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Environmental Impact and Benefit Assessment for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category

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Environmental Impact and Benefit Assessment for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category

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Abbreviations and Acronyms

ADF—Aircraft Deicing and Anti-icing Fluid
AMS—Aerospace Material Specification
atm—Atmospheres
BAF—Bioaccumulation Factor
BCF—Bioconcentration Factor
BOD—Biochemical or Biological Oxygen Demand
BOD_5—Five Day Biochemical Oxygen Demand
C—Celsius
CASRN—Chemical Abstracts Service Registry Number
$CBOD_5$—Five Day Carbonaceous Biochemical Oxygen Demand
cfs—Cubic Feet per Second
COD—Chemical Oxygen Demand
DO—Dissolved Oxygen
EPA—United States Environmental Protection Agency
EC_x—Effective Concentration for x% of test organisms
ESRI—Environmental Systems Research Institute
g—Gram
GA/C—General Aviation and/or Cargo
GIS—Geographical Information System
GCV—Glycol Collection Vehicle
IARC—International Agency for Research on Cancer
IRIS—Integrated Risk Information System
kg—Kilogram
K_{oc}—Soil organic carbon adsorption coefficient
K_{ow}—Octanol water partition coefficient
L—Liter
LC_x—Lethal Concentration for x% of test organisms
LOEC—Lowest Observed Effect Concentration
LOAEL—Lowest Observed Adverse Effect Level
m—Meter
MATC—Maximum Allowable Toxicant Concentration
MCL—Maximum Contaminant Level
mg—milligram
mm—millimeter
MSDS—Material Safety Data Sheet
NHD—National Hydrography Dataset
NOEC—No Observed Effect Concentration
NOAEL—No Observed Adverse Effect Level
NPDES—National Pollutant Discharge Elimination System
NRWQC—National Recommended Water Quality Criteria
NWRA—National Wildlife Refuge Area
POTW—Publicly Owned Treatment Works
RfC—Reference Concentration
RfD—Reference Dose
RSEI—Risk-Screening Environmental Indicators model
SAE—Society for Automotive Engineers

SOFP—Snow or Freezing Precipitation
TMDL—Total Maximum Daily Load
µg—microgram
WATERs—Watershed Assessment, Tracking, and Environmental Results
WOE—Weight of Evidence
WTP—Willingness to Pay

1 Introduction

The United States Environmental Protection Agency (EPA) is promulgating effluent limitation guidelines and new source performance standards for the Airport Deicing Point Source Category. The regulations address both the wastewater collection practices used by airports, and the treatment of those wastes. Airports in the scope of this regulation are defined as Primary Commercial Airports with greater than or equal to a 1,000 annual non-propeller-driven aircraft departures. This document discusses environmental impacts associated with deicing operations at these airports and the environmental benefits EPA estimates would result from pollutant discharge reductions under the final regulatory options. This document presents information on the environmental impacts airport deicing discharges have caused in the past and on their potential to do so in the future. The final regulatory options will reduce the frequency and severity of environmental impacts associated with airport deicing discharges. The regulatory options will primarily benefit surface waters, though soil and groundwater resources could benefit from pollutant discharge reductions, as well.

This introduction briefly describes the nature of airport deicing operations and their pollutant discharges and provides an overview of associated environmental impacts. Additional information on the characteristics of airport deicing operations and their discharges is available in the *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010). EPA's final rule addresses only those deicing activities that take place on the airfield side of airports where aircraft are active. It does not address pollutant discharges from deicing activities airports undertake to clear snow and ice from parking lots, roads, sidewalks and other airport surfaces beyond the airfield.

Chapter 2 of this document provides information on the chemical composition of airport deicing products used in the United States and discusses the potential for environmental impacts from various formulation ingredients. *Chapter 3* provides information on known locations and levels of U.S. airport deicing operation discharges and associated environmental impacts. *Chapter 4* discusses each of the final regulatory options in terms of the environmental benefits EPA estimates would result from each option.

1.1 Airport Deicing and Anti-icing Operations

The purpose of airport deicing operations is to ensure safe aircraft departures, landings, and travel on airport grounds. Frozen precipitation or frost on aircraft surfaces can compromise aircraft ability to obtain sufficient lift for departures or damage aircraft. Frozen precipitation on the airfield can cause loss of aircraft control due to lack of traction between aircraft wheels and airfield surfaces. Frost and frozen precipitation must be addressed if aircraft are to function safely under winter conditions.

There are two types of snow and ice removal operations. Deicing operations remove snow and ice accumulations from aircraft and airfield surfaces. Anti-icing operations prevent snow and ice from accumulating on aircraft and airfield surfaces, either before accumulation can take place or after a surface has been cleared by deicing operations. Both aircraft and airfield surfaces undergo deicing and anti-icing operations. In this document, the phrase "airport deicing operations" refers generally to all deicing and anti-icing operations that take place at airports.

Aircraft deicing removes snow and ice accumulations from aircraft surfaces. Aircraft deicing includes both "wet weather" and "dry weather" deicing. Wet weather deicing takes place during or after weather events that coat aircraft surfaces with snow or ice. Dry-weather deicing takes place when ambient temperatures are low enough, typically below 55° F, to allow frost or ice formation on aircraft surfaces. During a typical aircraft deicing process, trained personnel spray specially formulated and heated deicing fluids on aircraft surfaces at high pressure in order to remove snow and ice. Depending on the aircraft, snow and ice accumulation levels, and weather conditions, wet weather deicing of a single aircraft requires the use of a couple hundred to several thousand gallons of aircraft deicing fluid. Dry weather deicing requires less fluid than wet weather deicing because of lower ice accumulations during dry weather conditions.

Aircraft anti-icing takes place when weather conditions threaten to re-contaminate freshly deiced aircraft surfaces with new snow or ice. Aircraft anti-icing fluids are specially formulated to temporarily prevent snow and ice accumulation on deiced aircraft surfaces, protecting aircraft until their departure from an airport. Anti-icing is typically necessary only during wet weather conditions. The process consists of the spraying of a thin layer of anti-icing fluid onto aircraft surfaces by trained personnel. Aircraft anti-icing fluids are viscous and adhere to aircraft surfaces until take-off. The process requires a smaller volume of fluid than the aircraft deicing process.

Airfield pavement surfaces must also be cleared of snow and ice. Pavement deicing and anti-icing operations remove and prevent, respectively, snow and ice accumulations on airfield runways, taxiways, aprons, gate areas, and ramps. Airports use both mechanical and chemical means to clear airfield pavement. Most frequently, airports use mechanical means such as plows, blowers, and brooms to remove ice and snow (US EPA 2011). Because ice and snow can be difficult to remove by mechanical methods alone, many airports also apply liquid or solid chemical pavement deicers. Some of these deicers are applied prior to precipitation events as anti-icers in order to prevent ice formation or ease later removal of snow and ice. Airports also frequently apply sand to increase airfield traction.

Deicing operations typically take place during the winter when low temperatures and freezing precipitation (e.g., snowfall, freezing rain, and ice) occur. Local climate conditions determine both the duration and intensity of deicing seasons at individual airports. The deicing season can begin as early as September and continue through May in colder regions of the U.S. In general, however, December, January, and February are the peak deicing months for U.S. airports, and September and May have the lowest incidence of deicing activity. The majority of airports have a five month deicing season, though some airports have seasons as short as two months or as long as nine months.

The nature, frequency, and intensity of precipitation events also vary from airport to airport. Some airports rarely engage in deicing activities beyond aircraft frost removal, whereas other airports often cope with frequent and heavy snow or ice storms that necessitate both aircraft and pavement anti-icing and deicing. There can even be substantial variability among weeks or seasons at individual airports as weather patterns shift and affect the necessity for deicing activity. The nature and intensity of deicing activities and their associated pollutant discharges therefore vary substantially both among airports and among deicing seasons at individual airports.

1.2 Airport Deicing and Anti-Icing Product Formulations

Airport deicing products include aircraft deicing fluids, aircraft anti-icing fluids, and airfield pavement deicers. The materials used for aircraft deicing and anti-icing are specially formulated fluids with multiple chemical components. Pavements materials are typically simpler formulations and can be either solid or liquid in form.

Four aircraft deicing and anti-icing fluid (ADF) categories are available in the global market: Type I, Type II, Type III, and Type IV. Type I and Type IV are the fluid categories most commonly used at the U.S. primary commercial airports addressed by EPA's final regulatory options.

Type I fluids are aircraft deicers, and Type IV fluids are aircraft anti-icers. By volume, both fluids consist primarily of a freezing point depressant, typically propylene glycol or ethylene glycol, and water. The fluids also contain a relatively small volume, approximately 1-3%, of chemicals commonly known as "additives" which function as surfactants, corrosion inhibitors, pH modifiers, flame retardants, defoamers, dyes, oils, antioxidants, and antimicrobials. Type IV fluids also contain thickeners to increase their viscosity and allow them to adhere to aircraft surfaces until take-off. ADFs function by lowering the temperature at which snow and ice are able to adhere to aircraft surfaces.

Based on data from responses to the EPA Airline Deicing Questionnaire (2006b) the most commonly used ADF at commercial U.S. airports is Type I propylene glycol deicing fluid, accounting for approximately 77% of ADF use or purchase. A recent trend in ADF use has been increasing use of propylene glycol-based ADFs instead of ethylene glycol-based ADFs. *Table 1-1* presents EPA's estimate of national ADF use based on information provided in survey responses for the 2002-2003, 2003-2004, and 2004-2005 deicing seasons. Because glycol levels vary among individual manufacturer's ADF formulations, ADF quantities in *Table 1-1* are normalized to represent 100% glycol levels.

Table 1-1: U.S. Commercial Airports - National Estimate of Aircraft Deicing and Anti-Icing Fluid Use/Purchase *

Chemical	Average Total Airport Use/Purchase (million gallons/year)	Percentage of ADF Use/Purchase
Type I Propylene Glycol Aircraft Deicing Fluid	19.305	77.1
Type IV Propylene Glycol Aircraft Anti-Icing Fluid	2.856	11.4
Type I Ethylene Glycol Aircraft Deicing Fluid	2.575	10.3
Type IV Ethylene Glycol Aircraft Anti-Icing Fluid	0.306	1.2

Source: US EPA Airline Deicing Questionnaire (2006b).

[*] EPA used the ADF purchase information to represent usage, per airline industry recommendations. See US EPA (2010) for additional details.

Based on responses to the EPA Airport Deicing Questionnaire (2006c), the most commonly used pavement deicer on U.S. airfields is potassium acetate. Potassium acetate represents about 80 percent of all airfield deicing chemical use. A recent trend in pavement deicer use has been for U.S. airports to cease or decrease their use of urea due to water quality impact concerns. *Table 1-2* lists the total estimated national average airfield chemical usage (based on data for the 2002/2003, 2003/2004, and 2004/2005 deicing seasons) for primary commercial airports in the U.S.

Table 1-2: U.S. Commercial Airports - National Estimate of Pavement Deicer Chemical Use

Pavement Deicer Chemical	Estimated Total Airport Use (tons/year)
Potassium acetate	22,538
Airside urea	4,127
Propylene glycol-based fluids	3,883
Sodium acetate	3,100
Sodium formate	1,117
Ethylene glycol-based fluids	774

Source: US EPA Airport Deicing Questionnaire (2006c).

Based on EPA's national estimates of chemical or material usage, approximately 70 percent of airports use chemical pavement deicers with the remaining 30 percent relying on sand application for airfield deicing/anti-icing (US EPA 2011). Additional information on pavement deicer usage is provided in *Table A-1* in *Appendix A*.

The identity and environmental behavior of individual ADF and pavement deicer components is discussed in more detail in *Chapter 2*.

1.3 Airport Deicing Chemical Dispersion in the Environment

Because aircraft deicing and anti-icing fluids (ADFs) and pavement deicers are typically used in very open and exposed outdoor environments, their dispersion begins immediately after application. ADFs are typically applied to aircraft at specific airport locations. These locations vary by airport and can include gate areas, aprons, or deicing pads. ADFs are designed to drip and shear from aircraft surfaces after application in order to avoid compromising aircraft lift during take-off. Type I deicing fluids drip from aircraft relatively quickly. The majority of these fluids fall to the pavement at fluid application sites. The remainder drips or shears from aircraft as they travel on the airfield, primarily falling on pavement and other airfield surfaces. Type IV anti-icing fluids are designed to remain on aircraft surfaces for a longer period of time than Type I deicing fluids to protect aircraft surfaces from snow and ice accumulation until take-off. A relatively small amount of Type IV fluid falls to the pavement at application sites. Most Type IV fluid drips or shears from aircraft during taxiing or take-off, falling primarily on pavement or other airfield surfaces. A lesser quantity of ADF becomes airborne during application or aircraft taxiing and take-off and can be carried by wind to other parts of the airfield or beyond airport property lines.

Little quantified research is available on ADF dispersion after application. EPA's analysis of baseline pollutant loadings to the environment assumed that 75% of Type I fluids fall to the ground at application sites (Switzenbaum et al. 1999). Because Type IV fluids are designed to remain on the aircraft until take-off, EPA assumed that only 10% of these fluids fall to the ground at the point of application (US EPA 2011). The remainder of the fluids disperses in areas beyond the application site.

Airports apply pavement deicers directly to the ground. Treated surfaces can include runways, taxiways, aprons, ramps, and gate areas. The extent of pavement surface deicing varies with the nature of precipitation events.

Once on the ground, ADFs and pavement deicers can disperse in several ways. ADFs and pavement deicers on paved surfaces often flow into stormwater management systems. Many airfields also have vegetated or other pervious surfaces adjacent to paved areas. In these areas, ADFs and pavement can percolate through soil and eventually enter groundwater if present beneath the airport.

ADFs and pavement deicers in stormwater management systems can discharge to surface waters or, in some locations, enter stormwater collection and treatment systems. Airports most frequently collect and treat stormwater originating from ADF application sites. Stormwater from these sites tends to contain higher percentages of deicing pollutants than other airport areas. These areas are also relatively limited in size and therefore provide an easier collection and treatment opportunity. Airports are less likely to collect and treat ADFs and pavement deicers dispersed in other parts of the airfield because of the larger surface areas and larger stormwater volumes involved, both of which increase collection and treatment complexity and expense. In addition, stormwater pollutant concentrations tend to be lower in these areas, though total loadings can still be significant. ADFs and pavement deicers dispersed in the airfield are more likely to discharge to surface waters or infiltrate pervious airfield surfaces.

Because of variability among individual airports in ADFs and pavement deicers usage levels, extent and configuration of paved and pervious areas, and stormwater collection and treatment, there is great variability in the quantities of deicing activity pollutants that reach surface waters at individual airports.

The nature of ADF and pavement deicer dispersion in the environment is discussed in more detail in *Chapter 3*.

1.4 Environmental Impacts from Airport Deicing Operation Discharges

EPA has identified a number of cases in which airport deicing operation discharges to the environment have affected water quality, aquatic ecosystems, and human use of aquatic resources. Identified impacts include:

- Reductions in dissolved oxygen levels in water bodies receiving deicing stormwaters;
- Increased nutrient concentrations in water bodies receiving deicing stormwaters;
- Fish kills downstream of deicing stormwater outfalls;
- Impacts to aquatic ecosystems downstream of deicing stormwater outfalls, including reductions in organism abundance and diversity or elimination of the aquatic community;
- Contamination of groundwater and surface drinking water resources;
- Aesthetic impacts to surface waters, including foaming, noxious odors, and discoloration; and
- Complaints of headaches and nausea by people exposed to deicing stormwater odors.

Of particular and well-known concern is the oxygen demand exerted by ADF and pavement deicer-contaminated stormwater. All of the primary ingredients in ADFs and pavement deicers exert oxygen demand as they decay. As airport deicing materials decay in surface waters, they consume oxygen dissolved in the water column. If the level of dissolved oxygen becomes too low, aquatic organisms can be impaired or killed. Chronic low oxygen conditions can eventually change the biochemistry and overall community structure of aquatic ecosystems.

Discharges of raw or partially treated sewage from cities and towns were a common cause of low oxygen conditions in surface waters prior to implementation of more stringent sewage treatment requirements under the Clean Water Act. The oxygen depletion potential of airport deicing operation discharges is many times greater than that of raw sewage. For example, before application, Type I propylene glycol-based deicing fluid is generally diluted to a mixture containing approximately 50% propylene glycol. Pure propylene glycol has a BOD_5 concentration of approximately 1,000,000 mg/L. A typical diluted propylene-based deicing fluid could therefore have a BOD_5 concentration of approximately 500,000 mg/L. In comparison, raw sewage typically has a BOD_5 concentration of approximately 200 mg/L. The amount of fluid used to deice a single non-propeller-driven aircraft depends on the nature of the precipitation event and the size of the aircraft but can range from a couple hundred to several thousand gallons. Therefore, deicing a single non-propeller-driven aircraft can generate a BOD_5 load greater than that of one million gallons of raw sewage. A large hub airport often has several hundred flights each day. Pavement deicers applied to airfield pavement can also exert significant BOD. The BOD_5 generated from deicing activities at a large airport in a single day can therefore equal the BOD_5 associated with the raw sewage from more than one million people (or a large city) (US EPA 2008a).

In addition to oxygen demanding substances, airport deicing products also contain a number of additives. Some of these additives have toxic or other properties that could harm aquatic ecosystems. Other additives have not yet been publicly identified because of the proprietary nature of deicing material formulations and the limitations of currently available research on deicing product formulations. Without information on the identity of these additives, it is impossible to determine the potential environmental impacts from these chemicals.

Many of the surface waters to which airports discharge deicing materials are small streams with limited absorption and dilution potential for processing large quantities of oxygen demanding substances and other pollutants. EPA has evaluated the impairment status of a number of surface waters directly receiving airport deicing operation discharges and has found a large number of these waters to be listed as impaired under Section 303(d) of the Clean Water Act (see *Chapter 3*). Many of these waters have the types of impairments that can be associated with airport deicing operation discharges (e.g., depressed dissolved oxygen levels). Other waters are stressed and impaired by other types of pollutants (e.g., PCBs, pathogens). The final regulatory options will reduce the intensity of discharges of airport deicing pollutants to a number of these surface waters and have the potential to improve the health of these impaired aquatic resources.

Environmental impacts associated with airport deicing discharges are discussed in more detail in *Chapter 3*.

2 Airport Deicing Product Components and Environmental Behavior

Airport deicing products include aircraft deicing fluids, aircraft anti-icing fluids, and airfield pavement deicers. Aircraft deicing and anti-icing fluids (ADFs) are used on aircraft. Pavement deicers are used on airport runways, taxiways, aprons, ramps and gate areas. Each type of airport deicing product is specially formulated for the purpose it serves.

This chapter provides information on the basic composition of airport deicing products and summarizes information EPA was able to gather through a review of the literature available on the identity and quantity of specific chemicals used in airport deicing products (*Section 2.1*). This chapter also provides an overview of the environmental behavior and potential environmental impacts associated with these chemicals (*Section 2.2*). In addition to a broad review of the physical properties and fate and transport characteristics of approximately 99 chemicals that may be components or decay products of ADFs and airfield pavement deicers, more detailed discussions are provided for 12 chemical or chemical groups of potential environmental concern (*Section 2.2.2*).

