Protecting surface water quality from wastewater discharges through assimilative capacity studies

By Carolyn Brown and Bruce Rodgers

Municipalities and industries discharge treated wastewater into natural water bodies, such as streams, rivers and lakes. Although treated, these wastewaters contain trace contaminants, including nutrients, solids and metals. These substances may affect downstream water quality, for example, by contributing to the growth of nuisance algae, which can alter fish habitat and aquatic ecosystems.

In order to protect water quality, federal and provincial regulations exist to limit the discharge of wastewaters. These regulations recognize the impracticality of total elimination of wastewater discharges, due to technological or economic constraints. Because of this, existing regulations permit wastewater discharge and accept some degree of water quality alteration. The question that often arises is, "what is an acceptable quantity of wastewater discharge and associated degree of water quality alteration?"

Federal and provincial regulatory processes are similar, although the terminology used may vary. The federal process refers to wastewater strategies that ensure compliance with site-specific environmental quality objectives, whereas the provincial process refers to release limits that ensure compliance with environmental policy objectives.

An assimilative capacity study (ACS) achieves both requirements, by quantifying discharge limits that protect the environment.

What is assimilative capacity?

Assimilative capacity refers to the capacity of a water body to receive wastewater without harmful effects. Specifically, it refers to the quantity of wastewater that can be safely released to the water body under known conditions, while ensuring compliance with environmental quality and/or policy objectives. Wastewater quantity can be expressed in terms of either discharge rate and discharge quality for specific substances, or as a mass loading for specific substances.

An assimilative capacity study works through a series of steps, to quantify the capacity of the water body and determine safe release limits for discharge. All municipalities and industries that discharge, or are planning to discharge wastewater to a natural water body, may be required to undertake an ACS under federal and provincial regulations.

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Studies may also be required for a new discharge that is being proposed, or for a significant change to an existing discharge. Older discharges, which may lack sufficient technical documentation to support the existing license, may also need to undertake an ACS.

Qualified scientists and engineers are able to undertake an ACS. They should be experienced in environmental monitoring, environmental assessment and mathematical modeling of surface water systems. They should also have experience working with regulators, First Nations and diverse stakeholders.

An ACS typically includes the following steps:

Step 1: Characterize the receiving environment.

The water body that receives the discharge should be characterized based on the following:

- General description, including location, infrastructure and adjacent land use.
- Resource utilization, which is proximity to source water for drinking and proximity to other identified discharges.

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- Aquatic resources, which are types of biota, fisheries habitat, spawning habitat, environmentally sensitive areas.
- Morphometry, meaning physical geometry, water levels, currents, and hydrology.
- Statistical summaries of water quality characteristics and spatial and temporal trends.

The more that is understood about the receiving environment, the better.

Step 2: Determine the appropriate mixing zone.

Discharge and receiving waters come together within the mixing zone. These exist for most receiving environments, although they have greater relevance for discharges into large water bodies. The spatial extent of the mixing zone is influenced by the characteristics of the receiving environment, which are water depth, flow, density and quality, as well as the characteristics of the discharge, such as rate, configuration, density and quality.

Some regulators specify the allowable size for the mixing zone, whereas others specify objectives. A mixing zone should be as small as possible, not be used as an alternative to reasonable and practical treatment, or harmful to aquatic biota. It also should not overlap with other mixing zones.

Step 3: Establish environmental quality objectives.

Environmental quality objectives refer to the concentration of a substance in the water body that protects human health, aquatic life and the beneficial use of water. In many cases, these objectives correspond to federal or provincial water quality objectives, such as water quality guidelines from the Canadian Council of Ministers of the Environment. In other cases, water quality objectives are site-specific, accounting for site conditions such as for water bodies with naturally elevated water quality.

Step 4: Quantify the assimilative capacity in the receiving environment.

In simplest terms, assimilative capacity is the mass of a substance that can be discharged to the water body, without the substance concentration exceeding environmental quality objectives.

Federal and provincial regulators generally specify conditions under which the ACS should define assimilative capacity. Such conditions can either be fixed or variable.

A fixed condition refers to a unique worst case condition, under which assimilative capacity is defined. Worst case is often defined based on conditions having a 5 per cent or 10 per cent probability of occurrence. For example, the worst case for a discharge to a small river could occur during a low flow, having a five per cent or 10 per cent probability of occurrence. This provides a conservative interpretation of assimilative capacity.

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A variable condition considers the range of circumstances that occur in natural water bodies. It allows for the utilization of the available assimilative capacity in the water body as conditions vary. This approach can provide the same degree of protection as a fixed condition, but generally requires greater effort to manage the process.

Step 5: Characterize the quantity and quality of the wastewater discharge.

The nature of the municipal or industrial facility generally defines the nature of the wastewater discharge. The size and type of facility generally dictates the quantity and quality of the wastewater discharge. However, results of the ACS may also dictate the allowable quantity and quality of wastewater that can be safely discharged to the water body.

This may identify additional water treatment or management, to ensure compliance with environmental objectives in the receiving environment. This step may be iterative since the initial characterization of the wastewater discharge is required to inform the ACS, yet the results of the ACS are required to support the discharge limits.

Modelling an assimilative capacity study

Most ACSs rely on mathematical models to calculate the assimilative capacity of the receiving environment and derive safe discharge limits. Given the diversity of conditions that can be encountered in practice, a broad array of models exists.

Most models supporting an ACS rely on principles of mass conservation. This implies that the mass of a substance discharged, can be tracked through the water body, and potential changes in concentration, can be accounted for through mixing, physical and/or biochemical processes.

Steady-state models, in which conditions remain constant in time, are the most common type of model used to support an ACS.

Models can be further classified as near-field and far-field. A near-field model considers the complex mixing processes that occur immediately upon discharge. It is used most often to estimate the spatial extent of the mixing zone. Far-field models typically extend beyond the mixing zone, considering water quality effects throughout the water body, including accumulative effects with other identified discharges and/or complex physical and bio-chemical processes, such as dissolved oxygen kinetics.

Follow-up environmental monitoring provides the most conclusive validation of various assumptions included in an ACS. Monitoring can include field sampling for analysis of water quality, or monitoring biological indicators to demonstrate protection of the aquatic resource.

For example, federal regulators require pulp and paper mills and mines to undertake Environmental Effects Monitoring programs, to measure potential effects to water, sediment and biota.

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