all facilities that monitored for those parameters. These pollutant parameters were referenced by various common names in the database, which complicated extraction of concise data. The resulting large quantity of data could not feasibly be summarized, however, due to internal inconsistencies that included differences in units of measurement, varying monitoring time frames, extreme outliers, and apparent data entry mistakes.

To decrease the amount of data requiring analysis, several specific facilities throughout the basin were chosen to serve as representative case studies for which total loadings estimates would be calculated. These facilities were chosen according to location within the basin (to ensure that all states and each Great Lake were represented) and by the greatest average level of effluent flow (because high flow facilities could potentially have the greatest environmental impact). Additionally, these flow values could be used to calculate loadings in the frequent cases where pollutant measurements were reported as a concentration as opposed to quantity. Fifteen facilities were selected for analysis, and corresponding effluent measurements for basic pollutants were extracted from the PCS database. Calculation of pollutant loadings, their percent change and the number of violations from 2000 to 2005 were attempted, but data quality issues undermine confidence in the calculated values.

Although total effluent loadings were difficult to calculate with confidence, government-generated historical records of effluent limit violations can provide some insight into the performance of U.S. Great Lakes wastewater treatment facilities. The Enforcement and Compliance History Online (ECHO) is a publicly accessible data system funded by U.S. EPA. It was used to obtain violation information by quarter over a three-year time span for the group of 15 U.S. facilities previously selected for loadings calculations. The resulting compliance data are presented in Figure 3 according to each pollutant for which violations of permitted effluent levels occurred during the 12 possible quarters under investigation from 2003-2006. Both basic violations of effluent limits and "significant" levels of non-compliance with permitted effluent limits are displayed. Chloride, fecal coliform, and solids violations

were the most common, with copper, cyanide, and mercury having higher numbers of violations as well. Chloride, copper, mercury, and solids violations showed the most "significant" non-compliance with permitted levels.

Canada

In Ontario, wastewater treatment plants must report on the operation of the system and the quality of the wastewater treatment procedures on an annual basis to satisfy the requirements of the Ontario Ministry of Environment and the Certificate of Approval. Each report fulfills the reporting requirements established in section 10(6) of the Certificate of Approval made under the Ontario Water Resources Act (R.S.O. 1990, c. O.40). As a result of these requirements, effluent limit violations for BOD, phosphorus, and suspended solids should be available for future analysis. Data are too extensive to summarize at this time to a sufficient level of quality control.

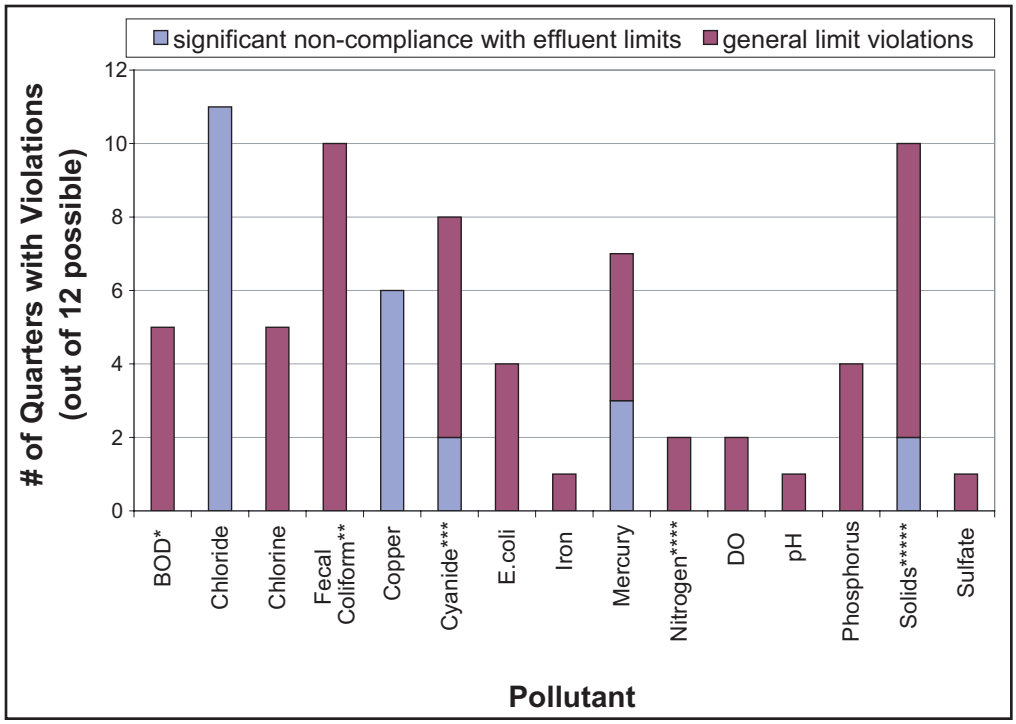

Figure 3. Total number of quarters with reported effluent limit violations by pollutant for selected U.S. facilities.