2.1 Airport Deicing Product Components

Many different types of aircraft deicing fluid, aircraft anti-icing fluid and airfield pavement deicer formulations are used at airports in the U.S. Manufacturers use a variety of freezing point depressants and additives to formulate their products. According to responses to EPA's Airport Deicing Questionnaire (2006c), the ADFs most widely used at U.S. airports consists of water, propylene glycol or ethylene glycol as a freezing point depressant, and a range of additives that differ by ADF manufacturer and specified fluid use. Pavement deicers typically consist of a chemical that serves as a freezing point depressant and, in many formulations, various additives. The pavement deicer freezing point depressants most widely used at U.S. airports are potassium acetate, urea, sodium acetate, sodium formate, propylene glycol, ethylene glycol, or a mixture of ethylene or propylene glycol and urea (see *Table 1-2*).

Manufacturers are generally willing to identify the freezing point depressants comprising the bulk of their airport deicing product formulations, but the identity of product additives and their concentration in product formulas is generally considered to be proprietary. Research by parties outside the airport deicing product manufacturing community indicates that some airport deicing products additives have toxic or other properties potentially harmful to aquatic ecosystems. Understanding the identity, quantity, and nature of chemicals present in airport deicing products is a useful step in characterizing the potential environmental risks associated with ADF and pavement deicer discharges. This section summarizes information EPA was able to gather through a review of the literature currently available on the identity and quantity of chemicals used in airport deicing products. A recently released study contains significant additional information on airport deicing products (Ferguson, et al. 2008).

2.1.1 Identification of Airport Deicing Product Components

To determine the chemical composition of ADFs and pavement deicers, EPA reviewed available data sources including Society for Automotive Engineer Aerospace Material Specifications (SAE AMSs), deicing product Material Safety Data Sheets (MSDSs), patent descriptions, peer-reviewed literature, other published reports, and data from EPA airport sampling events.

EPA's determination of the composition of ADFs and pavement deicers is incomplete, however, for several reasons. EPA relied on available data sources to identity components. These sources are limited because many airport deicing product ingredients are proprietary, and manufacturers do not, therefore, identify them in product labels, MSDSs, or other publicly available documents. Because a significant level of effort is required for an outside party to determine a deicing product's composition, the peer-reviewed literature on this subject is limited, particularly for chemicals present in formulations in low concentrations as are most airport deicing product additives. Even when the identity of an additive is available, it is sometimes known only by its trade name, and publicly available information for many such chemicals is limited or nonexistent.

In addition, although EPA endeavored to obtain current information on product formulations, it is possible given manufacturers' ongoing product development that some components listed in the literature are no longer in use. It is also possible that some components listed in patents have never been used either because a patented product has never been brought to market or because a final product incorporates only some of a wide group of possible components listed in a patent.

Despite these limitations, the results of the literature review provide an indication of the types and quantities of chemicals typically used in airport deicing product formulations.

2.1.1.1 *Standard Composition of Aircraft Deicing Fluids and Aircraft Anti-icing Fluids*

Four categories of aircraft deicing and anti-icing fluids (ADFs) are currently manufactured for the global market: Type I, Type II, Type III, and Type IV. Of these four categories, Type I and Type IV are the two categories commonly used at U.S. commercial airports.

ADFs are developed and manufactured to industry standards published in the U.S. by the Society for Automotive Engineers (SAE). SAE Aerospace Material Specifications (AMS) 1424 and 1428 are adopted on a voluntary basis by manufacturers and governments and include performance requirements for the three types of ADFs used in the U.S. (Types I, II, and IV).[1] The Association for European Airlines and the International Standards Organization publish similar standards, which are adopted voluntarily by manufacturers and governments in Europe and throughout the world, respectively. *Table 2-1* compares the characteristics and uses of the fluid categories.

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[1] Type III fluid is rarely used and intended only for small aircraft. AMS 1424 applies to SAE Type I fluids, and AMS 1428 applies to SAE Type II, III, and IV fluids (Boeing 2008).

Table 2-1: Comparison of Aircraft Deicing and Anti-Icing Fluid Characteristics by Type

	Function	Characteristics
Type I	Aircraft Deicing Fluid	➢ Low viscosity ➢ Provides short-term protection because flows quickly off aircraft surfaces after application ➢ Typically dyed orange to aid in identification and application of a consistent layer on aircraft ➢ Typically heated (130° - 180° F) and applied as a high pressure spray to remove snow, ice, and frost
Type II	Aircraft Anti-icing Fluid	➢ Contains a polymeric thickening agent to prevent immediate flow off aircraft surfaces and provide protection until aircraft take-off ➢ Fluid remains in place until aircraft attains speed of approximately 100 knots, at which point fluid shears from aircraft ➢ Typically colorless ➢ Useful only for larger aircraft ➢ Use of Type II fluids is diminishing in favor of Type IV fluids
Type IV	Aircraft Anti-icing Fluid	➢ Contains a polymeric thickening agent to prevent immediate flow off aircraft surfaces and provide protection until aircraft take-off ➢ Fluid remains in place until aircraft attains a certain speed, at which point fluid shears from aircraft ➢ Typically dyed green to aid in identification and application of a consistent layer on aircraft ➢ Provides longer-term protection than Type II fluids

Sources: Corsi et al. (2007); Ritter (2001).

Freezing point depressants comprise the majority of ADFs. One study in the literature states that a freezing point depressant, either ethylene glycol or propylene glycol, typically makes up 50% to 80% of ADF product as applied (Johnson et al. 2001). The rest of the product consists of water and various additives. These additives function as surfactants, corrosion inhibitors, thickeners, flame retardants, pH modifiers, defoamers, dyes, antimicrobials, oils, chelators, and antioxidants.

Surfactants help ADFs spread evenly across aircraft surfaces by lowering fluid surface tension. Thickeners are used in Type II, III, and IV fluids to increase fluid viscosity and allow them to maintain their protective position on aircraft surfaces until take-off.

A single formulation does not necessarily contain a different chemical for each additive function. Some formulations contain components that serve multiple functions. Other formulations need only contain a subset of additives because of beneficial interactions among component chemicals.

Three main classes of additives have been identified in the literature as widely used by ADF manufacturers: the corrosion inhibitors/ flame retardants benzotriazole (BT) and methyl-substituted benzotriazole (MeBT) (Cornell 2001; Pillard et al. 2001), the surfactant alkylphenol ethoxylates (APEOs) (Nieh 1992; Corsi et al. 2006), and the pH modifier triethanolamine (Boluk et al. 1999).

Less information is available on the proportions in which the various components are present in ADF formulations. One study states that typical ADFs consist of 50% to 80% ethylene glycol or propylene glycol and 20% to 50% water (Breedveld et al. 2002). A second study states that, in undiluted form, Type I deicing fluids consist of 88% propylene glycol or ethylene glycol, 0.5% to 0.6% methyl-substituted benzotriazole (MeBT) mixture, 1% to 2% proprietary additives (corrosion inhibitors, buffer, and surfactants), and water (Cornell 2001). A third study states that ADFs contain 0.5% to 0.6% MeBT and that the commercial mixture of MeBT is 45% 4-MeBT and 55% 5-MeBT (Pillard et al. 2001).

A number of patents exist for ADFs based on freezing point depressants other than ethylene glycol or propylene glycol (e.g., pentaerythritol, glycerol, sorbitol, xylitol and other chemicals) (Simmons et al. 2007). According to responses to EPA's Airport Deicing Questionnaire (2006c), ADFs based on these components are not used at major U.S. airports.

2.1.1.2 Standard Composition of Airfield Pavement Deicers

Several basic types of pavement deicers are used at U.S. primary commercial airports. These deicers include formulations consisting primarily of potassium acetate, urea, sodium acetate, sodium formate, propylene glycol, ethylene glycol, or a mixture of propylene or ethylene glycol and urea. These primary ingredients serve as freezing point depressants.

Pavement deicers are more simply formulated than ADFs and consist primarily of the primary freezing point depressant ingredient. Potassium acetate, sodium formate, and sodium acetate formulations are known to contain corrosion inhibitors, as well (Switzenbaum et al. 1999; Shi 2008; USDOT 2007) though the corrosions inhibitors' chemical identity is not known.

2.1.1.3 Detailed Listing of Potential Airport Deicing Product Components

Table 2-2 presents the chemicals for which EPA found some evidence of use in airport deicing product formulations through its literature review. Many of the chemicals in the table below are presented and discussed in Ferguson et al. 2008.

Table 2-2: Identification of Airport Deicing Product Components

Source	Current	CASRN	Chemical Name	Characterization
Johnson et al. (2001)	U	1303-96-4	Borax	Corrosion inhibitor
Johnson et al. (2001)	U	532-32-1	Sodium benzoate	Corrosion inhibitor
Corsi et al. (2006)	U	29878-31-7	4-methyl-1H-benzotrizole	Corrosion inhibitor
Ashrawi and Coffey (1993)	Y	-	Cobratec TT-50S, tolyltrizole solution	Corrosion inhibitor
Hu et al. (1998)	Y	110-65-6	Butyne-1,4diol	Corrosion inhibitor
Hu et al. (1998)	Y	107-19-7	Propargyl alcohol	Corrosion inhibitor
Hu et al. (1998)	Y	62-56-6	Thiourea	Corrosion inhibitor
Boluk et al. (1999)	Y	-	Sandocorin 8132, sodium dodecylbenzene sulfonate	Corrosion inhibitor
Moles et al. (2003)	Y	7778-53-2	Potassium phosphate	Corrosion inhibitor
Moles et al. (2003)	Y	10006-28-7	Potassium silicate	Corrosion inhibitor
Moles et al. (2003)	Y	13870-28-5	Sodium silicate	Corrosion inhibitor
Boluk et al. (1999); Hu et al. (1998); Nieh (1992)	Y	-	Benzyltriazole	Corrosion inhibitor
Boluk et al. (1999); Hu et al. (1998); Moles et al. (2003); Nieh (1992)	Y	29385-43-1	Tolyltriazole	Corrosion inhibitor
Johnson et al. (2001) and Hu et al. (1998)	Y	7631-99-4	Sodium nitrate	Corrosion inhibitor
Hu et al. (1998)	Y	-	AF-9020, polydimethylsiloxane	Defoamer
Hu et al. (1998)	Y	-	DC 1520, silicone antifoam	Defoamer
Boluk et al. (1999)	Y	-	Foamban	Defoamer
Hu et al. (1998), Boluk et al. (1999); Ma and Comeau (1990)	Y	-	Silicone antifoam [2]	Defoamer
Coffey et al. (1995)	Y	-	Eosin orange, tetrabromofluorescein	Dye
Chan et al. (1995)	Y	-	Malonyl green, C.I. Pigment Yellow 34	Dye
Lockyerm et al. (1998)	Y	-	Shilling green	Dye
Chan et al. (1995); Lockyerm et al. (1998)	Y	-	FD&C Blue #1, alphazurine	Dye
Chan et al. (1995); Lockyerm et al. (1998)	Y	-	FD&C Yellow #5, tartrazine	Dye
Johnson et al. (2001)	U	95-14-7	Benzotriazoles	Flame Retardant and Corrosion Inhibitor

Table 2-2: Identification of Airport Deicing Product Components

Source	Current	CASRN	Chemical Name	Characterization
Corsi et al. (2006)	Y	136-85-6	5-Methyl-1H-Benzotriazole	Flame Retardant and Corrosion Inhibitor
Ashrawi and Coffey (1993); Bloom (1986); Boluk et al. (1999); Hu et al. (1998); König-Lumer et al. (1982); Nieh (1992)	Y	57-55-6	1,2-Propylene glycol	Freezing point depressant
Back et al. (1999)	Y	608-66-2	Dulcitol	Freezing point depressant
Back et al. (1999)	Y	115-77-5	Pentaerythritol	Freezing point depressant
Boluk et al. (1999)	Y	25322-68-3	Polyethylene gylcol, mw from 62 to 106	Freezing point depressant
Sapienza et al. (2003)	Y	97-64-3	Ethyl lactate	Freezing point depressant
Sapienza (2003)	Y	147-85-3	Proline	Freezing point depressant
Sapienza (2003)	Y	72-17-3	Sodium lactate	Freezing point depressant
Sapienza (2003)	Y	54571-67-4	Sodium pyrrolidone carboxylate	Freezing point depressant
Lockyerrn et al. (1998); Westmark et al. (2001)	Y	107-88-0	1,3-Butanediol	Freezing point depressant
Ashrawi and Coffey (1993); Boluk et al. (1999); Nieh (1992)	Y	25265-71-8	Dipropylene glycol	Freezing point depressant
König-Lumer et al. (1982); Lockyerm et al. (1998)	Y	504-63-2	1,3-Propylene glycol	Freezing point depressant
Boluk et al. (1999); Westmark et al. (2001)	Y	112-27-6	Triethylene glycol	Freezing point depressant
Back et al. (1999); Sapienza et al. (2003)	Y	69-65-8	Mannitol	Freezing point depressant
Back et al. (1999); Simmons et al. (2007)	Y	149-32-6	Erythritol	Freezing point depressant
Back et al. (1999); Boluk et al. (1999); Westmark et al. (2001)	Y	56-81-5	Glycerol	Freezing point depressant
Back et al. (1999); Sapienza (2003); Sapienza et al. (2003)	Y	50-70-4	Sorbitol	Freezing point depressant
Ashrawi and Coffey (1993); Boluk et al. (1999); König-Lumer et al. (1982); Ma and Comeau (1990); Nieh (1992)	Y	111-46-6	Diethylene glycol	Freezing point depressant
Corsi et al. (2006)	Y	57-55-6	Propylene glycol	Freezing point depressant

Table 2-2: Identification of Airport Deicing Product Components

Source	Current	CASRN	Chemical Name	Characterization
Corsi et al. (2006)	Y	107-21-1	Ethylene glycol	Freezing point depressant
Comfort (2000)	Y	127-08-2	Potassium Acetate	Freezing point depressant
US EPA (2000a)	Y	590-29-4	Potassium Formate	Freezing point depressant
Comfort (2000)	Y	127-09-3 (anhydrous)	Sodium Acetate	Freezing point depressant
Comfort (2000)	Y	141-53-7	Sodium Formate	Freezing point depressant
US EPA (2000a)	Y	57-13-6	Urea	Freezing pont depressant
Hu et al. (1998); König-Lumer et al. (1982)	Y	-	Mineral oil	Oil used as hydrophobic agent
Ma and Comeau (1990)	Y	-	Dimethyl polysiloxane	Oil used as hydrophobic agent
Ma and Comeau (1990)	Y	-	White mineral oil (10 cSt)	Oil used as hydrophobic agent
Lockyerm et al. (1998)	Y	112-53-8	1-dodecanol	Oil used as hydrophobic agent
Nieh (1992)	Y	7558-79-4	Disodium phosphate	pH Modifier
Hu et al. (1998)	Y	7758-11-4	Dipotassium phosphate	pH Modifier
Boluk et al. (1999)	Y	111-42-2	Diethanolamine	pH Modifier
Boluk et al. (1999)	Y	141-43-5	Monoethanolamine	pH Modifier
Boluk et al. (1999)	Y	102-71-6	Triethanolamine	pH Modifier
US EPA (2000a)	Y	1310-58-3	Potassium hydroxide	pH Modifier
Ashrawi and Coffey (1993); Boluk et al. (1999); Hu et al. (1998)	Y	1310-73-2	Sodium hydroxide	pH Modifier
Haslim (2004)	U	112-53-8	Dodecanol [4]	Surfactant/Defoaming agent
Corsi et al. (2003)	Y	-	Alcohol ethoxylates	Surfactant
König-Lumer et al. (1982)	Y	-	Sodium alkylbenzenesulfonate	Surfactant
Bloom (1986)	Y	-	Oleic acid diamine	Surfactant
Bloom (1986)	Y	-	Oleyl propylene diamine	Surfactant
Bloom (1986)	Y	-	Palmitic acid diamine	Surfactant
Ashrawi and Coffey (1993)	Y	-	Aliphatic alcohol ethoxylates	Surfactant
Boluk et al. (1999)	Y	-	Siponate A-2466, sodium dodecylbenzene	Surfactant
Boluk et al. (1999)	Y	-	Sodium dodecylbenzene sulfonate [3]	Surfactant

Table 2-2: Identification of Airport Deicing Product Components

Source	Current	CASRN	Chemical Name	Characterization
Boluk et al. (1999)	Y	-	Tergitol TMN-10, branched secondary alcohol ethoxylate	Surfactant
Westmark et al. (2001)	Y	-	Emerest 2660 (OEG-12 oleate)	Surfactant
Westmark et al. (2001)	Y	-	Emsorb 6900 (PEG-20 sorbitan oleate)	Surfactant
Corsi et al. (2003)	Y	-	Decyl alcohol ethoxylate	Surfactant
Corsi et al. (2003)	Y	-	Lauryl alcohol ethoxylate	Surfactant
Corsi et al. (2003)	Y	-	Lauryl alcohol phosophoric acid-ester ethoxylate	Surfactant
Ashrawi and Coffey (1993); Nieh (1992)	Y	-	Ethylene oxide / propylene oxide block copolymers	Surfactant
Nieh (1992)	Y	-	Nonylphenol ethoxylate	Surfactant
Nieh (1992)	Y	-	Octylphenol ethoxylate	Surfactant
Corsi et al. (2007)	Y	-	Alkylphenol ethoxylates	Surfactant
Tye et al. (1987)	Y	9062-07-1	Iota-carrageenan	Thickening Agent
Tye et al. (1987)	Y	-	Kappa-carrageenan	Thickening Agent
Ma and Comeau (1990)	Y	9004-62-0	Hydroxyethylcellulose	Thickening Agent
Westmark et al. (2001)	Y	-	Welan gum	Thickening Agent
Ashrawi and Coffey (1993); Nieh (1992)	Y	-	Polyacrylic acid[1]	Thickening Agent
König-Lumer et al. (1982); Nieh (1992)	Y	-	Cross-linked polyacrylic acid	Thickening Agent
Lockyerm et al. (1998); Ma and Comeau (1990); Westmark et al. (2001)	Y	-	Xanthan gum	Thickening Agent
Johnson et al. (2001)	U	123-91-1	Dioxane [5]	
Johnson et al. (2001)	U	75-07-0	Acetaldehyde	
Johnson et al. (2001)	U	75-21-8	Ethylene oxide	
Johnson et al. (2001)	U	-	Polyamines	
Johnson et al. (2001)	U	37306-44-8	Triazoles	
US EPA (2000a)	Y	117-81-7	Bis (2-ethylhexyl) phthalate	
US EPA (2000a)	Y	84-74-2	Di-N-Butyl Phthalate	

Table 2-2: Identification of Airport Deicing Product Components

Source	Current	CASRN	Chemical Name	Characterization
US EPA (2000a)	Y	100-41-4	Ethylbenzene	
US EPA (2000a)	Y	-	M- + P-Xylene	
US EPA (2000a)	Y	112-40-3	N-Dodecane	
US EPA (2000a)	Y	108-88-3	Toluene	
Corsi et al. (2006)	Y	25154-52-3	Nonylphenol	
Corsi et al. (2006)	Y	-	Octylphenol	

1. Carbopol polyacrylic acid 1610, 1621, 1622, 672, and 934 were listed in the literature.
2. Silicone antifoam was listed in the literature as SAG 7133, SAG 1000, and Siltech E-2202.
3. Siponate DS and Siponate DDB-40 sodium dodecylbenzene sulfonate were listed in the literature.
4. CASRN for this chemical is provided as that of 1-dodecanol.
5. CASRN for this chemical is provided as that of 1,4-Dioxane.

