Review of the State of Knowledge of Municipal Effluent Science and Research

Review of Existing and Emerging Technologies
Review of Wastewater Treatment Best management Practices

Executive Summary

This report addresses Tasks 2 and 3 of the CCME Project #352-2005 titled “Review of the State of Knowledge of Municipal Effluent Science and Research”. The Task 1 Report was issued in June of 2005. The objectives for Tasks 2 and 3 are as follows:

1. (Task 2) Prepare an annotated summary of existing and emerging treatment technologies for treatment of conventional pollutants, harmful substances and emerging pollutants from the Task 1 report. The technologies will be assessed for their applicability to variations in Canadian climates, environments, regions and receiving waters.
2. (Task 3) Provide a review of best management practices for specific issues related to municipal wastewater treatment, including but not limited to:
   - Infiltration and inflow to municipal sewer systems
   - Reduction and treatment of sanitary and combined sewer overflows (SSOs and CSOs)
   - Management of hauled wastes such as septage, landfill leachate or industrial/commercial wastewaters
   - Small or remote community wastewater issues, including treatment cost and pollutant management
   - Discharges of treated effluents to marine environments
   - Lagoon issues, including ice cover and ammonia removal in winter, and algae removal in summer
   - Flow reductions to wastewater treatment plants using alternative technologies and source control plans, including water reuse and reclamation technologies
   - Aging collection system needs and upgrading practices
   - Wastewater treatment facility performance monitoring and quality control practices.

Advanced and Off-the-Shelf Technologies

Technologies reviewed as advanced and off-the-shelf processes included: biological nutrient removal; membrane bioreactors; Integrated fixed film activated sludge; moving bed bioreactors, biological aerated filter; sand filtration; membrane filtration (microfiltration, nanofiltration, reverse osmosis); chemically enhanced precipitation; constructed surface wetlands; and constructed subsurface wetlands.

Most of the technologies involving an advanced biological treatment process are expected to provide a level of treatment for the various substances that is higher than conventional nitrifying activated sludge. Processes that may not be as acceptable include the constructed wetlands processes with respect to nutrients and emerging contaminants. Chemically enhanced precipitation does not increase removal of ammonia-nitrogen well compared to nitrifying activated sludge. Without disinfection, BNR processes will not have adequate pathogen reduction, but with disinfection pathogen removal would be considered excellent. Much more information on the emerging innovative technologies is required to completely assess the process capabilities for removing the various types of substances in municipal effluents.

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Most of the innovative biological processes are applicable to a wide range of conditions in Canada, in terms of discharge to different receiving environments (marine, freshwater, land), particularly in temperate climatic zones. In rural areas, operators may not have the technical expertise or resources to operate the innovative biological systems. The non-biological process of chemically enhanced precipitation may not reduce ammonia concentrations to required levels, whether for concerns about eutrophication or for effluent toxicity considerations. Constructed wetlands are a good technology for remote areas of Canada, but sustained periods of freezing conditions, especially in the Arctic and sub-Arctic, would require the inclusion of winter storage so that the wastewater is discharged to the wetland during above-freezing temperatures. Land availability would likely restrict the use of constructed wetlands for treatment in large urban areas.

There are many gaps in our knowledge of treatment removal efficiency for toxicity, metals, pesticides, PAHs and hydrocarbons in the advanced processes such as membrane bioreactors, IFAS, MBBRs, and BAFs, as well as sand filtration and chemically enhanced precipitation. In addition, a variety of emerging contaminants such as different PPCPs, fragrances, flame retardants, perfluorinated compounds and other contaminants of emerging environmental concerns need to be characterized for removal in wastewater treatment. Current analytical capabilities can be a significant limitation in this effort, however. It is clear that much more information on the advanced technologies is required

Source Control

Certain metal and organic substances in wastewater can interfere with the microorganisms involved in aerobic and anaerobic treatment. The concentrations of substances that have been reported to interfere with biological treatment process are typically in the mg/L concentration range, which is generally higher than most substances would be found in raw wastewater. The mixed liquor solids of activated sludge can adsorb many of the metal and organic compounds, resulting in concentrations that are significantly increased compared to the raw wastewater levels.