Data were compiled from 15 different facilities according to the total number of quarters that were in non-compliance of at least one pollutant effluent limit permit during 2003-2006.

* = combination of violations for 5-day BOD listed as total % removal and total

** = combination of violations for fecal coliform listed as general and analytical method "M-FC broth, 44.5C" totals

*** = combination of violations for cyanide listed as A and CN totals

**** = combination of violations for total nitrogen listed as N and as NH3

***** = combination of violations for solids listed as total settleable, total dissolved, total suspended, and suspended % removal

Source: U.S. EPA (2006a), Office of Enforcement and Compliance Assurance. http://www.epa.gov/echo/index.html

Since results from the Municipal Water Use Database were not available at this time, 10 Canadian municipalities in the Great Lakes basin provided effluent data for analysis. Municipalities were randomly chosen based on their proximity to the Great Lakes and their population of over 10,000. Most of the chosen municipalities had one to three WWTPs in their jurisdiction, with a total of 22 Canadian treatment plants being examined for this indicator report. The WWTPs assessed were an even mixture of primary, secondary and tertiary treatment plants. Data from 2005 annual reports for each WWTP were used to analyze wastewater treatment procedures and associated effluent quality, with special focus on BOD, phosphorus, suspended solids and *E. coli*.

These parameters are regulated by most WWTPs, and current targets exist to minimize environmental and health impacts. For example, Ontario WWTPs have a target of 50% for the removal of BOD, but levels must not exceed 20 mg/L in a 5 day span. The target for the removal of suspended solids is 70%, with a limit of 25 mg/L in a 24 hour sample period. Wastewater effluent limits for phosphorus in Ontario have been set at 1.0 mg/L. The *E. coli* concentration limit for WWTPs is generally <200 *E. coli* counts per 100 mL.

Out of the 22 Ontario WWTPs examined in 2005, levels of BOD, suspended solids, and *E. coli* concentrations collectively exceeded Ministry of the Environment Certificate of Approval limits 6 times. BOD levels were above the limit 3 times; total suspended solids exceeded the limits once, and *E. coli* concentrations exceeded the limit twice. Phosphorous levels did not exceed the limit for any WWTP in Ontario in 2005. There were 6 odor complaints from WWTPs throughout 2005, and these were from a primary treatment plant.

Pressures
There are numerous challenges to providing adequate levels of wastewater treatment in the Great Lakes basin. These include: facility aging, disrepair and outdatedness; population growth that stresses the capabilities of existing plants and requires the need for more facilities; new and emerging contaminants that are more complex and prolific than in the past; and new development that is located away from urban areas and served by decentralized systems (such as septic systems) that are much harder to regulate and monitor. The escalating costs associated with addressing these challenges continue to be a problem for both U.S. and Canadian municipalities (U.S. EPA 2004, Government of Canada 2002).

Management Implications
Despite demonstrated significant progress in wastewater treatment across the basin, nutrient enrichment, sediment contamination, heavy metals, and toxic organic chemicals still pose threats to the environment and human health. To maintain progress on these issues, and to ensure that current achievements in water pollution control are not overwhelmed by the demands of future urban population growth, governments should continually invest in wastewater treatment infrastructure improvements. In addition, investments are needed to control or mitigate polluted urban runoff and untreated municipal stormwater, which have emerged as prime contributors to local water quality problems throughout the basin (Environment Canada 2004).

In Canada, municipal wastewater effluent (MWWE) is currently managed through a variety of policies, by-laws and legislation at the federal, provincial/territorial and municipal levels (CCME 2006). This current variety of policies unfortunately creates confusion and complex situations for regulators, system owners and operators. As a result, the Canadian Council of Ministers of the Environment (CCME) has established a Development Committee to develop a Canada-wide Strategy for the management of MWWE by fall 2007. An integral part of the strategy's development will be to consult with a wide variety of stakeholders to ensure that management strategies for MWWE incorporate their interests, expertise and vision. The strategy will address a number of governance and technical issues, resulting in a harmonized management approach (CCME 2006).

WWTPs are challenged to keep up with demands created by urban development. The governments of Canada and Ontario and municipal authorities, working under the auspices of the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA), have been developing and evaluating new stormwater control technologies and sewage treatment techniques to resolve water quality problems (Environment Canada 2004). Under COA, Canada and Ontario will continue to build on this work, implementing efficient and cost effective projects to reduce the environmental damage of a rapidly expanding urban population (Environment Canada 2004).

The presence of chemicals of emerging concern in wastewater effluent is another developing issue. Current U.S. and Ontario permit requirements are based on state or provincial water quality laws that are developed according to pollutants anticipated to exist in the community. This means the existence of new potentially toxic substances can be overlooked. For example, even in areas with a high degree of municipal wastewater treatment, pollutants such as endocrine-disrupting substances can inadvertently pass through wastewater treatment systems and into the environment. These substances are known to mimic naturally occurring hormones and may have an impact on the growth, reproduction, and development of many species of wildlife. Additional monitoring for these pollutants and corresponding protection and regulation measures are advised.