U = Unknown if chemical is currently used in deicing formulas.
Y = Chemical identified as currently used in deicing formulas as of the date of reference publication.
Of the 111 identified ingredients, 61 (55%) were identified in sources that were published in 2000 or later.

2.2 Environmental Behaviors of Airport Deicing Product Components

This section provides an overview of the characteristics of many of the potential airport deicing product components identified in *Table 2-2*. EPA's review focused on characteristics that influence a component's potential to disperse in and impact the environment. The ultimate behavior of ADFs and pavement deicers in the environment is a function of both chemical-specific factors and airport-specific hydrological, geochemical, biological, and climatic factors. This chapter presents chemical-specific information which is then considered in environmental context in *Chapter 3*.

It is important to note that the individual components of ADFs and pavement deicers have varying fate and transport properties that cause deicing products to disaggregate into their individual components once they enter the natural environment. Fresh and concentrated wastestreams located closer to the point of ADF and pavement deicer application are more likely to reflect original product properties. Older and more dilute wastestreams further from the site of application have characteristics determined by the presence or absence of individual pollutants and the transformation and transport processes they have undergone. For this reason, it is important to consider the nature of individual product components in addition to the nature of the original product.

The Society for Automotive Engineers (SAE) sets technical standards for aircraft deicing and anti-icing and fluids (ADFs). At this time, SAE requirements addressing ADF environmental impacts are limited. SAE AMS 1424 requires Type I fluids entering the market after August 2002 to have a mammalian toxicity (LC_{50}) greater than 5,000 mg/L and a fluid aquatic toxicity (LC_{50} for several different aquatic organism species) greater than 4,000 mg/L (SAE 2007). Research has shown that even at levels less than 4,000 mg/L, sub-lethal toxic effects will be exerted on aquatic organisms (Corsi et al. 2006). In addition, the toxicity standard does not apply to Type IV fluids, the more toxic of the two commonly used ADFs (Corsi et al. 2006). SAE also provides no guidance for ADF BOD or COD content. SAE has considered setting toxicity standards for additional fluids (US EPA 2000a) as well as a more stringent toxicity requirement for Type I fluids.

Appendix A contains tables that summarize information on the physiochemical properties of many known and potential ADF and pavement deicer components and their potential decay products as cited in *Table 2-2.* Except where otherwise noted, all of the information in the tables is from the U.S. National Library of Medicine's Hazardous Substances Databank and ChemFinder databases, which compile data from a wide variety of sources. In some cases, the sub-citations within these databases are incomplete or not supplied and therefore cannot be reported here. Other information sources include deicing and chemical-specific literature, as cited in the tables. For some physiochemical properties, information either does not exist or was not attainable from these sources; therefore a number of table entries are blank.

EPA collected information on components present in airport deicing products regardless of whether they were present in large and small proportions. Although some components (such as many deicing product additives) constitute a relatively small proportion of ADFs and pavement deicers, their properties may be such that they contribute disproportionately to toxic or other harmful effects to the environment associated with airport deicing discharges.

Components are organized in functional groups in *Table A-2* through *Table A-39.* For example, *Table A-2* contains information for chelators, *Table A-3* contains information for sugar-based freezing point depressants, and *Table A-4* contains information for acetate-based freezing point depressants, etc. A number of the substances within a table share similar properties. Other substances may have very different or unknown properties. These attributes are noted in each table. *Table A-40* presents available information on ecological toxicity values associated with potential components. *Table A-41* presents information on human health effects associated with potential components.

Characteristics of 12 of the 99 potential ADF and pavement deicer components are presented in greater detail in *Section 2.2* and in *Table A-42* through *Table A-53* in *Appendix A*. These 12 components or component groups were chosen for a more detailed analysis for one or more of the following reasons: the component is a well-known ingredient in airport deicing products; the component is released to the environment in significant quantities; or the component has environmental impact potential.

2.2.1 Environmental Behaviors

EPA collected information on a wide variety of individual chemical environmental behaviors of potential interest in the context of discharges from airport deicing activities. Information was collected on traits of interest for assessing a chemical’s ability to disperse in the environment, its potential to impacts aquatic ecosystems and organisms, and its potential to impact human health and aquatic resource uses such as drinking water supply, recreation, and aesthetic enjoyment.

Chemical-specific factors such as water solubility, affinity for solid surfaces and organic matter, volatility, degradation rates and products, and microbial acclimation needs influence environmental fate and transport of ADF and pavement deicer components. Some components have traits that elevate their potential for environmental impact in the aquatic environment.

Chemical-specific factors alone do not determine potential for environmental impact. Hydrological, geochemical, biological, and climatic factors all influence fate and transport of ADFs and pavement deicers in the environment. Specific factors can include flow volumes and patterns in receiving waters, water and soil/aquifer chemistry, microbial community characteristics, aquatic biological community composition, amount and intensity of sunlight, quantity and type of precipitation, and air temperature range and seasonal distribution.

Individual component traits must therefore be considered in concert with information about discharge quantities and the nature of the receiving environment in order to fully assess potential for environmental impact. The summary below presents the information EPA was able to gather on individual chemical traits. *Chapter 3* discusses these traits in the context of the discharge environment.

2.2.1.1 Fate and Transport Behaviors

After application of ADFs to aircraft or pavement deicers to airfield pavement, environmental fate and transport of the chemicals in these products depends on both physical processes and chemical-specific behaviors.

Airport deicing product components enter the aquatic environment through a variety of physical pathways. Most deicing chemicals discharge to the aquatic environment through stormwater discharge to surface waters. A certain quantity of chemicals enters surface waters through groundwater discharge or aerial deposition. Some deicing wastewaters undergo treatment but can retain certain components unaffected by treatment. These components can enter the aquatic environment when treated wastewaters are discharged to surface waters. Once in surface water, components may travel to downstream surface waters.

Airport deicing product components can also percolate into soil horizons. The components can accumulate, degrade, or move into groundwater. Components in groundwater can accumulate, degrade, or travel with groundwater flow.

During the physical transport of individual components, chemical-specific processes are underway, as well. To help assess environmental fate, transport, and impact potential from ADF and pavement deicer components on aquatic ecosystems and organisms, EPA gathered information on three characteristics:

- Volatilization
- Adsorption
- Biodegradation

These traits are described in further detail below.

Volatilization

Volatilization is a process whereby chemicals dissolved in water escape into the air. Chemicals with higher volatilization potential are typically of less concern to aquatic receptors because they tend to enter the atmosphere before discharge to surface waters or to be removed quickly from the water column. Some volatile pollutants can be a concern to human health, however, if inhaled.

EPA used the air/water partitioning coefficient H to estimate a chemical's volatilization potential. H represents the ratio of a chemical's aqueous phase concentration to its equilibrium partial pressure in the gas phase (at 25 degrees Celsius). Units are typically expressed as atm.m3/mole.

Volatilization data for individual deicing product components is summarized in *Table A-2* through *Table A-40* in *Appendix A*.

Adsorption

Adsorption is a process whereby chemicals associate preferentially with organic carbon found in soils and sediments. Highly adsorptive compounds tend to accumulate in sediments. In aquatic ecosystems, such chemicals are more likely to be taken up by benthic invertebrates and to affect local food chains. Both accumulation in sediment and local food chain impacts make these chemicals more likely to affect predator organisms higher on the food chain, including human beings.

EPA gathered information on the adsorption coefficient (K_{oc}) to assess the potential of organic ADF and pavement deicer components to associate with sediment organic carbon. K_{oc} represents the ratio of the target chemical adsorbed per unit weight of organic carbon in the soil or sediment to the concentration of that same chemical in solution at equilibrium.

Metals in the aquatic environment typically concentrate in the sediment phase but do not bind to organic carbon (except nickel). EPA assumes that all metals show a high affinity for sediments independent of their negligible K_{oc} values.

Adsorption data for individual deicing product components is summarized in *Table A-2* through *Table A-40* in *Appendix A*.

Biodegradation

Biodegradation is a process whereby organic molecules are broken down by microbial metabolism. Biodegradation represents an important removal process in aquatic ecosystems. Compounds that are readily biodegraded generally represent lower intrinsic toxicity and accumulation hazards because they can be eliminated more rapidly from ecosystems. These compounds are therefore less likely to create long-term toxicity problems or to accumulate in sediments and organisms. Chemicals that biodegrade slowly or not at all can accumulate and linger for longer periods of time in sediments, and represent a greater hazard to aquatic receptors.

EPA gathered information on biodegradation half-life to estimate the potential for an organic chemical to biodegrade in the aquatic environment. Biodegradation half-life represents the number of days a compound takes to be degraded to half of its starting concentration under prescribed laboratory conditions.

Biodegradation data for individual deicing product components is summarized in *Table A-2* through *Table A-40* in *Appendix A*.

2.2.1.2 Aquatic Organism and Community Impact Behaviors

Aquatic organisms and communities are exposed to airport deicing product components when they enter surface waters. EPA gathered information on three chemical-specific behaviors relevant to examining airport deicing product components' potential to directly impact aquatic organisms and communities:

- Aquatic Toxicity
- Bioconcentration Factors
- Chemical and Biological Oxygen Demand

These traits are described in further detail below.

Aquatic Toxicity

EPA gathered information on both acute and chronic aquatic toxicity. Acute toxicity assessments show the impact of a pollutant after a relatively short exposure duration, typically 48 and 96 hours for invertebrates and fish, respectively. The primary endpoint of concern is mortality, reported as the LC_{50}. The LC_{50} represents the concentration lethal to 50% of test organisms for the given duration of the exposure.

Chronic toxicity assessments indicate the impact of a pollutant after a longer-duration exposure, typically from one week to several months. The endpoints of concern are one or more sub-lethal responses, such as changes in reproduction or growth of the affected organisms. The results are reported in various ways, including EC_5, EC_{10}, or EC_{50} (i.e., the concentrations at which 5%, 10%, or 50% of test organisms show a significant sub-lethal response), NOEC (No Observed Effect Concentration), LOEC (Lowest Observed Effect Concentration), or MATC (Maximum Allowable Toxicant Concentration). MATC is defined as the highest level of a chemical acceptable in a water supply above which a specific effect occurs.

The summary also contains information on National Recommended Water Quality Criteria set by EPA to protect aquatic organisms from acute and toxic effects. Acute and chronic aquatic toxicity data for several ADF and pavement deicer components are summarized in *Table A-40* in *Appendix A.*

Bioconcentration Factors

The bioconcentration factor (BCF) is a good indicator of the potential for a chemical dissolved in the water column to be absorbed by aquatic biota across external surface membranes such as gills. The BCF is expressed in units of liters per kilogram and is defined as follows:

$$\text{BCF} = \frac{\text{equilibrium chemical concentration in target organism (mg/kg, wet weight)}}{\text{mean chemical concentration in surrounding water } (\mu\text{g/L})}$$

EPA examined BCF values because they can indicate chemicals with the ability to bioconcentrate in aquatic organisms and transfer up the food chain if they are not metabolized and excreted. Pollutant transfer up the food change can result in significant levels of pollutant exposure for predator organisms (including human beings) consuming contaminated fish, shellfish, or other aquatic organisms.

The bioaccumulation factor (BAF) is a better measure than the BCF of the potential for a chemical dissolved in the water column to be taken up by aquatic biota because it accounts for vertical accumulation of the chemical in the food chain, whereas the BCF does not. For this reason, BCFs underestimate risk to aquatic organisms. Because field-measured BAFs are not readily available for many chemicals, EPA instead collected BCFs for deicing product components. This information is summarized in *Table A-2* through *Table A-40* in *Appendix A*.

Chemical and Biological Oxygen Demand

Oxygen demand, or the oxygen consumed by a substance when decaying in water, is reported as either biochemical or biological oxygen demand (BOD), carbonaceous biochemical oxygen demand (CBOD), or chemical oxygen demand (COD). BOD is a measure of the amount of oxygen consumed by the biological processes that break down organic matter in water. The greater the BOD level, the greater the degree of pollution (US EPA 2008f). CBOD is a test method that departs from customary methods for determining BOD in its use of a chemical inhibitor to block nitrification, thus preventing the nitrogenous, or second stage, BOD from being consumed. COD is a measure of the oxygen-consuming capacity of inorganic and organic matter present in water. COD is expressed as the amount of oxygen consumed in milligrams per liter (mg/l). Results do not necessarily correlate to BOD results because the chemical oxidant in the COD test may react with substances that bacteria do not metabolize (US EPA 2008f).

EPA has developed aquatic life NRWQC for ambient DO that take into account life stages and temperature preferences of different types of fish. The 7-day mean DO concentration for early life stages is 9.5 mg/l for cold water fish and 6.0 mg/l for warm water fish. The 7-day mean minimum DO for older life stages is 5.0 mg/l for cold water fish and 4.0 mg/l for warm water fish (US EPA 1986). Low dissolved oxygen levels are the reason for the listing of 5,401 miles of impaired waters in the United States or about 13% of total impaired miles (US EPA 2008b).

A well-known example of ecological alteration due to high BOD levels is the anoxia that is an annual occurrence throughout the Chesapeake Bay. For several months every year, large areas of the bay are unfit for fish or shellfish (US EPA 1998b). A past example of BOD impact was the Delaware River in the vicinity of Philadelphia and Camden. Every summer for many years, this area experienced severe DO "blocks" due to excessive BOD input from point sources. The anoxic conditions prevented several anadromous fish species (e.g., Atlantic menhaden and shad) from migrating upstream to spawn. Since the early 1980s, however, conditions have improved to the point that these species are once again able to swim upstream in large numbers to reproduce (Delaware Estuary Program 1996).

2.2.1.3 Human Health and Aquatic Resource Use Impact Behaviors

Human beings can be exposed to airport deicing product components through several aquatic resource pathways. Exposure occurs when a pollutant comes into contact with the human envelope—the lungs, gastrointestinal tract, or skin—resulting in inhalation, ingestion, or dermal absorption. Human beings also experience aesthetic impacts through sight, smell, and taste of aquatic resources affected by airport deicing discharges.

Human beings come into contact with surface waters during recreational activities such as fishing, nature observation, boating, and swimming. Exposure can involve skin contact, fish consumption, or inhalation of volatile chemicals. People who live in communities near surface waters containing airport deicing discharges can also inhale chemicals that volatilize from surface waters.

Drinking water is an additional exposure pathway. Many drinking water supply systems draw water from surface water sources. If a drinking water treatment process does not remove airport deicing product components from source water, human beings can be exposed to them through water ingestion or dermal exposure and inhalation during bathing. Airport deicing product components can also enter groundwater and be drawn into industrial, commercial, municipal, and residential wells. Some groundwater undergoes treatment before use and some is used without treatment, particularly groundwater from residential wells.

To help assess the potential for impacts to human health and aquatic resource use from ADF and pavement deicer components, EPA gathered available information on component toxicity, carcinogenic potential, and aesthetic impact potential. These traits are described in further detail below.

The assessment of human health risk from a pollutant has four traditional steps:

1. Hazard Identification
2. Exposure Assessment
3. Dose-Response Analysis
4. Risk Characterization.

The amount of chemical human beings are exposed to through ingestion, inhalation, or dermal absorption is an important variable contributing to risk associated with that chemical. A dose-response function is used to fully characterize human health risk from a given chemical. This section summarizes information available on chemical-specific characteristics. *Chapter 3* summarizes information available on the quantities of deicing chemicals airports discharge to the environment, the manner in which they disperse, and the potential for human exposure.

Human Toxicity

EPA examined human health toxicity data both for outcomes resulting in cancer and for outcomes other than cancer (e.g., increased liver weight or respiratory effects). EPA’s Integrated Risk Information System (IRIS) and other toxicity databases separate outcomes into these two types. The reasoning for this delineation is the assumption that there is no safe level of exposure to cancer-causing chemicals. Even a small exposure increases cancer risk to a certain extent. For chemicals that result in health effects other than cancer, there is thought to be a threshold level below which exposure is “safe.”

Some chemicals are toxic at low doses. Other chemicals must be present at high levels to create a toxic effect. Some chemicals display hormesis and are beneficial at low doses, yet toxic at higher doses. Information on chemical toxicity is available in the toxicological and epidemiological literature. The discipline of toxicology utilizes laboratory studies on animals (*in vivo*) or cells (*in vitro*). Epidemiological studies examine human health outcomes in relation to chemical exposures on a day-to-day basis (time series studies) or over many years (cohort studies). Data on personal exposures to a chemical integrated over the population of interest and combined with chemical toxicity information are used to estimate human health risk from a chemical. Unfortunately, the toxicity of many chemicals either has not been studied or is not well understood.

EPA located toxicity information for 12 chemicals and chemical categories listed as potential ADF and pavement deicer components. EPA reviewed the following information sources for this data:

- Integrated Risk Information System (IRIS)
- Risk-Screening Environmental Indicators Model (RSEI)
- National Recommended Water Quality Criteria (NRWQC)
- Maximum Contaminant Levels for Drinking Water (MCLs)
- Peer-reviewed journal articles and government reports

Table A-41 in *Appendix A* summarizes the results for all 12 chemicals and chemical categories for which EPA was able to locate information.

Cancer Outcomes

EPA and the International Agency for Research on Cancer (IARC) use weight of evidence (WOE) classifications to qualitatively define carcinogens based on available data. The EPA defines six WOE guidelines, described below. IARC uses a similar scheme.

Category Weight-of-Evidence:

- A. Sufficient evidence from epidemiological studies to support a causal relationship between exposure to the agent and cancer.
- B1. Limited evidence from epidemiological studies and sufficient animal data.
- B2. Sufficient evidence from animal studies but inadequate or no evidence or no data from epidemiological studies.
- C. Limited evidence of carcinogenicity in animals and an absence of evidence or data in humans.
- D. Inadequate human and animal evidence for carcinogenicity, or no data.
- E. No evidence for carcinogenicity in at least two adequate animal tests in different species or in both adequate epidemiological and animal studies, coupled with no evidence or data in epidemiological studies.

For chemicals with a sufficient WOE, quantitative measures have been set. Since there is thought to be no safe level of exposure for carcinogens, many databases report slope factors or unit risks for carcinogens. There may be an oral slope factor (corresponding to ingesting a chemical in food), a drinking water unit risk (corresponding to ingesting a chemical in drinking water), and an inhalation unit risk (corresponding to inhaling a chemical from the air).

IRIS notes that the Oral Slope Factor represents the upper-bound (approximating a 95% confidence limit) estimate of the slope of the dose-response curve in the low-dose region for carcinogens. The units of the slope factor are usually expressed as the inverse of milligrams per kilogram-day $(\text{mg/kg-day})^{-1}$. The Inhalation Unit Risk is defined as the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 gram per cubic meter $(\text{g/m}^{3)}$ in air.

A number of assumptions are used to develop these values. For example, a person is assumed to weigh 70 kilograms, drink 2 liters of water per day, and breathe air at a rate of 20 cubic meters per day continuously for 70 years. Other assumptions are made in regard to animal-to-human extrapolation as most toxicological studies are performed on animals rather than humans. Assumptions are also made about low-dose extrapolations since study animals are generally exposed to much higher levels of pollutants than humans are expected to encounter.