Most municipalities have in place a sewer use bylaw that regulates the concentrations and quantities of substance discharged to municipal sewers for treatment. The sewer use regulations are generally targeted at businesses such as restaurants and industrial dischargers. Bylaws are intended to limit the discharge of substances to the sewer to prevent overloading of the treatment facility and possible discharge of toxic substances in effluents. Controlled parameters typically include pH, solvent extractable material of mineral or synthetic origin, solvent extractable material of animal or vegetable origin, biochemical oxygen demand, suspended solids, phosphorus, Total Kjeldahl nitrogen, phenolic compounds, chlorides and sulphates, fluorides, many individual heavy metals and cyanides. Some municipalities may also impose limits or include limits on other substances, such as a number of specific organic compounds. Industrial cooling waters, which may contain slimicides and corrosion inhibitors, and once-through cooling water, may also be prohibited from discharge to municipal sewers on the basis of both toxic substance and hydraulic loading concerns.

Materials subject to complete prohibitions in wastewaters discharged to sewers include: fuels, PCBs, pesticides, severely toxic materials, waste radioactive materials, hauled sewage, waste disposal site leachate, acute hazardous waste chemicals, hazardous industrial wastes, hazardous waste chemicals, ignitable wastes, pathological wastes, PCB wastes and reactive wastes.

Municipalities also implement pollution prevention programs to restrict the discharge of materials to sewers. Mercury in dental amalgams, silver from dental and hospital X-rays and photo-processing wastes and fats, oil and grease from restaurants and large food service operations are specific examples.

Several substances, such as some metals and pesticides, are not readily removed by a basic level of secondary treatment (non-nitrifying conventional activated sludge). For such substances, when wastewater treatment has difficulty in achieving a high level of removal, source control may be the best option for prevention of discharge to receiving environments.

Best Management Practices

Best Management Practices originally were implemented in urban settings as flood and drainage controls. More recently, however, the BMPs serve several purposes such as treatment of stormwater and protection of receiving waters. There are a variety of Best Management Practices that can be implemented to restrict the entry of contaminants in aquatic environments.

The Best Management Practices for control of infiltration and inflow (I/I) involve urban runoff control, and include regulatory controls, source controls, detention facilities, infiltration facilities, vegetative practices and filtration practices. The BMPs are generally applicable to all regions of Canada, although harsh winter conditions in Northern Canada may restrict the implementation of some practices such as constructed wetlands or grassed swales to intermittent seasonal discharges.

The technologies for combined sewer overflow (CSO) reduction and treatment include source control, collection system controls, storage, physical treatment (racks and screening), chemical precipitation biological treatment and disinfection. Such technologies are applicable to most regions of Canada. Remedial plans to eliminate bacterial contamination of recreational swimming often include some form of stormwater detention. Higher storm flows can also be treated at the wastewater treatment plants when the step feed model of activated sludge is implemented. Permafrost in northern Canada may prevent the adoption of technologies where below-grade construction is required.

Sanitary sewer overflows (SSOs) can result from many causes including aging infrastructure, poor design, blockages by grease, obstruction from large solids (branches and roots). Most Canadian municipalities are faced with aging infrastructure. Implementation of sewer use programs will reduce blockages due to grease accumulation, and sewer maintenance programs, involving television cameras and maintenance records can identify blockages due to roots. The programs needed to prevent these problems can be implemented across Canada.

Review of the literature did not reveal any specific Best Management Practice for identification and removal of cross-connections. Monitoring of dry weather flows in storm sewers for evidence of sewage contamination is a common sense first step. Ranking of areas for removal of cross-connections as applied by the City of Edmonton is a practical approach for prioritizing areas of a municipality for reducing extraneous flows. The techniques appear to be applicable Canada-wide.

Discharge of septage to municipal wastewater treatment plants appears to have the potential for greater impact than does landfill leachate for mechanical plants such as conventional activated sludge or extended aeration processes. The elements of a best management practice for septage treatment at wastewater treatment facilities include construction of an equalization storage facility at the reception site, equipped with an odour control device. Coarse screening of the septage prior to discharge to the treatment facility, as practiced by the Capital Regional District, may be advantageous.