The methodologies used in previous U.S. national assessments of wastewater treatment could potentially be used to estimate loadings trends and performance measures for additional pollutants in the Great Lakes. The QA/QC safeguards included in such methods could lead to useful analyses of watershed-based point source controls. Substantial resources in terms of time and funding would need to be allocated in order to accomplish this task.

Comments from the author(s)
A number of challenges and barriers to the full implementation of this indicator report were encountered during its preparation. Included were:

Population estimates
The actual proportion of the entire population receiving municipal wastewater treatment is difficult to calculate. Several different population estimates exist for the region, but in the U.S. they were compiled by county, and therefore represent a skewed total for the population that actually resides within the boundaries of the Great Lakes watershed. GIS analysis of census data needs to be completed in order to obtain a more accurate estimate of the Great Lakes population.

Data availability

In Canada, only one year was assessed due to lack of available data. In future years, data from the Environment Canada Municipal Water Use Database would be useful to use. The database is currently only updated to 1999, which unfortunately was not useful for this report. The newest survey will be out within the next year and the data should be examined in future assessments for this indicator.

Loadings calculations

Several problems exist in the calculation of effluent loadings. For example, actual effluent flow is not consistently monitored in the U.S. Although influent levels are obtainable for every facility, effluent levels might not be comparable, since a substantial volume may be removed during treatment processes. Because effluent flow data are necessary to calculate loadings from concentration values of pollutants, precise estimates of total loadings to Great Lakes waters may be next to impossible to obtain on a large scale without actual effluent flow data.

Consistancy in implementation of analysis

Consistent guidelines and practices for the analysis of wastewater treatment in both the U.S. and Canada would be helpful. In the U.S., data were compiled from several different databases, with population information derived from a separate source than effluent monitoring reports. In Ontario, data from 10 randomly chosen municipalities serving a population of 10,000 or greater were used for analysis, while in the U.S., wastewater treatment facilities were chosen for "case studies." These approaches for analysis of wastewater treatment might provide a fragmented, and perhaps biased, view of the treatment patterns in the Great Lakes basin.

Consistancy in monitoring and reporting

To successfully correlate wastewater treatment quality with the environmental status of the Great Lakes basin, a more organized monitoring program must be implemented. Although wastewater treatment plants provide useful monitoring information, they only report the quality of the effluent at that specific municipality, rather than the overall quality of the Great Lakes. Additionally, differences in monitoring requirements between Canada and the U.S. make assessments of the quality of wastewater treatment difficult on a basin-wide scale. Implementation of a more standardized, updated approach to monitoring contaminants in effluent and a standardized reporting format and inclusive database, accessible to all municipalities, researchers, and the general public, should be established for binational use. This would make trend analysis easier, and thus provide a more effective assessment of the potential health hazards associated with wastewater treatment for the Great Lakes as a whole.

Automated data processing

Considering all the difficulties encountered while attempting to adequately summarize the vast amount of U.S. effluent monitoring data contained in the PCS database, a logical solution would be an application that could automate accurate calculations. Such an application previously existed that was capable of producing effluent data mass loadings reports from the PCS database, and annual NPDES Great Lakes Enforcement reports were once compiled. However, the application used to calculate loadings was discontinued due to the modernization of the PCS system that is currently underway, and resources have not yet been available to extend the overhaul to this tool. Incorporating this component into the current modernization could take years due to various logistical problems, including the inherent quality assurance issues (personal communication with James Coleman 2006). Despite these problems, the reinstatement of such a tool would solve the data summarization needs presented in this indicator report and could lead to an effective, comprehensive, and time-efficient analysis of pollutant loadings to the Great Lakes from U.S. wastewater treatment plants.

Further development of this indicator

The ultimate development of this progress report into a reportable Great Lakes indicator is necessary and would be possible in the near future if:

- Increased manpower and time could be dedicated to indicator development,
- Revisions were made to the proposed indicator that included a decreased scope, more realistic reporting metrics, and a less-strenuous reporting frequency,
- The data retrieval process were streamlined with appropriate quality controls, and
- A workgroup was created of members that held specific expertise regarding wastewater systems, treatment plant analytical methods, municipal infrastructure, permitting, and who had knowledge of and access to the relevant databases.

Note:
Since the preparation of this progress report, an assessment of municipal sewage treatment and discharges into the Great Lakes basin was compiled by Sierra Legal Defence Fund. The *Great Lakes Sewage Report Card* (2006) analyzes 20 Great Lakes cities and graded them on a variety of parameters relating to their sewage management systems. The full report is available to download online at, http://www.sierralegal.org/reports/great.lakes.sewage.report.nov.2006b.pdf.

Acknowledgments
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