Non-cancer Outcomes

For compounds resulting in health effects other than cancer, safe exposure thresholds are deemed to exist. IRIS has developed both reference doses (RfDs) and reference concentrations (RfCs), corresponding to ingestion and inhalation exposures.

IRIS states: "…the RfDs and RfCs are estimates (with uncertainty spanning perhaps an order of magnitude) of daily exposure [RfD], or continuous inhalation exposure [RfC], to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer effects during a lifetime."

Because most toxicological studies are conducted on animals, animal-to-human and low-dose extrapolation assumptions are also a factor in determining RfCs and RfDs. Generally, a point of departure from a toxicological study is selected and divided by uncertainty factors to account for these issues. Care must be taken when comparing RfD or RfC values from IRIS to other reference levels, because other reference sources may not use the same uncertainty factors or may use none at all.

Water Quality Guidelines

EPA also examined two types of water quality standards for this analysis. National Recommended Water Quality Criteria (NRWQC), set by EPA, aim to protect the health of human beings who consume water and aquatic organisms or solely aquatic organisms from contaminated aquatic habitats. The criteria, expressed in micrograms per liter (µg/L), represent surface water pollutant concentrations that are likely to cause adverse health effects in human beings if exceeded.

EPA also examined human health-based drinking water criteria. These criteria are usually presented as Maximum Contaminant Levels (MCLs) and are also developed by EPA. MCLs for non-carcinogens represent chemical-specific concentrations (expressed in µg/L) below which adverse health effects are not expected in exposed populations. MCLs for carcinogens represent chemical-specific concentrations (expressed in µg/L) that generally are expected to result in less than one additional cancer case per million lifetime exposures if the level is not exceeded in drinking water supplies.

Aesthetic Impacts

Human beings experience aesthetic impacts to aquatic resources in a variety of ways including impacts to water's visual appearance or its smell or taste. These impacts can affect human use or enjoyment of affected water and surrounding areas.

Objectionable tastes, odors, colors, and foaming have been reported in surface waters containing airport deicing operation discharges. These effects are generated in at least two ways. First, certain deicing product components are inherently likely to cause these effects. For example, dyes can directly add color to water. Airport deicer components and their breakdown products (e.g., urea, ammonia, ethylene glycol, propylene glycol, polymers of acrylic acid, and ethanolamines, have characteristic and potentially unpleasant odors. Glycols have a distinctive sweet odor. Solvents such as ethylbenzene, toluene, and xylenes can also add objectionable odors to water and their volatility lowers the detection threshold of those odors. Information on taste is not as readily available as information for odor, but glycols are known to have a somewhat sweet flavor and many surfactants taste bitter. The causes of foaming are not clear.

The second route by which ADFs and pavement deicers can cause adverse aesthetic impacts is through die-off of aquatic biota. Fish, macrophytes, and invertebrates can die when dissolved oxygen levels fall in or toxic substances enter surface water. Algae and heterotrophic microorganisms inhabiting the water column can die, as can the epilithon, the biotic layer covering the substrate of a stream or lake. This dead biomass can decay aerobically if the water recovers sufficient oxygen, or anaerobically in a process known as putrefaction, which generates particularly foul odors. This decomposition process also releases proteins, polysaccharides, and other organic compounds which can provide building blocks for the generation of persistent foams in water. Under the resulting anoxic conditions, the reduction of iron and manganese ions to more soluble species can impart color to water (Zitomer 2001).

2.2.2 Detailed Airport Deicing Product Component Profiles

This section summarizes available information on 12 ADF and pavement deicer components or component groups. These components were chosen for a more detailed analysis for one or more of the following reasons: the component is a well-known ingredient in airport deicing products; the component is released to the environment in significant quantities by airport deicing operations; or the component has environmental impact potential. Additional information on these components is summarized in *Table A-42* through *Table A-53* in *Appendix A*.

2.2.2.1 Acetate

Sodium acetate and potassium acetate are used as freezing point depressants in airfield pavement deicers and are applied in large quantities at a number of airports. The dissolution of these chemicals after application releases acetate ($C_2H_3O_2$) into the environment in its ionic form. Acetate can impact aquatic environments through consumption of dissolved oxygen during degradation. This section and *Table A-42* of *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of acetate.

Fate and Transport

Acetate is not expected to volatilize (US NLM 2008).

Acetate ions are soluble in water (US NLM 2008). The solubility of acetate from particular compounds, for example sodium acetate, depends on the solubility of those compounds. Sodium acetate has a solubility of 1,190 grams per liter at 0° C (US NLM 2008).

The degree to which acetate ions adsorb or complex with soil or water constituents or remain dissolved in surface water or groundwater depends on site-specific factors. The rate of transport of acetate through soil will depend on a combination of the degradation rate and interactions with soils/sediments. Therefore, transport rates will be site-specific (US NLM 2008).

Acetate is rapidly biodegraded under aerobic conditions in surface water, groundwater, and soil (US NLM 2008). Acetate is also anaerobically biodegradable (US NLM 2008). Acetate in soil, derived from calcium magnesium acetate, was completely degraded within three to six days (D'Itri 1992). Since aerobic degradation is rapid, acetate plumes are rare, except possibly in anaerobic groundwater (Maest 2008). Formate can slow the breakdown of acetate in anaerobic environments (US NLM 2008). Acetate degradation produces bicarbonate, carbon dioxide, and water (D'Itri 1992).

Acetate has a moderately high BOD falling between the BODs of urea and formate. Acetate's BOD and COD are lower than those of propylene and ethylene glycol. One formulated pavement deicer product consisting primarily of sodium acetate is reported to have a BOD_5 of 0.58 g O_2/g product (Fyve Star, Inc. 2008).

Ecological Effects

Acetate anions decay through a process that consumes dissolved oxygen present in surface waters and groundwater. Chemicals that exert oxygen demand during the degradation process reduce the level of dissolved oxygen available for aquatic organisms, which require a certain level of dissolved oxygen to function and survive. For additional information on the impacts of oxygen demand, see Sections 2.2.1.2, 2.2.2.1, and 2.2.2.2.

Human Health and Aquatic Resource Use Effects

EPA's literature search did not locate conclusive reports on the human health effects of acetate. Acetate may contribute to aesthetic impacts, however. Acetate decomposition consumes dissolved oxygen in surface waters. Low dissolved oxygen levels in surface waters can cause unpleasant odors and discoloration of water.

2.2.2.2 Alcohol Ethoxylates

Alcohol ethoxylates ($CH_3(CH_2)_n(OCH_2\ CH_2)_yOH$) are a major class of non-ionic surfactants that are widely used in a variety of consumer and industrial products, including laundry detergents (HERA 2007). Their use in ADFs as a surfactant additive has been documented in the literature. Their use may, in part, be in response to concerns about potential environmental impacts associated with the use of nonylphenol ethoxylate surfactants. Surfactants typically compose less than 2% of ADFs by volume. This profile and Table A-41 in *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of alcohol ethoxylates.

Fate and Transport

Alcohol ethoxylates are a class of nonionic surfactants possessing alkyl chains with 12 to 18 carbons and ethoxylates with 0 to 18 units (Belanger et al. 2006).

Sorption to organic carbon and solids in the water column and subsequent burial in sediments is an important removal process in aquatic systems. Rates of sorption vary by ethoxymer and increase with increasing number of ethoxylate units and attendant hydrophobicity (Belanger et al. 2006). In soil, sorption to solids and organic carbon is a significant partitioning process (Belanger et al. 2006), and can reduce the chemical's rate of migration through the soil. Rates of sorption vary by ethoxymer, and increase with increasing hydrophobicity (Belanger et al. 2006).

Anaerobic breakdown has been documented in laboratory experiments simulating wastewater treatment (Belanger et al. 2006). Aerobic degradation also occurs. Rates of biodegradation vary by compound, but extremely rapid biodegradation is expected for all ethoxymers (Belanger et al. 2006). Rapid degradation was observed in natural estuarine waters with an alkyl half-life of 2.1 days and an ethoxy half-life of 6.3 days under environmental conditions (temperature unknown) (Vashon 1982). Linear and monobranched alcohol ethoxylates were completely biodegraded within 20 days and approximately 5% of the initial amount of multibranched alcohol ethoxylates remained after 30 days (Marcomini et al. 2000, as cited in Environment Canada 2002a).

Alcohols and fatty alcohols are alcohol ethoxylates' primary degradation products (Belanger et al. 2006). Anaerobic degradation also produces methane. The degradation intermediates of alcohol ethoxylates are less toxic than the parent compounds, and polyethylene glycol is the primary intermediate product (Environment Canada 2002a). Aerobic degradation occurs by stepwise removal of ethylene oxide units, and simultaneous degradation of the alkyl chain can also occur, proceeding to complete degradation into carbon dioxide and water (Environment Canada 2002). However, the following intermediate products are also expected, depending on the form of the parent compound (Environment Canada 2002):

- **Parent Compound:** Linear alcohol ethoxylates

  Intermediate Compounds: Linear fatty alcohol, carboxylic fatty acid, polyethylene glycol, monocarboxylated polyethylene glycol, and dicarboxylated polyethylene glycol.

- **Parent Compound:** Monobranched alcohol ethoxylates

  Intermediate Compounds: Carboxylated alcohol ethoxylates with a carboxylic group on the alcohol chain, monocarboxylated polyethylene glycol, dicarboxylated polyethylene glycol, carboxylated alcohol ethoxylates with a carboxylic group on the polyethoxylic chain, and carboxylic fatty acid.

- **Parent Compound:** Multibranched alcohol ethoxylates

  Intermediate Compounds: Carboxylated alcohol ethoxylates with a carboxylic group on the polyethoxylic chain and carboxylic fatty acid.

Alcohol ethoxylates can also increase the mobility of other substances through soil and groundwater because of their physical properties as nonionic surfactants (Krogh et al. 2003).

Ecological Effects

Available information suggests that alcohol ethoxylates can have acute and chronic toxic effects on aquatic organisms. These effects vary by carbon chain length. Typical alcohol ethoxylate surfactant chain length ranges from 9 to 18 carbons and 3 to 8 ethoxylate groups. Toxicity generally declines as the number of ethoxylates increases (Campbell 2002).

A summary of chronic toxicity data from 60 studies conducted between 1977 and 2004 on fish, aquatic invertebrates, and aquatic plant and algae species states that alcohol ethoxylates' effects on aquatic species include reduced growth rates, impaired reproduction, and reduced survival of neonates, as well as acute mortality. Alcohol ethoxylates may cause diminished growth rates and reduced cell counts in algae species at concentrations as low as 0.03 mg/L (Belanger et al. 2006).

The concentrations at which alcohol ethoxylates lead to acute mortality in aquatic species are similar to the concentrations at which nonylphenol ethoxylates lead to acute mortality. However, alcohol ethoxylates degrade more quickly in the aquatic environment to relatively non-toxic compounds, whereas nonylphenol ethoxylate degradation typically yields nonylphenol, which is toxic as well as persistent in the aquatic environment.

Human Health and Aquatic Resource Use Effects

Human beings have regular contact with alcohol ethoxylates through a variety of industrial and consumer products such as soaps, detergents, and other cleaning products (US EPA 2000b). Exposure to these chemicals can occur through ingestion, inhalation, or contact with the skin or eyes. Studies of acute toxicity show that volumes well above a reasonable intake level would have to occur to produce any toxic response. Moreover, no fatal case of poisoning with alcohol ethoxylates has ever been reported. Multiple studies investigating the acute toxicity of alcohol ethoxylates have shown that the use of these compounds is of low concern in terms of oral and dermal toxicity (HERA 2007).

Clinical animal studies indicate these chemicals may produce gastrointestinal irritation such as ulcerations of the stomach, pilo-erection, diarrhea, and lethargy. Similarly, slight to severe irritation of the skin or eye was generated when undiluted alcohol ethoxylates were applied to the skin and eyes of rabbits and rats. The chemical shows no indication of being a genotoxin, carcinogen, or mutagen (HERA 2007). No information was available on levels at which these effects might occur, though toxicity is thought to be substantially lower than that of nonylphenol ethoxylates. Concentrations of alcohol ethoxylates in aquatic resources affected by airport deicing discharges are expected to be fairly low.

2.2.2.3 Dyes

Manufacturers add dye to ADFs to help ADF users track their presence on aircraft and airfield surfaces and to help them to distinguish Type I from Type IV fluids. Numerous dyes are found in ADFs, including alphazurine, tetrabromofluorescein, tartrazine, malonyl green, and shilling green dyes. Because of the proprietary nature of ADF formulations, the identity of all ADF dyes in use is not known. Type I ADFs are typically orange, and Type IV ADFs are typically green. Dyes and other ADF additives typically compose less than 2% of ADF volume. While some ADF dyes have been found to be safe for human consumption and are regularly used as food colorants, others may be detrimental to ecosystems or have unknown impacts. This section and *Table A-44* in *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of ADF dyes.

Fate and Transport

Dyes are a diverse group of substances. Fate, transport, and partitioning behaviors depend on the specific dye in question. Most ADF dyes are expected to be at least somewhat water-soluble. Dyes reported as present in ADFs include: eosin orange (tetrabromofluorescein), FD&C Blue #1 (alphazurine), FD&C Yellow #5 (tartrazine), malonyl green (C.I. Pigment Yellow 34), and shilling green.

EPA was unable to locate information on the fate and transport behavior of these dyes through its literature search. However, in general, dyes tend to absorb ultraviolet radiation and have the potential to form decay products more toxic than the original parent dye compound.

Ecological Effects

The ecological effects of many ADF dyes have not been well documented.

Tetrabromofluorescein, a red dye, is not considered to be toxic to aquatic organisms except in very high concentrations. Aquatic invertebrates may have a somewhat lower sensitivity threshold than fish. It is not likely to bioaccumulate (Environment Canada 2008a).

No toxicity testing data is available for alphazurine, but some studies suggest that long-term degradation products of this dye may be of concern (ScienceLab 2005).

Malonyl green uses C.I. Pigment Yellow 34 which is a substance listed as being of environmental concern in the European Union due to the potential for highly toxic effects from two of its constituents, lead chromate and lead sulfate. These substances are also considered to be persistent in the environment and potentially bioaccumulative (Environment Canada 2008b).

EPA found no toxicity data for shilling green or tartrazine through its literature search.

Human Health and Aquatic Resource Use Effects

EPA found limited information on human health effects of ADF dyes through its literature search. Dyes may contribute to discoloration of surface waters downstream of airport deicing discharge outfalls.

2.2.2.4 Ethylene Glycol

Ethylene glycol ($C_2H_6O_2$) is well known as one of two freezing point depressants used in most Type I and Type IV ADFs. Most of the ADF currently applied at U.S. airports is based on the other main freezing point depressant, propylene glycol, but a sizeable fraction of current ADF usage continues to be based on ethylene glycol. These fluids are applied in large quantities at a number of airports. Before dilution for application, an ADF can consist of nearly 90% ethylene glycol. For this reason, large quantities of ethylene glycol are released to the environment during airport deicing activities. Ethylene glycol is also used in some airfield pavement deicer formulations. Ethylene glycol contamination has been detected in surface waters, groundwater, sediments, and wastewater discharges at or near airports using ADFs.

When released to surface waters in large quantities, the chemical has the potential to consume large quantities of dissolved oxygen from the water column, potentially affecting the ecosystem and human use of aquatic resources. This profile and *Table A-45* in *Appendix A* summarize available information on the environmental fate and transport, ecological effects, and human effects of ethylene glycol.

Fate and Transport

This section summarizes the environmental fate and transport characteristics of ethylene glycol. As discussed in previous sections, deicing products containing ethylene glycol can enter surface waters, soil, and groundwater on or near airports.

Volatilization of ethylene glycol from soil or water is not, in general, expected. However, ethylene glycol can be released into the atmosphere by spray application of ADFs to aircraft, particularly under windy conditions, and by shearing of ADFs from aircraft during taxiing and take-off. Ethylene glycol's atmospheric half-life is 50 hours at 25° C (US NLM 2008).

Ethylene glycol is freely soluble in water and is highly mobile in both surface water and groundwater (US NLM 2008). Tracer experiments appear to show that ethylene glycol moves through soil with groundwater. It adsorbs poorly to clay and sandy clay soils (US NLM 2008).

Ethylene glycol undergoes rapid microbial degradation in both soil and water. It can be degraded both aerobically and anaerobically (Johnson et al. 2001). Photolysis and hydrolysis are expected to be insignificant degradation pathways.

As with other glycols, unacclimated microbial communities in surface waters and soils often experience a lag of several days before degradation begins. Microbial communities acclimated to glycol inflows can begin degradation much sooner. Additives in ADFs, however, can significantly delay degradation (Johnson et al. 2001) as can low temperatures (US NLM 2008). Even though ethylene glycol itself may be completely degraded within a few days under optimal conditions, the full theoretical biological oxygen demand may not be observed for several weeks (US NLM 2008).

Ethylene glycol degradation requires a great deal of oxygen, with a reported $CBOD_5$ of 0.4 to 0.7 g O_2/g of ethylene glycol or 400 to 800 g O_2 per liter of ethylene glycol (D'Itri 1992).

In various field soils, 90% to 100% degradation of ethylene glycol was observed in 2 to 12 days (study temperatures unknown). Ethylene glycol in ADFs was completely degraded in soils along airport runways within 29 days at 8° C (US NLM 2008). Ethylene glycol in river water degraded completely in three days at 20° C and in 5 to 14 days at 8° C (US NLM 2008). Ethylene glycol should exhibit minimal partitioning to sediments or suspended particles in water. Given these behaviors, the distance ethylene glycol travels in surface water, groundwater, and soil will depend primarily on the balance between rates of transport and degradation (US NLM 2008).

Anaerobic degradation can be complete, producing methane and carbon dioxide, or incomplete, producing ethanol and acetate (Johnson et al. 2001). When there is insufficient oxygen to allow complete aerobic degradation, anaerobic degradation occurs unless inhibited by ADF additives or high concentrations of metabolic byproducts.

Ecological Effects

Ethylene glycol toxicity data for aquatic organisms is relatively limited in its scope and availability. However, available data indicates ethylene glycol may cause general chronic toxicity effects at high concentrations (>3400 mg/L), including slower growth and inhibited reproduction. It can also cause acute mortality. A study by Corsi et al. (2006) found that in certain Type I formulations, ethylene glycol contributed as much as 87% of the total toxic effect to the algae *Selenastrum capricornutum*. However, it contributed a much smaller percentage of the toxicity of the formulation to the fathead minnow (35%), the daphnid *Ceriodaphnia dubia* (47%), and Microtox testing (9%). It also contributed a much smaller percentage of the toxicity of a Type IV formulation to all four of the aforementioned tests (ranging from less than 1% to 19%).

Ethylene glycol is known to exert high levels of biological oxygen demand (BOD) during degradation in surface waters. This process can adversely affect aquatic life by consuming oxygen aquatic organisms need to survive (Corsi et al. 2001). Large quantities of dissolved oxygen (DO) in the water column are consumed when microbial populations decompose ethylene glycol. As described above, ethylene glycol degradation requires a great deal of oxygen, with a reported $CBOD_5$ of 0,4 to 0.7 g O_2/g of ethylene glycol, or 400 to 800 g O_2 per liter of ethylene glycol (D'Itri 1992).