The contribution of municipal landfill leachate to daily wastewater treatment plant flow is very small. Nitrifying wastewater treatment facilities were deemed capable of meeting target effluent concentrations in winter operation. Facultative lagoons were similarly deemed capable of meeting effluent quality target with the exception of ammonia-N. The elements of a best management practice for leachate treatment at wastewater treatment facilities include construction of an equalization storage facility at the reception site, equipped with an odour control device. Intermittent sand filtration was recommended as a polishing step to achieve ammonia-N target concentrations in lagoon effluents.

The problems faced by small municipalities with funding for required treatment levels, hiring and maintaining staff and understanding the technicalities of wastewater treatment are common across Canada, but may be particularly acute in the Canadian North. Many resources are available through technical associations, government agencies and internet portals. Funding opportunities may be available by participating in technology demonstration projects.

Most developed nations have implemented either long outfalls to deep water and/or secondary treatment to deal with common problems of bacterial levels, elevated nutrient, which can contribute to depleted dissolved oxygen levels, plastics floatable materials, and sediments with elevated levels of heavy metals, pesticides and other substance. Treatment of wastewater to secondary levels or higher offers environmental improvements in nutrient removal and reduced levels of potentially toxic substances either dissolved or associated with suspended solids. Canadian coastal cities have not generally matched the tendency of other developed nations to move to secondary treatment, although there is some indication, such as with Charlottetown and Summerside in PEI, that this is changing.

Other than Iqaluit (estimated population of 6500), there are no large Canadian municipalities in Northern Canada located on marine coasts. Prevailing currents off Canada's east and west coasts tend to bring colder Arctic waters down, and so effluents are generally discharged into cold marine waters. Organic substances discharged in municipal wastewater to Arctic marine environments (the Arctic Ocean. Hudson Bay) would tend to persist for long periods because both biodegradation and volatilization to the atmosphere are slow under cold conditions (relative to southern Canada).

Facultative lagoon treatment is one of the most common methods of treatment for small communities across Canada. Most of the problems experienced in lagoon treatment are common to all locales. In winter, biological removal of ammonia in facultative lagoons is curtailed and ammonia concentrations in effluent discharges may exceed regulatory limits. Toxic gases such as hydrogen sulphide accumulate under ice cover, and produce foul odours and potentially toxic effluents when the ice cover breaks up in spring. Aerated lagoons are less susceptible to the winter problems experienced by facultative lagoons because aeration in the initial cell reduces the potential for ice cover. Depending on whether the lagoon discharge is seasonal or continuous, the end-of-pipe effluent may be acutely lethal to test organisms. Technologies such as intermittent sand filters and static aerators may reduce some of these toxicity and odour concerns.

Source control is a measure that can be adopted across Canada to reduce total wastewater flow. Programs can be provided that are either incentives (grants) or disincentives (financial penalties and fines). Improvements in domestic plumbing devices, (low-flush toilets, low-flow showerheads) in new developments can significantly reduce wastewater volumes. Water reclamation is not practiced to any extent at this time in Canada, but with the apparent onset of global warming, the need to practice water reclamation and reuse appears inevitable, as it has already become well-entrenched in the southern U.S.

Canadian municipalities need to maintain their infrastructure to provide safe drinking water and proper sanitation. In, Ontario alone, the investment required to return Ontario's current water and wastewater systems to a state of good repair - and maintain that condition for the indefinite future – is estimated to be between $30 and $40 billion over the next 15 years (Water Strategy Expert Panel, 2005). Other provinces are faced with similar challenges. There are many best practices provided by Infraguide Canada that municipalities can use to understand the condition of their infrastructure and take the necessary measures to attack the problem.

Benchmarking is a procedure that Canadian municipalities can conduct on their own through voluntary programs such as Qualserve, offered by the American Water Works Association. Adoption of ISO Certification by Canadian wastewater treatment facilities is in its infancy. There is a growing trend in the U.S. for this level of environmental management. Municipalities that have become certified as ISO 14001 compliant indicate that many advantages result.