Sufficient DO levels in surface waters are critical for the survival of fish, macroinvertebrates, and other aquatic organisms. If oxygen concentrations drop below a minimum level, organisms emigrate, if able and possible, to areas with higher oxygen levels or eventually die (US EPA 1993). This effect can drastically reduce the amount of useable aquatic habitat. Reductions in DO levels can reduce or eliminate bottom-feeder populations, create conditions that favor a change in a community's species profile, or alter critical food-web interactions.

An example of dissolved oxygen impacts deriving from airport deicing operation discharges is the impairment of Gunpowder and Elijah Creeks in northern Kentucky. News reports have shown that discharges from Cincinnati/Northern Kentucky International Airport, specifically ethylene glycol, are to blame for the creeks' states, which were so degraded at the time of the reports that they did not support life (Kelly and Klepal 2004).

Human Health and Aquatic Resource Use Effects

Human exposure to ethylene glycol can occur through dermal contact, inhalation, ingestion, and eye contact (NIOSH 2005a). Exposure typically targets the eyes, skin, respiratory system, and central nervous system, and manifests through irritation to the eyes, skin, nose, and throat; nausea, vomiting, abdominal pain, lassitude (weakness, exhaustion); dizziness, stupor, convulsions, central nervous system depression; and skin sensitization (NIOSH 2005a). Effects can occur at concentrations as low as 2 mg/kg*day. Children and adults are expected to similarly express pollutant exposure symptoms (US HHS 2007a).

No negative health effects have been reported in persons chronically exposed to ethylene glycol at natural levels found in the environment (US HHS 2007b), though available monitoring data indicate that ethylene glycol is typically found only near areas of release (e.g., production facilities and airports). Workers involved in airport deicing operations have produced urine samples containing ethylene glycol. Further research is still needed, however, to fully assess the cancer potential, developmental toxicity, and other human health impacts of this pollutant, particularly with respect to the general public (US HHS 2007b).

Several articles have reported a strong sweet odor downstream from airport deicing outfalls which is believed to derive from ethylene and/or propylene glycol (e.g., Eddy 1997). Additionally, anoxic waters, which can result from the high BOD ethylene glycol exerts, typically produce a strong, unpleasant odor (State of Ohio Environmental Protection Agency 2001).

2.2.2.5 Formate

Sodium formate is used as a freezing point depressant in airfield pavement deicers and is used in large quantities at a number of airports. The dissolution of sodium formate after application releases formate (CH_2O_2) into the environment in its ionic form. Formate can impact aquatic environments through consumption of dissolved oxygen during degradation. This section and *Table A-46* of *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of formate.

Fate and Transport

Formate is not expected to volatilize (US NLM 2008).

Formate ions are very soluble in water though the solubility of formate in compounds depends on the solubility of those compounds (US NLM 2008). Sodium formate has a solubility of 972 g/L at 20° C (US NLM 2008). Depending on site-specific factors, formate ions may adsorb or complex with soil or water constituents or remain dissolved in surface water or groundwater (US NLM 2008).

Formate is slowly hydrolyzed in water (US NLM 2008). It is subject to rapid aerobic degradation, and can be anaerobically degraded by methanogens (US NLM 2008). Researchers observed that the aerobic degradation rate appears to decrease sharply with decreasing temperatures (Hellsten et al. 2005). The aerobic degradation of formate produces carbon dioxide and bicarbonate (Hellsten et al. 2005).

Formate has a slightly lower BOD and COD than acetate and a lower BOD and COD than ethylene and propylene glycol. Sodium formate granules in one formulated deicing product (Kilfrost CIM) are reported to have a COD of 0.3 g O_2/g product. The product's BOD was not reported (Reeves et al. 2005).

Ecological Effects

Formate anions decay through a process that consumes dissolved oxygen present in surface waters and groundwater. Chemicals that exert oxygen demand during the degradation process reduce the level of dissolved oxygen available for aquatic organisms, which require a certain level of dissolved oxygen to function and survive. For additional information on the impacts of oxygen demand, see Sections 2.2.1.2, 2.2.2.1, and 2.2.2.2.

Human Health and Aquatic Resource Use Effects

EPA's literature search did not locate conclusive reports on the human health effects of acetate. Formate may contribute to aesthetic impacts, however. Formate decomposition consumes dissolved oxygen in surface waters. Low dissolved oxygen levels in surface waters can cause unpleasant odors and discoloration of water.

2.2.2.6 Nonylphenol and Nonylphenol Ethoxylates

The widespread use of nonylphenol ethoxylates ($C_9H_{19}\text{-}C_6H_4O(CH_2CH_2O)_nH^a$) as a surfactant additive in Type I and Type IV ADF formulations has been well documented in the literature. Nonylphenol is a common decay product of nonylphenol ethoxylates. Surfactants typically comprise less than 2% by volume of ADFs. There is currently uncertainty, however, over the extent to which manufacturers have recently modified ADF formulations to replace nonylphenol ethoxylates with other types of surfactants.

Nonylphenol ethoxylates and nonylphenol can have toxic and estrogenic properties and persist in the environment. They can cause mortality and endocrine disruption in aquatic organisms. Some preliminary data suggest that nonylphenol may cause cancer and reproductive problems in human beings.

Nonylphenol ethoxylate and nonylphenol contamination has been detected in surface waters, groundwater, sediments, aquatic organisms, and wastewater discharges at or near airports using ADFs. This profile and *Table A-47* in *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of nonylphenol and its ethoxylates.

Fate and Transport

This section summarizes the environmental fate and transport characteristics of nonylphenol ethoxylates and nonylphenol. As discussed in previous sections, airport deicing products containing nonylphenol ethoxylates and nonylphenol can enter surface waters, soil, and groundwater on or near airports. Nonylphenol and its ethoxylates are a large class of alkylated phenols with varying physical properties; fate, transport, and partitioning behavior vary somewhat by ethoxymer.

Nonylphenol has very low volatility. Its ethoxylates are also not expected to volatilize readily. However, nonylphenol ethoxylates can be released into the atmosphere by spray application of ADF to aircraft, particularly under windy conditions, and by shearing of ADF from aircraft during taxiing and take-off. Nonylphenol ethoxylates are expected to degrade rapidly in air (Environment Canada 2002).

Nonylphenol ethoxylates are likely to partition to organic matter or minerals in soil, but this tendency varies by ethoxymer and degree of hydrophobicity. Migration of nonylphenol ethoxylates through the soil has been observed (Environment Canada 2002). In water, as in soil, nonylphenol ethoxylates may sorb to organic matter or particulates (Environment Canada 2002). The decay product nonylphenol is likely to partition to sediments and mineral particles in water and soil but can still leach through soils (Environment Canada 2002).

Degradation of nonylphenol ethoxylates varies by ethoxymer and tends to produce some recalcitrant compounds with endocrine disrupting potential, including nonylphenol, nonylphenol monoethoxylate, nonylphenol diethoxylate, nonylphenoxyacetic acid, and nonylphenoxyethoxyacetic acid (Environment Canada 2002). Observed half-lives for nonylphenol ethoxylates in environmental media range from 3 to 26 days under ideal aerobic conditions with an acclimated microbial community (Staples et al. 2001).For nonylphenol, a biphasic degradation profile has been observed in soils with relatively rapid initial degradation of 30-50% during the first several weeks and the remainder degrading with a half-life of approximately 90 days (Environment Canada 2002). Degradation rate also appears to be strongly dependent on the environmental medium. Half-lives of nonylphenol range from 2.4 hours to 0.74 d in water (US NLM 2008). The photolytic half-life of nonylphenol in the upper layer of surface water is 10-15 hours but is much slower in deeper layers. In a sediment mesocosm, a half-life of 66 days was observed for nonylphenol (Environment Canada 2008a).

Ecological Effects

Nonylphenol ethoxylates are highly toxic to many aquatic species. Nonylphenol ethoxylates degrade quickly and are therefore chiefly of concern because of their acute effects. Nonylphenol, the primary degradation product of nonylphenol ethoxylates persists in water for substantially longer time periods than nonylphenol ethoxylates and is more likely to contribute to chronic, as well as acute, effects. It is one of the most prevalent contaminants in U.S. streams, both in terms of the number of streams affected and the concentrations found (US EPA 2005).

The primary impacts of these chemicals on aquatic life are sublethal toxic effects, although at sufficient doses both can cause mortality. Nonylphenol ethoxylate toxicity has not been studied to the same extent as nonylphenol toxicity, but several types of adverse impacts have been noted. These impacts include acute mortality in some sensitive species at concentrations as low as 2.8 mg/L, reproduction impacts, diminished egg emergence in aquatic animals, and growth impairment in algae and aquatic animal species. Nonylphenol ethoxylates are not thought to bioaccumulate in any species (Environment Canada 2001). A study by Corsi et al. (2006) found that in certain Type I and Type IV deicing formulations, nonylphenol ethoxylates were responsible for 40 to 50% of toxicity in one Type I and one Type IV formulation for several species. However, it was not detected in three of the other formulations tested, and was responsible for only a small fraction of toxicity in the remaining four.

An EPA study of the effects of nonylphenol on aquatic life found that at concentrations as low as 0.01 mg/L, impacts include reproduction impairment, reduced numbers of live offspring, diminished growth, and reduced offspring survival (US EPA 2005). Several other studies address estrogenic or other reproductive effects, including evidence suggesting increased vitellogenin concentrations in fish from chronic nonylphenol exposure and, at high concentrations, impacts on sex ratios and spawning habits. Nonylphenol has also been shown to inhibit growth and cellular counts in algae and to potentially bioaccumulate in some mollusk species. EPA has stated that the maximum acceptable one-hour average concentrations of nonylphenol in freshwater is 28 µg/L and 7.0 µg/L in saltwater. The maximum acceptable four-day average is 6.6 µg/L in freshwater and 1.7 µg/L in saltwater (US EPA 2005).

Human Health and Aquatic Resource Use Effects

Human exposure to nonylphenol and its ethoxylates can occur through ingestion, inhalation, and absorption through the eyes or skin (US EPA 2006a). Fish consumption is the largest contributor to human exposure, and is estimated to account for roughly 70 to 80% of typical daily doses (UNEP et al. 2004). This pollutant primarily affects the upper respiratory system and kidneys. Exposure symptoms can include skin and eye irritation, tissue decay, swelling, mottled kidneys, lethargy, coughing, wheezing, shortness of breath, headache, nausea, diarrhea, and vomiting. Data show that low concentrations of these chemicals act as mild irritants. High concentrations of nonylphenol and its ethoxylates may be extremely destructive to the upper respiratory tract, eyes, and skin (US EPA 2006a, Cox 1996), but human beings are unlikely to encounter such concentrations through exposure to aquatic resources contaminated by airport deicing products. The no observed adverse effect level is considered to be 10 mg/kg*day.

Current evidence of this pollutant as a genotoxin or carcinogen is inconclusive, but data seem to suggest that nonylphenol ethoxylates cause breast cancer cells to increase in number. Nonylphenol has also demonstrated estrogenic behavior, causing an increase in breast tumor numbers and size, reproductive problems, and various hormonal disruptions (UNEP et al. 2004).

2.2.2.7 Polyacrylic Acid

Polyacrylic acid $(C_3H_4O_2)_n$ is composed of a connected series of acrylic acid monomers. This chemical is used as a thickener in some Type IV ADFs to make them viscous enough to maintain their position on aircraft surfaces until aircraft take-off. Thickeners and other ADF additives typically make up less than 2% of ADF volume. During degradation in the natural environment, polyacrylic acid can break down into its component monomers. Polyacrylic acid and acrylic acid monomers have been linked to human health problems, adverse impacts on aquatic life, and disruptions of aquatic community trophic webs. This section and *Table A-48* in *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of polyacrylic acid.

Fate and Transport

Polyacrylic acids comprise a family of polymers. They are usually marketed as mixtures of polymers by molecular weight. The behavior of these mixtures in the environment may vary somewhat, but overall they are fairly similar (US NLM 2008).

Polyacrylic acids are not expected to volatilize from water or moist soil (US NLM 2008). Slow volatilization from dry soil is possible (US NLM 2008). They are not expected to adsorb to soils or particulates, therefore potential for transport in soils, surface waters, and groundwater is high (US NLM 2008).

Biodegradability decreases with an increasing number of polymerized units and increasing formula molecular weight. Biodegradability drops off sharply between molecular weights 700 and 1,000, and for polymers with more than seven units (Larson et al. 1997). It appears that monomers and dimers of acrylic acid are completely biodegradable, but there is evidence that polymers of three to seven units are incompletely biodegraded (Larson et al. 1997).

Non-polymerized (monomeric) acrylic acid biodegrades fairly quickly under both aerobic and anaerobic conditions. For example, it was 68% degraded within two weeks with an activated sludge inoculum. In a 42-day anaerobic study with a sewage seed inoculum, 71% was degraded (US NLM 2008).

It is possible for substances such as polyacrylic acids, which are slowly biodegradable, to accumulate in soils and to enhance the growth of microbial biomass in those soils. If microbial growth is high enough, the pores of the soil can become plugged with microbial biomass. This process can lead to plume spreading as new loadings of polyacrylic acid contaminated runoff are forced around regions of low permeability.

Ecological Effects

Acute toxicity impacts on numerous invertebrates and fish have been noted for acrylic acid, primarily in the form of mortality but also in the form of behavioral changes in the water flea (*Daphnia magna)*. Some studies also note growth rate inhibition and biomass reductions in green and blue-green algae. These effects may occur at levels as low as 0.17 mg/L (IPCS 1997).

Human Health and Aquatic Resource Use Effects

Exposure to acrylic acid can occur through inhalation, ingestion, and skin or eye contact, and can cause a variety of ailments including irritation to the eyes, skin, and respiratory system; eye and skin burns; skin sensitization; and lung, liver, and kidney disease (as revealed through animal studies) (NIOSH 2005b).

Currently there have been no reports of poisoning incidents in the general population. Most data indicate that this pollutant is of low to moderate acute toxicity by the oral route (NOAEL 140 mg/kg/day), and moderate acute toxicity by the inhalation (LOAEL 15 mg/m^3) or dermal route. It is unclear what concentration is non-irritant. Available reproduction studies indicate that acrylic acid is not teratogenic (i.e., does not cause birth defects) and has no effect on reproduction. The current data available are inconclusive regarding carcinogenic health hazards associated with acrylic acid exposure (US NLM 2008).

Acrylic acid monomers have a strong acrid odor, though no reports have linked this odor specifically to airport deicing discharges (BAMM 2006).

2.2.2.8 Potassium

Potassium acetate is used as a freezing point depressant in airfield pavement deicers and is applied in large quantities at a number of airports. The chemical is typically applied in liquid form and releases potassium into the surrounding environment in its ionic form. Following dissolution after application, solid forms of potassium acetate also releases potassium in its ionic form to the environment. Potassium can elevate measures of salinity, conductance, or total dissolved solids (TDS) in surface waters. It can impact aquatic environments and, at high levels, cause health problems in human beings. This section and

Table A-49 of *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of potassium.

Fate and Transport

Ionic potassium is highly soluble and highly mobile in both surface water and groundwater. In soil, potassium can accumulate in areas where there is insufficient water available to transport it through the soil horizon. Otherwise, it is transported easily through soil and can enter and travel with groundwater.

As an elemental ion, potassium is not subject to decay and persists in the environment. It is not expected to volatilize.

Ecological Effects

Most freshwater surface waters contain a small quantity of potassium. Fish require potassium for growth, reproduction, and survival. Freshwater fish actively assimilate potassium from food and water. Saltwater fish are generally at lower risk of potassium deficiency than freshwater fish because marine water contains higher levels of potassium then fresh water. High potassium loadings or long turnover times, however, can create surface water ion balance issues that can impact aquatic organism functioning and survival (Public Sector Consultants 1993).

Exposure to high levels of potassium can cause osmoregulatory dysfunction in aquatic organisms. Freshwater fish tissues typically have higher potassium content than surrounding water. Under normal conditions, freshwater fish use their gills, circulatory system, and kidneys to work against this osmotic gradient in order to prevent the influx of excess water and the loss of potassium from their tissues. Specialized cells in fish gill epithelium use potassium and sodium ions to transport chloride into or out of fish tissue (Jobling 1996). In marine fish, chloride ions are pumped from fish against an osmotic gradient. This process helps to maintain optimal osmotic potential between the fish and its environment.

The process moves potassium ions in the opposite direction in freshwater fish. The gill has mechanisms which actively work to re-import potassium into the blood on order to replace potassium lost through the gills. When external potassium levels exceed internal potassium levels, these osmoregulatory mechanisms can lead to rapid fish dehydration, ionoregulatory system imbalance, and impairment to fish functioning and survival.

Exposure to excessive potassium concentrations can interfere with these essential osmoregulatory mechanisms in both freshwater and saltwater fish, requiring fish to expend more energy to maintain homeostasis or, if concentrations are high enough, cause death through ionic imbalance.

In lakes, increased salt concentrations can also lead to increased density of water layers, leading to or exacerbating stratification during cold or still weather to the point that normal seasonal overturn does not occur (D’Itri 1992).

Plants use potassium to regulate ion transport. Plants exposed to high concentrations of potassium suffer adverse effects similar to those associated with potassium deficiencies by causing deficiencies in magnesium and calcium (Motavalli et al. 2008), which are essential for growth, reproduction, and survival.

Human Health and Aquatic Resource Use Effects

Potassium is an essential part of the human diet. This element is an essential in preventing and treating high blood pressure, hypoglycemia, diabetes, kidney disease, obesity, and potentially paralysis. The absence of adequate potassium in the diet may lead to listlessness, fatigue, gas pains, constipation, insomnia, and low blood sugar. Moreover, deficient individuals may have weak muscles and a slow, irregular pulse (IFIC 2005).

This element is beneficial at lower levels but may have detrimental health impacts if consumed in excess. U.S. health guidelines advise that no more than 4,700 mg potassium be consumed each day (US HHS and DoA 2005). However, many humans do not consume *enough* potassium. Human beings may ingest potassium from airport deicing discharges through consumption of contaminated drinking water sources.

2.2.2.9 Propylene Glycol

Like ethylene glycol, propylene glycol ($C_3H_8O_2$) is a well-known freezing point depressant used in many Type I and Type IV ADFs. These fluids are applied in large quantities at a number of airports. Most ADF in current use at U.S. airports is based on propylene glycol. Before dilution for application, an ADF can consist of nearly 90% propylene glycol. Propylene glycol is also used in some airfield pavement deicer formulations. For this reason, large quantities of propylene glycol can be released to the environment during airport deicing activities. Propylene glycol contamination has been detected in surface waters, groundwater, sediments, and wastewater discharges at or near airports using ADFs.

Though more expensive than ethylene glycol, propylene glycol is considerably less toxic to human beings and other mammals. When released to surface waters in large quantities, however, it has the potential to consume large quantities of dissolved oxygen from the water column, potentially affecting the ecosystem and human use of aquatic resources. This profile and *Table A-50* in *Appendix A* summarizes available information on the environmental fate and transport, ecological effects, and human effects of propylene glycol.

Fate and Transport

This section summarizes the environmental fate and transport characteristics of propylene glycol. As discussed in previous sections, deicing products containing propylene glycol can enter surface waters, soil, and groundwater on or near airports.

Volatilization of propylene glycol from soil or water is not, in general, expected (US NLM 2008). However, propylene glycol can be released into the atmosphere by spray application of ADF to aircraft, particularly under windy conditions, and by shearing of ADF from aircraft during taxiing and take-off. Propylene glycol's atmospheric half-life is 32 hours at 25° C (US NLM 2008).

Propylene glycol is freely soluble in water, and has very high mobility in soils, sediments, surface water, and groundwater (US NLM 2008). Estimates of log K_{OW} for propylene glycol are low, and range from –0.92 (US NLM 2008) to –1.41 (French et al. 2001, as cited in Jaesche et al. 2006). These low estimates of K_{OW} support the observations of Jaesche et al. (2006), who found negligible soil sorption in laboratory experiments. Propylene glycol should also exhibit minimal partitioning to sediments or suspended particles in water. Given these behaviors, the distance propylene glycol travels in surface water, groundwater, and soil will depend primarily on the balance between rates of transport and degradation.

Propylene glycol undergoes rapid microbial degradation in both soil and water. It can biodegrade under both aerobic and anaerobic conditions. For unacclimated microbial communities, there is often a lag of several days before glycol degradation begins. Microbial communities acclimated to glycol inflows can begin degradation much sooner. Additives in ADFs, however, can significantly delay degradation (Johnson et al. 2001). In microcosm experiments under aerobic conditions, degradation rates of up to 95 milligrams of propylene glycol per day per kilogram of dry soil were observed by Klecka et al. (1993; as cited in Jaesche et al. 2006). Jaesche et al. (2006) found that in subsoil materials, the anaerobic degradation of propylene glycol was very slow and was dependent on the import of microbiota from surface soils.

Propylene glycol degradation is also temperature-dependent. In laboratory experiments with field-collected soils, propylene glycol was not observed to degrade anaerobically at 4º C, and degraded anaerobically at 20° C only in soil that was rich in organic matter (Jaesche et al. 2006).

During anaerobic wastewater treatment, propylene glycol degrades first to propionaldehyde, then to propionate and 1-propanol. The final products are acetate, methane, and carbon dioxide (Jaesche et al. 2006).

Propylene glycol degradation requires a great deal of oxygen, with an estimated $CBOD_5$ of 1 g O_2/g of propylene glycol, or 1,000 g O_2 per liter of propylene glycol (Mericas and Wagoner 1994; Safferman et al. 1998, all as cited in Johnson et al. 2001).

Anaerobic degradation of propylene glycol can increase the efflux of terminal electron acceptors such as iron and manganese (hydr)oxides from soils (Jaesche et al. 2006). Over time, continued input of propylene glycol can therefore lead to a reduction in soil's redox potential, promoting anoxic conditions in the soil (Jaesche et al. 2006).

Ecological Effects

Data on propylene glycol's toxicity for aquatic organisms is relatively limited, though it is generally perceived as being relatively low. Available data indicate that propylene glycol may cause general chronic toxicity effects, including slower growth and inhibited reproduction, as well as acute mortality at concentrations greater than 5000 mg/L. A study by Corsi et al. (2006) found that in certain Type I formulations, propylene glycol had a greater toxic effect on its own than did the formulation.[2] However, it contributed a much smaller percentage of the toxicity of the formulation to the fathead minnow, the daphnid *Ceriodaphnia dubia*, and Microtox testing for both Type I and Type IV fluids (ranging from less than 1% to 51%).

Propylene glycol is known to exert high levels of biological oxygen demand (BOD) during degradation in surface waters. This process can adversely affect aquatic life by consuming oxygen aquatic organisms need to survive (Corsi et al. 2001). Large quantities of dissolved oxygen (DO) in the water column are consumed when microbial populations decompose ethylene glycol.

Sufficient DO levels in surface waters are critical for the survival of fish, macroinvertebrates, and other aquatic organisms. If oxygen concentrations drop below a minimum level, organisms emigrate, if able and possible, to areas with higher oxygen levels or eventually die (US EPA 1993). This effect can drastically reduce the amount of useable aquatic habitat. Reductions in DO levels can reduce or eliminate bottom-feeder populations, create conditions that favor a change in a community's species profile, or alter critical food-web interactions.

Human Health and Aquatic Resource Use Effects

Unlike ethylene glycol, a cause of acute toxicity in human beings and other mammals, propylene glycol is generally considered to be safe and a rare cause of toxic effects. Human exposure to propylene glycol can occur through dermal contact, inhalation, ingestion, and eye contact

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[2] The paper explains that this may be caused either by uncertainty in calculating the relative toxicity factors, or by the possibility that the interactions of all chemicals in a deicing formulation may result in lower toxicity than propylene glycol alone.

Humans typically come in contact with propylene glycol through ingestion of food and medications and through dermal contact with cosmetics or topical medications. Background concentrations in foods range from < 0.001% in eggs and soups to about 15% in some seasonings and flavorings. No health effects have been reported in persons chronically exposed to propylene glycol at levels found in the environment. Some special-risk groups may be more sensitive at lower levels; these include neonates, infants and the elderly, or those with pre-existing skin or eye conditions or allergies (US HHS 2007b).

Extensive topical application has been known to cause burns to the skin. The common use of propylene glycol in burn creams has been associated with hyperosmolality, lactic acidosis (the build-up of lactic acid in the body), intravascular hemolysis (the rupturing of blood vessels), central nervous system depression, seizures, coma, hypoglycemia (low blood sugar) and renal failure, although only in very high doses (US HHS 2007b). For example, one study found an LD50 in the rat of 30,000 mg/kg (US EPA 2000a). However, it is expected that this level of exposure through human contact with propylene glycol-contaminated aquatic resources would be very unlikely.

Several news articles have reported strong sweet odors downstream from airport deicing outfalls which are believed to be linked to ethylene glycol and propylene glycol discharges (e.g., Hopey 1998). Additionally, anoxic waters, which can result from the high BOD propylene glycol exerts, typically produce a strong, unpleasant odor (State of Ohio Environmental Protection Agency 2001).

2.2.2.10 Sodium

Sodium acetate and sodium formate are used as freezing point depressants in airfield pavement deicers and are applied in large quantities at a number of airports. The dissolution of these chemicals after application releases sodium into the environment in its ionic form. Sodium can elevate measures of salinity, conductance, or total dissolved solids (TDS) in surface waters. It can impact aquatic environments and, at high levels, cause health problems in human beings. This section and *Table A-51* of *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of sodium.

Fate and Transport

Sodium is highly soluble and highly mobile in both surface water and groundwater. In soil, sodium can accumulate in areas where there is insufficient water available to transport it through the soil horizon. Otherwise, it is transported easily through soil and can enter and travel with groundwater.

When sodium replaces calcium in soil through an anion exchange process, the structure of the soil can deteriorate, and aeration and water availability decrease (D'Itri 1992). Poor soil structure due to high sodium levels can also increase the soil mobility of metals (Amrhein and Strong 1990, as cited in D'Itri 1992).

As an elemental ion, sodium is not subject to decay and persists in the environment. It is not expected to volatilize.

Ecological Effects

Most freshwater surface waters contain a small quantity of sodium. High sodium loadings or long turnover times, however, can create surface water ion balance issues that can impact aquatic organism functioning and survival (Public Sector Consultants 1993).

Freshwater aquatic organisms are very sensitive to excess sodium in surface waters. Exposure to high levels of sodium can cause osmoregulatory dysfunction. Freshwater fish tissues typically have higher sodium content than surrounding water. Under normal conditions, freshwater fish use their gills, circulatory system, and kidneys to work against this osmotic gradient in order to prevent the influx of excess water and the loss of sodium from their tissues.

Sodium loss and water influx takes place at the fish gill surface. Specialized cells in fish gill epithelium use potassium and sodium ions to transport chloride into or out of fish tissue (Jobling 1996). In marine fish, chloride ions are pumped from fish against an osmotic gradient. This process helps to maintain optimal osmotic potential between the fish and its environment.

In freshwater fish, the process moves ions in the opposite direction. The fish's circulatory system moves excess water to the kidney where it is rapidly excreted. The gill has mechanisms which actively work to re-import sodium into the blood on order to replace sodium lost through the gills. When external sodium levels exceed internal sodium levels, these mechanisms can contribute to rapid fish dehydration, ionoregulatory system imbalance, and impairment to fish functioning and survival.

Exposure to excessive potassium concentrations can interfere with these essential osmoregulatory mechanisms in both freshwater and saltwater fish, requiring fish to expend more energy to maintain homeostasis or, if concentrations are high enough, cause death through ionic imbalance.

In lakes, increased salt concentrations can also lead to increased density of water layers, leading to or exacerbating stratification during cold or still weather to the point that normal seasonal overturn does not occur (D'Itri 1992).

Both aquatic and terrestrial plants are susceptible to damage following exposure to excess sodium in surface water, soil, porewater, and groundwater. Sodium-induced plant damage occurs in several ways (Moran et al. 1992). First, increasing osmotic pressure of the surrounding water (for aquatic plants) or soil solution increases sodium migration into and water diffusion from the cells, causing dehydration. Second, sodium ion accumulation in plant tissues can reach toxic concentrations. This is often visible in leaf margins, as transpiration pulls water into the leaves. As water evaporates from leaves, sodium ions remain behind and accumulate to toxic levels (University of Illinois Extension 2008). Sodium inhibits many enzymes in plants and is particularly harmful when intracellular potassium is low relative to sodium, as discussed below (Zhu 2007). Third, sodium stress induces the production of abscisic acid, which causes stomata to close and reduces gas exchange and photosynthesis (Zhu 2007).

In addition, the mineral composition of the soil can become unbalanced, making plant nutrient absorption more difficult (Moran et al. 1992). Sodium out-competes potassium for uptake by plant roots, eventually leading to potassium deficiency. Sufficient potassium levels are critical for maintaining adequate cell turgor (fluid pressure), membrane potential, and enzymatic activity (Zhu 2007).

Human Health and Aquatic Resource Use Effects

Sodium is a necessary component of the human diet. While this element is vital in small amounts, excessive consumption may have adverse health effects. Health guidelines advise humans to consume 2,300 mg (1 teaspoon) of sodium per day (US HHS and DoA 2005). At elevated levels, this element is known to cause high blood pressure and possibly calcium loss. Human beings may ingest sodium from airport deicing discharges through consumption of contaminated drinking water sources.

2.2.2.11 Tolyltriazoles, Benzotriazoles, and Methyl-substituted Benzotriazoles

The Society of Automotive Engineers (SAE) requires glycol-based ADFs to contain a fire suppressant because of concerns about ADF flammability in some aircraft electrical systems. The use of tolyltriazoles ($C_7H_7N_3$), benzotriazoles, or methyl-substituted benzotriazoles as flame retardants and corrosion inhibitors in ADFs has been documented in the literature. Tolyltriazole refers to a mixture of the 4-methyl and 5-methyl isomers of benzotriazole. Methyl-substituted benzotriazoles have a methyl group attached to the benzene ring. These chemicals, along with other ADF additives, typically comprise less than 2% of ADF volume. Studies have identified the presence of these chemicals in drainage ditches, groundwater, wells, and soils on or near airports where ADFs have been used. This profile and *Table A-52* in *Appendix A* summarizes data on these chemicals' environmental fate and transport, ecological effects, and human effects.

Fate and Transport

Volatilization of tolyltriazole is not expected (US NLM 2008).

Benzotriazoles are highly polar and dissolve well in water (Weiss et al. 2006). All triazoles are expected to be highly mobile in surface water, groundwater, and soils (US NLM 2008, Breedveld et al. 2003). Methyltriazoles are known to be mobile in groundwater (US NLM 2008). However, triazoles may protonate in some environmental matrices, and the cationic form would be expected to bind to organic material and clays (US NLM 2008). Methylbenzotriazole was found to sorb to digested sludge (Gruden et al. 2001), and thus may be able to bind to organic carbon in soil. Sorption is not expected to be very significant in soils, however. Breedveld et al. (2003) found that benzotriazole showed very little sorption in various soil matrices, and only peat and compost with a high organic carbon content showed significant sorption.

Photolysis is a potential route of degradation in environmental media with high exposure to light (US NLM 2008).

Biodegradation of these compounds varies by isomer. 5-methylbenzotriazole is much more aerobically degradable than the 4-methylbenzotriazole isomer (Weiss and Reemtsma 2005). The same pattern was observed in bench-scale bioreactor experiments in which 5-methyltriazole was completely biodegraded within 17 days, but 4-methyltriazole was only 25% biodegraded after 28 days, and the remainder was recalcitrant to further degradation (Weiss et al. 2006). Furthermore, 5-methylbenzotriazole was found to be "unstable" in cooling towers (an aerobic environment), whereas 4-methylbenzotriazole was not degraded (Gruden et al. 2001).

Another study found that methylbenzotriazole (isomer not specified) was not anaerobically digestible in lab experiments (Gruden et al. 2001). Anaerobic degradation was not observed for benzotriazole and its derivatives in lab reactor experiments (Tham and Kennedy 2005). Davis et al. (2000) have demonstrated that higher plants and white rot fungi can take up and degrade triazoles. No information was located on the degradation products of benzotriazoles.

Weiss and Reemtsma (2005) found that both benzotriazole and 4-methylbenzotriazole survived bank filtration treatment although 5-methylbenzotriazole did not. Ozonation appears to be capable of almost completely removing benzotriazole and 4- and 5-methylbenzotriazole from wastewater and might also be able to remove them during drinking water treatment, where this technology is used (Weiss et al. 2006).

One study found that up to 300 mg/l of benzotriazole only slightly inhibited the anaerobic degradation of glycols, that up to 20 mg/l of 5,6-dimethylbenzotriazole did not inhibit their anaerobic degradation, and that 300 mg/l of 5-methylbenzotriazole was capable of severely inhibiting their anaerobic degradation (Johnson et al. 2001).

Benzotriazole and methylbenzotriazole have been detected in groundwater near an airport at levels greater than 100 mg/l. This concentration is high enough to be potentially toxic to microbiota, fish, and invertebrates (Cancilla et al. 1998). At two airports, 4-methyltriazole was detected in all wells sampled, but 5-methyltriazole was not detected in any of the wells (Cancilla et al. 2003 and Cancilla et al. 1998). Breedveld et al. (1997) reported soil concentrations of up to 13 mg/kg in a drainage ditch and up to 1.1 mg/l in groundwater at Oslo Airport one to two years after deicing was discontinued.

Ecological Effects

Triazoles are a major contributor to ADF toxicity and may be responsible for the majority of total toxicity in some formulations (Corsi et al. 2006). Triazoles are several orders of magnitude more acutely toxic than glycols to multiple aquatic species, including the bluegill (*Lepomis macrochirus*) and the water flea (*Daphnia magna)*. The LC_{50} for the waterflea for tolyltriazole is 74 mg/L. Tolyltriazole is considered to be more toxic than other benzotriazoles. Though not likely to bioaccumulate, triazoles may persist in the aquatic environment due to their resistance to natural degradation (British Environment Agency 2000).

Human Health and Aquatic Resource Use Effects

EPA’s search of publicly available literature yielded no consistent or conclusive information on the impact of triazoles on human health or the aesthetic attributes of receiving waters.

2.2.2.12 Urea (Ammonia)

Urea (NH_2CONH_2) is used as a freezing point depressant in airfield pavement deicers and is applied in large quantities at a number of airports. It is typically used as a solid pavement deicer or in combination with ethylene or propylene glycol as a liquid pavement deicer. Urea is also a common fertilizer that enhances plant growth. Urea forms ammonia (NH_3) during decay. Ammonia is toxic to aquatic organisms at low concentrations and can cause both organism mortality and reproduction impairment. Ammonia can further decay in aquatic environments into several nitrogen-containing compounds (e.g., nitrate) that can fertilize aquatic plants and foster biological overgrowths. Ammonia may cause minor to severe dermal or pulmonary irritation to human beings who come into contact with it. Urea and ammonia have been documented as contaminants in surface waters, groundwater, and soil in and near airports using urea as a pavement deicer. This section and *Table A-53* of *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of formate.

Fate and Transport

Urea has a low vapor pressure and is not expected to volatilize readily from soil or water (US NLM 2008). Ammonia, a by-product of urea degradation. is quite volatile.

Urea has a solubility of 545 g/l, making it reasonably soluble (US NLM 2008). Urea is transported readily in surface water and its presence has been documented in groundwater at several airports using urea as a pavement deicer. This is despite the fact that urea’s soil infiltration is thought to be minimal except where the soil is sandy (D’Itri 1992). Transport Canada (1990) (as cited in D’Itri 1992) reported that between 64 and 100% of applied urea can reach surface waters via overland flow. Urea can also accumulate in snowbanks and be released as a large load in a short amount of time during snowmelt (D’Itri 1992).

Urea biodegrades well under aerobic conditions and produces ammonia which eventually degrades to nitrate. The degradation rate is temperature dependent and is expected to be slow during winter. After 14 days in river water at 8° C, degradation was almost nil (Evans and Patterson 1973 as cited in D’Itri 1992). At 20 degrees Celsius, urea fully degraded to ammonia within 4 to 6 days (Cryotech 2008).

Urea contains 46% nitrogen by weight, making it a potential contributor to undesirable eutrophication of surface waters (D’Itri 1992). Urea’s BOD is approximately 1.8 g O_2/g urea (Cryotech 2008) and is much higher than that of acetate and formate-based pavement deicers, as well as higher than that of ethylene glycol or propylene glycol-based pavement deicers and ADFs.

Ammonia levels in runoff from airports have been commonly reported at levels between 2 and 15 mg/L and can be higher (D'Itri 1992). These levels are potentially toxic to fish and other aquatic organisms.

Ecological Effects

Urea is not particularly toxic to aquatic life. However, urea degrades to ammonia which is highly toxic to many aquatic organisms. EPA established a National Recommended Water Quality Criterion for ammonia in 1984 and last revised it in 1998. Because of ammonia's unique properties, the criteria are dependent on pH, temperature, and organism life stage. Ammonia is most toxic in its un-ionized form which is more likely to exist at higher temperatures and pH levels. If salmonids are present, acute criteria range from 0.885 to 32.6 mg N/l, depending upon pH. If salmonids are not present, acute criteria range from 1.32 to 48.8 mg N/l. Chronic criteria, which do not vary according to salmonid presence or absence, range from 0.254 to 3.48 mg N/l, depending upon pH (US EPA 1998a).

Ammonia is capable of causing acute mortality in many aquatic organisms, particularly at higher concentrations. Ammonia can also cause a host of chronic effects in aquatic organisms, including reproduction inhibition, diminished juvenile growth, and reduced embryo and neonate survival. Salmonid fish are particularly sensitive, and EPA's ammonia standard is stricter for water bodies in which they are present. For example, one study determined an LC_{50} for the rainbow trout (*Oncorhynchus mykiss*) of 0.068 mg/L (US EPA 1998a). Ammonia has been noted as a major cause of fish kills (US EPA 1991; USDA 1992). In addition, if surface water substrate sediments are enriched with nutrients, the concentrations of nitrites on the overlying water can be raised enough to cause nitrite poisoning or "brown blood disease" in fish (USDA 1992).

Ammonia further decays in aquatic environments to nitrates. Nitrates function as a source of nitrogen nutrients. Surface water eutrophication due to excessive nutrient levels can produce ecological impacts such as nuisance algal blooms, death of underwater plants (due to reduced light penetration through turbid waters), reduced dissolved oxygen levels, and impaired aquatic organism populations.

Human Health and Aquatic Resource Use Effects

A person ingests an average of 0.36 mg/day of ammonia through drinking water sources (US HHS 2004). Ammonia begins to be noticeable to drinking water consumers at 35 ppm (taste) to 50 ppm (odor). Low levels of exposure may not cause any problems in healthy individuals but may harm sensitive individuals such as those with asthma. At higher concentrations, ammonia exposure may also cause skin burns to the exposed area. Children respond to ammonia exposure in much the same way as adults. No evidence has been found to suggest that low-level chronic ammonia exposure causes birth defects or other developmental problems. However, chronic exposure has been found to cause transient respiratory distress (US HHS 2004).

Data for assessing the carcinogenic potential of ammonia are limited. At consumption levels of 200 milligrams per day, ammonia may act as a cancer promoter. However, well-designed animal studies have not yet been conducted in order to better elucidate ammonia's role as a potential carcinogen (US HHS 2004).

At high exposure levels, effects include irritation to the eyes, nose, and throat; dyspnea (breathing abnormalities), wheezing, and chest pain; pulmonary edema; pink frothy sputum; skin burns, and vesiculation (formation of blisters or vesicles) (NIOSH 2005c). Human exposure to such high levels through aquatic resources contaminated by airport deicing discharges is not expected.

3 Environmental Impact Potential under Current Airport Deicing Practices

This chapter summarizes the potential environmental impacts of airport deicing operation discharges under current conditions and industry practices. *Chapter 4* presents information on environmental improvements and benefits expected under each of EPA's final regulatory options.

This chapter provides information on facilities within scope of the final rule *(Section 3.1),* discusses factors that influence airport deicing pollutant discharges to the environment and provides an overview of current airport deicing pollutant discharges *(Section 3.2),* discusses factors influencing pollutant concentrations in surface waters *(Section 3.3),* summarizes documented environmental impacts from airport deicing activities *(Section 3.4),* and discusses potential impacts to impaired waters and other resources *(Section 3.5).*

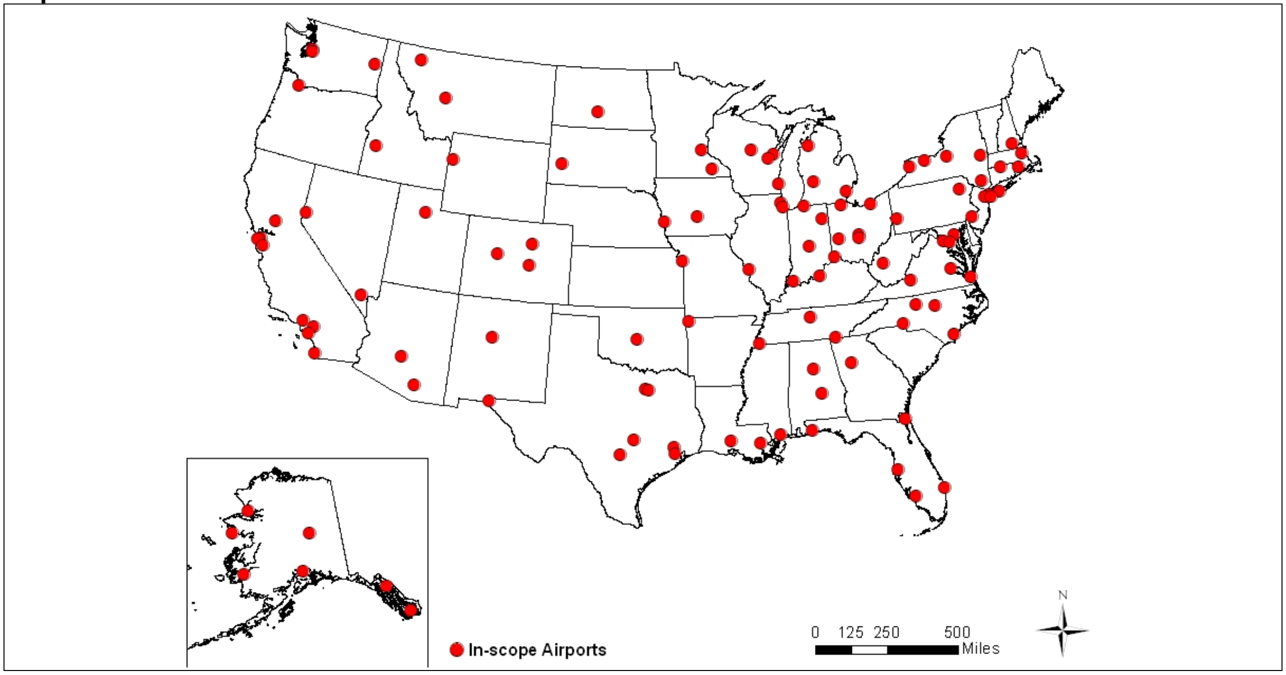
3.1 Universe of In-scope Airports

In determining the scope of the final regulatory options, EPA aimed to capture those airports that perform the majority of deicing operations in the United States. EPA's final regulatory options address airports with the following characteristics:

- Classified by FAA as primary commercial airports;
- Not categorized by FAA as general aviation or cargo airports;
- Greater than or equal to 1,000 non-propeller-driven aircraft departures annually; and
- Conduct aircraft or airfield pavement deicing operations.

EPA focused on primary commercial airports with greater than or equal to 1,000 annual non-propeller-driven aircraft departures because these airports are more likely to operate during inclement winter weather and conduct the majority of airport deicing operations. Although deicing takes place at some general aviation and cargo airports and primary commercial airports with fewer than 1,000 annual non-propeller-driven aircraft departures (see *Table 3-1*), EPA focused on an airport category that conducts the majority of airport deicing activity. *Table B-1* in *Appendix B* lists the airports within scope of the final regulatory options. *Figure 3-1* presents a map of the in-scope airports listed in *Appendix B*.

Figure 3-1: In-scope Airports for EPA's Effluent Guideline Regulations for Airport Deicing Operations



As shown in *Figure 3-1*, airports engaging in deicing activities are widely distributed throughout the U.S. These airports vary greatly, however, in the levels at which they conduct aircraft and pavement deicing and in their discharge environments. These variables are discussed in *Section 3.2.*

3.2 Airport Deicing Pollutant Discharges to the Environment

Airport deicing pollutant discharges to the environment vary widely among individual airports. Pollutant discharges can also vary widely from day to day at any individual airport. This variability is driven by individual airport deicing practices and environmental contexts and the weather-dependent nature of deicing activities and discharges. This section discusses a number of factors that influence airport deicing pollutant loads and also describes EPA's quantified estimates of national and individual airport deicing pollutant discharges.

3.2.1 Factors Influencing Airport Deicing Pollutant Discharge to the Environment

Several factors influence the nature and quantity of pollutant loadings to the environment at individual airports:

- Deicing product selection;
- Air traffic composition and levels;
- Airport treatment and collection practices;
- Airfield design; and
- Weather conditions.

3.2.1.1 Deicing Product Selection

Deicing product choice is the first determinant of deicing pollutant loadings at an individual airport. A variety of ADF and pavement deicer formulations are available for purchase and use by airports and airlines. These formulations contain one or two of several freezing point depressants, which constitute most of the formulation, as well as a variety of chemical additives. The formulations chosen by an airport or airlines affect the chemicals that will discharge to the environment. For example, an airport that chooses a potassium acetate-based pavement deicer will discharge potassium, undegraded acetate, COD/BOD, and unidentified additives to the environment; whereas an airport that chooses a urea-based pavement deicer will discharge undegraded urea, ammonia, nitrates, and higher levels of BOD/COD to the environment. For additional information on the types and quantities of different chemicals found in ADF and airfield pavement deicer formulations, see *Chapter 2*.

Multiple factors drive deicing product choice including airport climate, product performance, cost, availability, and compatibility with aircraft and airport infrastructure. Weather conditions also strongly influence the need for use of different types of airport deicing products. For example, during winter freezing precipitation events, the use of Type I ADF for aircraft deicing, Type IV ADF for aircraft anti-icing and pavement deicers may all be necessary to maintain aircraft operations. Environmental release of chemicals from all three product types would therefore be expected under these conditions. During calm winter conditions, use of only Type I ADF to remove light layers of frost from aircraft may be necessary, and under these conditions releases of chemicals associated with Type IV ADF and pavement deicers would not be expected.

3.2.1.2 Air Traffic Composition and Levels

Airports vary widely in the types of aircraft using their facilities and in total number of aircraft departures during the winter deicing season. EPA has focused the scope of the rule on those airports that have higher levels of non-propeller-driven aircraft departures (1,000 or more annually). Non-propeller-driven aircraft are more likely than other types of aircraft (e.g., propeller-driven aircraft) to continue operating during inclement winter weather. Airports with larger numbers of non-propeller-driven aircraft departures are more likely to use ADF and pavement deicers to maintain operations and therefore are more likely to discharge deicing pollutants.

The type of non-propeller-driven aircraft also makes a difference in the quantity of ADF released to the environment since larger non-propeller-driven aircraft require larger quantities of ADF than smaller non-propeller-driven aircraft for both deicing and anti-icing.

In addition, all other factors being equal, airports with larger numbers of non-propeller-driven aircraft and other aircraft departures will use larger quantities of deicing products.

3.2.1.3 Airport Deicing Pollutant Treatment and Collection Practices

Airports vary widely in the nature of their deicing pollutant collection and treatment practices. All airports discharge some or all of their deicing pollutants to surface waters near airports. Some airports collect a portion of their deicing wastewaters and either treat them on-site or send them off-site to a publically owned treatment works (POTW) or other facility for treatment and discharge. Other airports discharge stormwater containing deicing pollutants to soil and groundwater. Many airports have a combination of these discharge conditions. EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010) provides additional information on the collection and treatment systems found at individual airports.

ADF and pavement deicer chemicals disperse widely during use. Type I and Type IV ADF drip and shear from aircraft during application, taxiing, and take-off. Airports apply pavement deicers to large expanses of airfield pavement found at many airports, including aprons, gate areas, taxiways, and runways. Due to this widespread product dispersion, large quantities of airport stormwater frequently contain some level of deicing pollutants. The large quantities and dispersed nature of contaminated stormwater make it difficult for airports to collect and treat more than a fraction of released deicing product. For this reason, most airports discharge the majority of their deicing pollutants to the environment.

Deicing collection and treatment systems vary in design and effectiveness by airport. EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010) describes collection and treatment technologies and their effectiveness in reducing deicing pollutant discharges in detail. For today's final rule, EPA assessed two ADF stormwater collection technologies and one stormwater treatment technology for the purpose of constructing regulatory options for exsiting airports. The assessed collection technologies include glycol collection vehicles (GCVs) and GCVs used in combination with "plug and pump" systems. The assessed treatment technology is anaerobic fluid bed (AFB) biological treatment. EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010) also discusses other approaches airports use to reduce discharge of deicing pollutants to surface waters.

3.2.1.4 Airfield Design

The configuration of airport grounds and infrastructure relative to surface waters, pervious surfaces, and groundwater also affect deicing pollutant dispersion in the environment. Influential airport design elements include:

- Stormwater infrastructure collection and delivery efficiency;
- Runway and taxiway proximity to surface waters;
- Airfield imperviousness;
- Airfield slope; and
- Amount of vegetation buffer between impervious areas and surface waters.

Stormwater collection and delivery systems at airports vary in their design delivery efficiency and condition. Some systems deliver large fractions of airport stormwater to a chosen destination quickly and without substantial volume loss during delivery. Other systems are designed or are in a condition such that substantial volumes of stormwater are lost prior to ultimate discharge. Pervious or partially pervious system elements such as unlined ditches and ponds and leaking stormwater pipes and storage units allow stormwater loss. Deicing pollutants in stormwater lost from collection and delivery systems typically enter the soil column where they degrade, accumulate, or eventually enter groundwater if present on airport grounds. Groundwater and the pollutants it contains may ultimately discharge to nearby surface waters or flow beyond airport property lines. In these situations, infiltration may slow and reduce pollutant discharges to surface waters, but not eliminate them. In other cases, pollutants in groundwater may degrade before they discharge to surface waters or cross airport property lines.

Deicing pollutants can also degrade during stormwater transport and storage. Degradation rates are slower under cold temperatures and increase as temperatures rise. Systems that discharge stormwater more slowly, particularly those that hold stormwater until later in the year when average temperatures rise, allow greater opportunity for degradation of deicing pollutants prior to discharge. The degradation process can remove some chemicals of concern in deicing discharges. In some cases, however, degradation can create new pollutants of concern or a volume of stormwater with very low dissolved oxygen levels, both of which can be of concern if discharged to surface waters in sufficient quantities. For additional information on airport deicing product degradation products, see *Chapter 2*.

In general, the closer airport runways and taxiways are to surface waters, the greater the potential for deicing pollutants to enter those waters through stormwater flow, groundwater flow, or aerial deposition. Shorter distances reduce pollutant loss from stormwater transport systems, degradation, and soil retention. Shorter distances also make it more likely that ADF released to the air during taxiing and takeoff can be carried by the wind to surface waters. Some airport takeoff flight paths extend directly over surface waters and ADF shed during takeoff can fall directly into those surface waters. Conversely, greater distances increase opportunities for pollutant loss, retention, and degradation.,

As the imperviousness and slope of the airport grounds increase, the amount of stormwater runoff available to mobilize and carry deicing pollutants to surface waters tends to increase. Pervious areas on airfields can include areas of vegetation or bare soil as well as paved areas with cracked surfaces. Vegetation buffers between impervious areas where ADF and pavement deicers are initially released and surface waters can decrease the amount of stormwater and pollutants entering surface waters by providing an opportunity for stormwater infiltration and pollutant accumulation or degradation in the soil column.

Pollutants associated with Type IV fluids and pavement deicers, in particular, are affected by overall airfield design because of their widespread dispersion in the airfield. A smaller proportion of Type I fluids are affected by overall airfield design because most are released to the environment close to ADF application sites. Type I ADF dispersion is therefore most influenced by the design of the particular portions of the airfield that contain and drain stormwater from ADF application sites.

3.2.1.5 Weather Conditions

Because the use of ADF and airfield pavement deicers is so weather-dependent, deicing pollutant discharges among individual airports vary widely with differences in climate and typical winter weather conditions. Deicing pollutant discharges can also vary widely from year-to-year and day-to-day at individual airports as winter weather conditions vary at airports on seasonal and daily bases. In addition to influencing choice of deicing product for application, as discussed above, weather conditions also influence the quantity of product applied and its dispersion in the environment.

Important factors influencing the quantity and dispersion of airport deicing products include:

- Precipitation type (e.g., freezing rain, sleet, snow, rain or a mixture);
- Ground and air temperatures;
- Precipitation event magnitude; and
- Precipitation event timing.

Winter precipitation types range from rain to freezing rain, sleet, and snow. Some individual precipitation events contain two or more of these precipitation types. Precipitation type affects both the quantity of deicing product used as well as its dispersion. For example, freezing rain tends to coat aircraft with ice. Ice coatings tend to require greater quantities of Type I ADF to remove than loose, dry snow or light frost.

Precipitation type and ground and air temperatures also affect pollutant dispersion. Precipitation that is liquid, such as rain, or that melts, such as snow on a warm ground surface, mobilizes deicing pollutants and moves them through stormwater transport systems to discharge more quickly than solid precipitation that accumulates on airfield surfaces. After a snow event, a significant quantity of ADF and pavement deicers can be trapped in plowed snowbanks or snow storage units and will not enter stormwater transport systems or surface waters, soil, or groundwater until ground and air temperatures are high enough to allow the snow to melt. Rates and timing of snowmelt can vary widely among airports (e.g., Fairbanks International in Alaska versus Dallas-Fort Worth International in Texas) and among winter seasons or snow events at individual airports.

Ground and air temperatures are also important in their influence on rates of pollutant degradation since higher temperatures allow higher degradation rates.

Strong winds associated with some weather events can increase aerial deposition of ADF on the airfield and adjacent surface waters.

Another factor that influences deicing pollutant discharge is precipitation event magnitude. In general, as precipitation quantity increases, use of greater quantities of ADF and pavement deicer is required. In addition, larger precipitation events tend to produce more stormwater. Larger quantities of stormwater tend to mobilize and discharge deicing pollutants more quickly than smaller quantities of stormwater. The timing of stormwater availability from a specific event will, however, be dependent on the type of precipitation and its melting rate, as discussed above. Because larger stormwater quantities move deicing pollutants more quickly, they may reduce the quantity of pollutants that infiltrate soil and other pervious airport surfaces.

Another important factor is the timing of precipitation events. Precipitation events that take place during periods of high air traffic levels (e.g., holidays, morning rush times) require deicing operations for a greater number of aircraft and the use of greater quantities of deicing materials (see *Aircraft Traffic Composition and Levels* above).

3.2.2 Quantified Airport Deicing Pollutant Discharge Estimates

EPA estimated seasonal pollutant discharges from airport deicing operations based on current airport practices and conditions. EPA had sufficient information to quantify a portion of the total discharge of chemical oxygen demand (COD) and ammonia from airport deicing operations. A more detailed description of EPA's estimation methodology and results is available in the *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010).

Table 3-1 presents facility-specific ADF application site and pavement deicer COD discharges for each airport within scope of the final rule.. EPA did not have sufficient information to estimate facility-specific discharges from individual airports EPA did not survey. As discussed above, COD discharge levels in *Table 3-1* do not reflect COD discharges associated with Type I and Type IV ADF dispersed beyond ADF application sites.

Table 3-1: Partial Chemical Oxygen Demand Discharges from Pavement Deicers and ADF Application Sites at Surveyed Airports within Scope of the Final Rule

Airport Name	Pavement Deicer COD Discharge (pounds/year)	ADF Application Site COD Discharge (pounds/year)	Airport Service Level
Albany Intl	213,511	103,086	Small Hub
Albuquerque Intl Sunport	2,617	491,959	Medium Hub
Aspen-Pitkin Co/Sardy Field	36,366	85,963	Non-Hub
Austin Straubel International	117,358	355,646	Small Hub
Austin-Bergstrom Intl	9,976	137,629	Medium Hub
Baltimore-Washington Intl	866,733	1,289,506	Large Hub
Bethel	143,501	47,733	Non-Hub
Birmingham Intl	0	47,717	Small Hub
Bismarck Municipal	9,195	200,305	Non-Hub
Bob Hope	0	0	Medium Hub
Boeing Field/King County Intl	5,851	29,510	Non-Hub
Boise Air Terminal/Gowen Fld	631,466	272,543	Small Hub
Bradley Intl	440,956	1,669,398	Medium Hub
Buffalo Niagara Intl	913	1,718,928	Medium Hub
Central Wisconsin	299,374	416,170	Non-Hub
Charlotte/Douglas Intl	381,832	1,308,047	Large Hub
Cherry Capital	36,467	0	Non-Hub
Chicago Midway Intl	797,303	0	Large Hub
Chicago O'Hare Intl	8,248,121	8,204,552	Large Hub
Cincinnati/Northern Kentucky International	1,740,966	772,137	Large Hub
City of Colorado Springs Municipal	128,158	433,971	Small Hub
Cleveland-Hopkins Intl	1,532,252	3,480,467	Medium Hub
Dallas Love Field	125	213,039	Medium Hub
Dallas/Fort Worth International	10,373	557,682	Large Hub
Denver Intl	2,012,384	729,709	Large Hub
Des Moines Intl	289,289	460,483	Small Hub
Detroit Metropolitan Wayne County	1,056,284	0	Large Hub
El Paso Intl	0	0	Small Hub
Eppley Airfield	171,538	1,058,801	Medium Hub
Evansville Regional	16,585	192,217	Non-Hub
Fairbanks Intl	819,984	299,205	Small Hub
Fort Wayne International	761,916	511,705	Non-Hub
General Edward Lawrence Logan Intl	1,589,955	9,147,072	Large Hub
General Mitchell International	742,538	898,664	Medium Hub
George Bush Intercontinental Arpt/Houston	0	56,571	Large Hub
Gerald R. Ford International	38,863	563,544	Small Hub
Glacier Park Intl	710	367,815	Non-Hub

Table 3-1: Partial Chemical Oxygen Demand Discharges from Pavement Deicers and ADF Application Sites at Surveyed Airports within Scope of the Final Rule

Airport Name	Pavement Deicer COD Discharge (pounds/year)	ADF Application Site COD Discharge (pounds/year)	Airport Service Level
Greater Rochester International	168,122	1,152,208	Small Hub
Gulfport-Biloxi Intl	0	0	Small Hub
Hartsfield - Jackson Atlanta Intl	179,433	1,382,287	Large Hub
Helena Regional	0	0	Non-Hub
Indianapolis Intl	768,086	2,728,125	Medium Hub
Jackson Hole	0	0	Non-Hub
Jacksonville Intl	0	0	Medium Hub
James M Cox Dayton Intl	99,807	357,499	Small Hub
John F Kennedy Intl	2,837,634	5,155,239	Large Hub
John Wayne Airport-Orange County	0	0	Medium Hub
Juneau Intl	1,018,715	430,969	Small Hub
Kansas City Intl	344,044	1,200,632	Medium Hub
Ketchikan Intl	a	a	Non-Hub
La Guardia	1,383,792	4,216,728	Large Hub
Lafayette Regional	0	14,201	Non-Hub
Lambert-St Louis Intl	2,921,256	1,154,584	Large Hub
Long Island Mac Arthur	0	166,102	Small Hub
Louis Armstrong New Orleans Intl	0	0	Medium Hub
Louisville Intl-Standiford Field	447,728	490,009	Medium Hub
Lovell Field	0	39,586	Non-Hub
Manchester	306,0048	1,715,962	Medium Hub
Mc Carran Intl	0	60,923	Large Hub
Memphis Intl	334,157	1,946,410	Medium Hub
Metropolitan Oakland Intl	0	0	Large Hub
Minneapolis-St Paul Intl/Wold-Chamberlain	782,829	5,968,923	Large Hub
Montgomery Rgnl (Dannelly Field)	0	2,214	Non-Hub
Nashville Intl	93,454	349,329	Medium Hub
Newark Liberty Intl	1,520,336	10,762,687	Large Hub
Nome	22,429	28,231	Non-Hub
Norfolk Intl	*	235,637	Medium Hub
Norman Y. Mineta San Jose International	0	0	Medium Hub
Northwest Arkansas Regional	352,337	293,595	Small Hub
Ontario Intl	0	334	Medium Hub
Outagamie County Regional	130,836	551,842	Non-Hub
Palm Beach Intl	0	0	Medium Hub
Pensacola Regional	0	0	Small Hub
Philadelphia Intl	1,362,130	1,436,522	Large Hub
Phoenix Sky Harbor Intl	0	0	Large Hub
Piedmont Triad International	228,269	655,787	Small Hub
Pittsburgh International	703,466	3,689,998	Large Hub
Port Columbus Intl	356,775	2,927,149	Medium Hub
Portland Intl	178,213	855,437	Medium Hub

Table 3-1: Partial Chemical Oxygen Demand Discharges from Pavement Deicers and ADF Application Sites at Surveyed Airports within Scope of the Final Rule

Airport Name	Pavement Deicer COD Discharge (pounds/year)	ADF Application Site COD Discharge (pounds/year)	Airport Service Level
Raleigh-Durham Intl	134,976	977,382	Medium Hub
Ralph Wien Memorial	43,492	23,743	Non-Hub
Rapid City Regional	10,907	242,540	Non-Hub
Reno/Tahoe International	48,138	569,580	Medium Hub
Richmond Intl	174,098	339,643	Small Hub
Rickenbacker International	45,481	102,180	Non-Hub
Roanoke Regional/Woodrum Field	62,222	314,124	Non-Hub
Rochester International	*	197,799	Non-Hub
Ronald Reagan Washington National	371,666	1,229,789	Large Hub
Sacramento International	0	0	Medium Hub
Salt Lake City Intl	2,488,385	1,687,338	Large Hub
San Antonio Intl	*	121,626	Medium Hub
San Diego Intl	0	0	Large Hub
San Francisco International	0	0	Large Hub
Seattle-Tacoma Intl	56,346	1,502,208	Large Hub
South Bend Regional	69,136	0	Small Hub
Southwest Florida Intl	0	0	Medium Hub
Spokane Intl	1,063,075	0	Small Hub
Stewart Intl	370,095	184,745	Non-Hub
Syracuse Hancock Intl	6,729	791,854	Small Hub
Tampa Intl	0	0	Large Hub
Ted Stevens Anchorage Intl	6,082,395	2,265,902	Medium Hub
Theodore Francis Green State	91,602	572,884	Medium Hub
Toledo Express	137,067	359,704	Non-Hub
Tucson Intl	0	17,873	Medium Hub
Washington Dulles International	1,810,018	5,686,802	Large Hub
Wilkes-Barre/Scranton Intl	*	405,801	Non-Hub
Will Rogers World	30,291	472,260	Small Hub
William P Hobby	0	0	Medium Hub
Wilmington Intl	0	20,756	Non-Hub
Yeager	79,800	283,685	Non-Hub

Chemical oxygen demand (COD) loads were calculated from data provided in response to the EPA Airport Deicing Questionnaire (2006c) and the EPA Airline Deicing Questionnaire (2006b).
* – The airport reported that the quantity of pavement deicer usage was unknown (US EPA 2006c).
a) Ketchikan was sent an airport questionnaire but did not respond.

EPA also estimated facility-specfic annual ammonia discharges from urea pavement deicer use for airports within scope of the final rule (*Table 3-2*). EPA does not have sufficient information to estimate facility-specific ammonia discharge levels at individual airports EPA did not survey.

Table 3-2: Ammonia Discharge from Deicing Operations at Surveyed Airports within Scope of the Final Rule

Airport Name	Pavement Deicer Ammonia Discharge (pounds/year)
Austin Straubel Intl	25,387
Bethel	38,105
Boise Air Terminal/Gowen Field	152,740
Bradley Intl	9,478
Central Wisconsin	69,856
Charlotte/Douglas Intl	84,821
Fairbanks Intl	187,883
Fort Wayne Intl	161,593
General Edward Lawrence Logan Intl	5,782
Glacier Park Intl	189
Juneau Intl	270,506
Manchester	20,844
Northwest Arkansas Regional	10,186
Piedmont Triad Intl	52,441
Raleigh - Durham Intl	35,841
Ralph Wien Memorial	5,659
Reno/Tahoe Intl	6,330
Ronald Reagan Washington National	44,141
Salt Lake City Intl	634,519
South Bend Regional	18,358
Spokane Intl	281,824
Stewart Intl	85,905
Ted Stevens Anchorage Intl	1,423,212
Yeager	15,572

EPA was able to create national estimates of COD and ammonia discharges from ADF application sites and pavement deicers. EPA estimated national COD loads from ADF application sites using discharge estimates for airports EPA surveyed in conjunction with airport weighting factors developed as part of the EPA Airport Deicing Questionnaire sample frame. EPA estimated COD and ammonia loads from pavement deicer use using reported usage levels for airports EPA surveyed in conjunction with airport weighting factors. A more detailed description of EPA's COD estimation methodology is available in the *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2011). *Table 3-3* presents the estimate of current national COD loads from ADF application sites and pavement deicers by airport hub size category. COD discharges associated with ADF dispersed in areas beyond ADF application sites are not reflected by the figures in *Table 3-3.*

Table 3-3: Estimate of National Baseline COD Discharges from ADF Application Sites and Airfield Pavement Deicing by Airport Hub Size Category

Airport Hub Size	ADF Application Site COD Discharge (pounds/year)	Pavement Deicer COD Discharge (pounds/year)
Large	65,999,304	33,121,243
Medium	26,678,898	12,086,529
Small	9,255,083	7,161,186
Nonhub	16,408,625	6,641,781
General Aviation/Cargo	2,268,284	1,309,591
Total	**120,610,194**	**60,320,330**

EPA also calculated current, baseline national ammonia discharges associated with airport use of urea as a pavement deicer. These discharges are presented by airport hub size category in *Table 3-4*.

Table 3-4: Estimate of National Baseline Ammonia Discharges from Airfield Payment Deicing by Airport Hub Size Category

Airport Hub Size	Ammonia Discharge (pounds/year)
Large	769,263
Medium	1,495,705
Small	1,286,277
Nonhub	852,775
General Aviation/Cargo	NA
Total	**4,404,020**

Other pollutants in addition to COD and ammonia discharge from airport deicing operations. EPA has not quantified discharge levels of these other pollutants. *Chapter 1* discusses current levels of airport deicing product usage in the U.S. *Chapter 2* discusses the range of pollutants potentially present in ADF and pavement deicer products.

3.3 Factors Influencing Airport Deicing Pollutant Concentrations in Receiving Surface Waters

Pollutant concentrations in the environment, as well as total discharges, are of interest because of their influence on the manner in which some pollutants impact the environment. As discussed in *Chapter 2*, a number of pollutants have threshold levels above which impacts have been documented.

A number of factors influence airport deicing pollutant concentrations in surface waters. An important factor is the total quantity of pollutants discharging to surface waters. Factors influencing total pollutant discharges from airports are discussed in *Section 3.2*.

ADFs and pavement deicers, as applied, contain certain concentrations of chemicals (see *Chapter 2*). Before they enter surface waters, however, ADF and pavement deicers typically undergo dilution with precipitation and, in some cases, a certain amount of degradation. Pollutant concentrations in deicing-contaminated stormwater are typically lower, therefore, than the concentrations found in airport deicing products as-applied.

When deicing pollutants enter surface waters, they are typically diluted further. Receiving water volume, waterbody flow rate, and waterbody mixing dynamics influence dilution levels. Surface water characteristics such as vegetation, stream slope, presence of ice and snow cover, stream channel obstacles, and tidal influences can significantly affect flow rate and mixing. High vegetation levels and low stream channel slopes tend to retard flow. Channel depressions can slow low flows and significantly increase residence times of deicing pollutants in receiving streams. Snow pack and ice in streams can also alter flow either by altering stream channel characteristics. Snow pack and ice can create depressions in a channel that can reduce stream flow. They can also increase flow by filling in existing stream channel depressions and reducing resistance to flow. Stream channel obstacles such as woody debris, rocks, and falls can increase turbulence and mix pollutants with greater volumes of water. Tidal currents can also increase mixing and dilution.

Many of the surface waters that directly receive airport deicing pollutants are small, low-flow, and relatively low-slope streams. *Figure 3-2* summarizes available flow rate data for surface waters directly receiving deicing discharges from airports EPA surveyed. According to available data, 62% of initial receiving waters have a flow rate of 20 cubic feet per second (cfs) or less.

Figure 3-2: Initial Receiving Water Discharge Flows at EPA Surveyed Airports

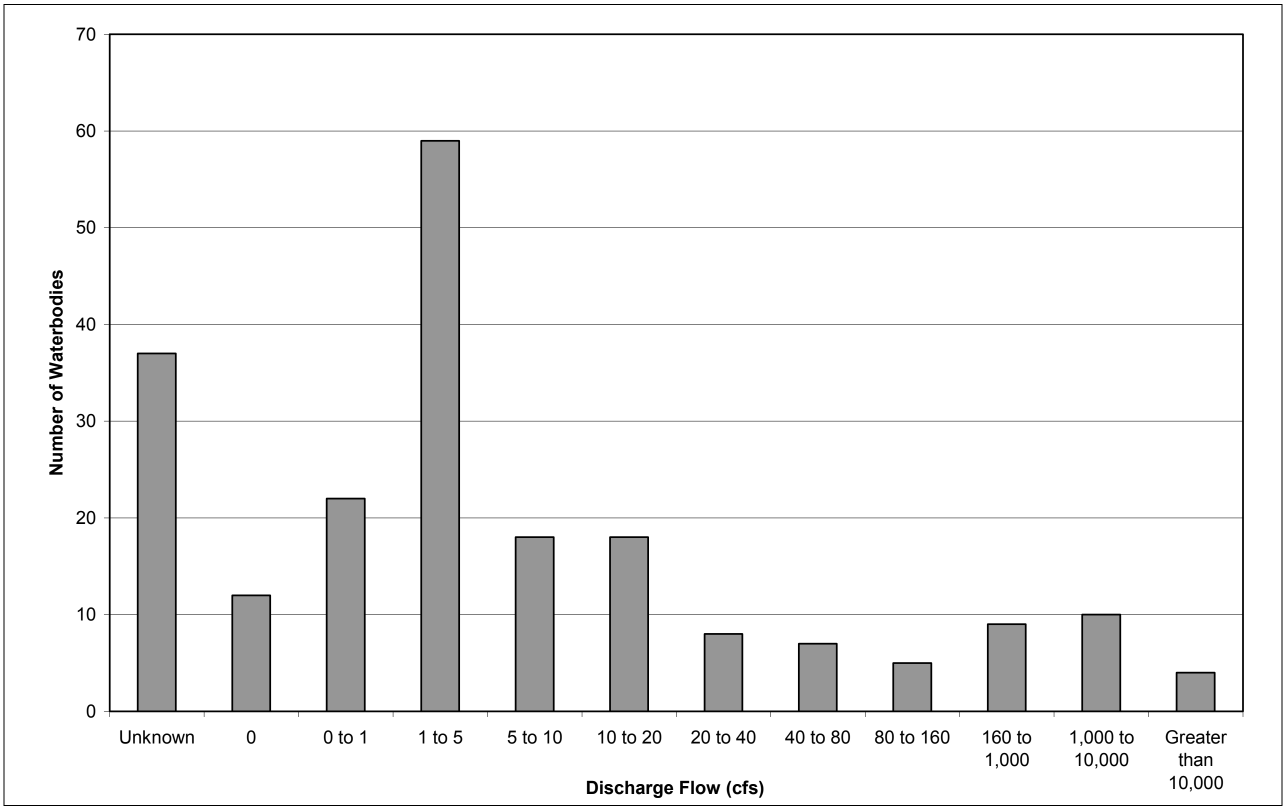
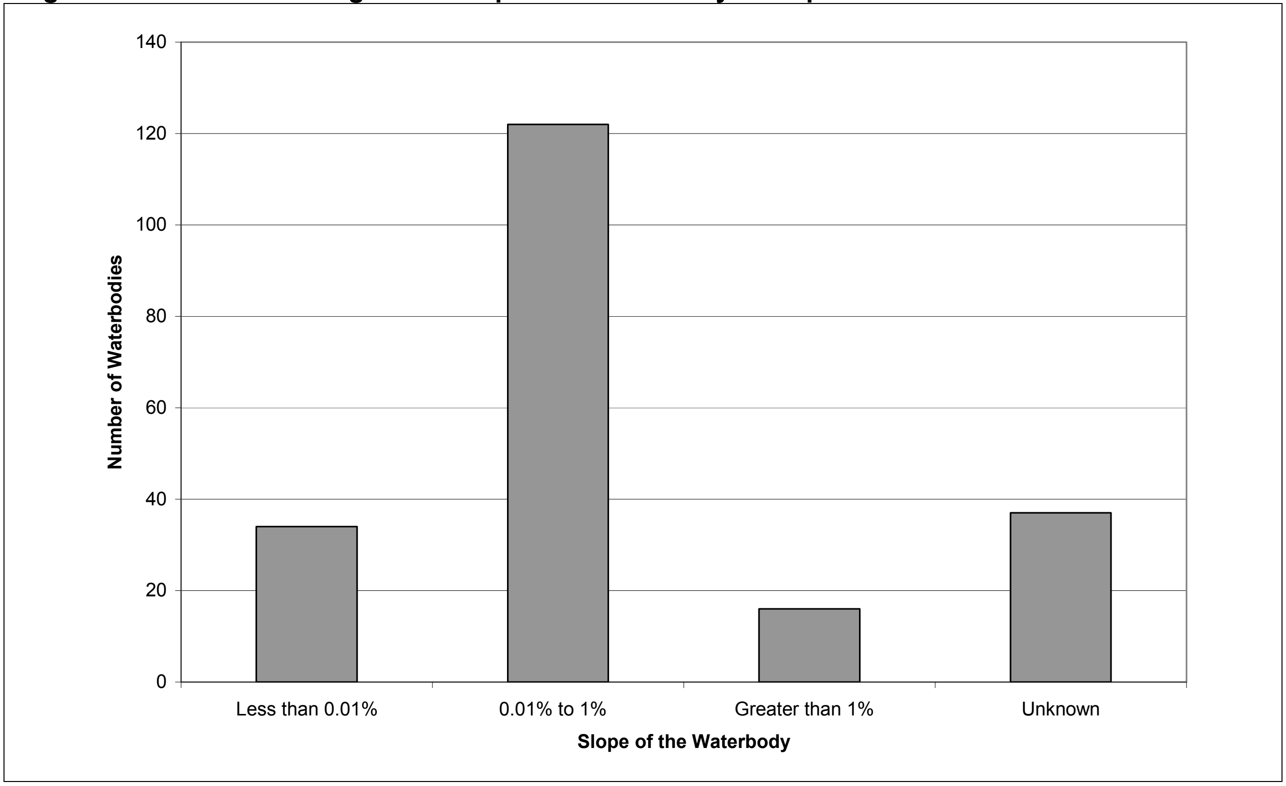


Figure 3-3 summarizes available slope data. According to available data, 75% of initial receiving waters have a slope of less than 1%.

Figure 3-3. Initial Receiving Water Slopes at EPA Surveyed Airports



Low slope and flow streams are more likely to show impacts from deicing pollutant discharges because of the lower volume of water available for pollutant dilution and the potential for greater pollutant retention time.

Rate of pollutant delivery versus rate of dilution is an important dynamic. The frequency and timing of deicing and precipitation events during the winter season affect both rates. As described in *Section 3.2.1*, precipitation quantity and type is an important determinant of the quantity and rate at which pollutants are delivered to surface waters. Precipitation quantity and type also affects the quantity of surface water flow available for dilution of discharged pollutants as well as the rate at which those pollutants travel downstream. High levels of rain or melted precipitation typically create higher surface water flow and move pollutants downstream more quickly. Numerous combinations of precipitation and deicing event frequency and intensity result in highly variable deicing pollutant delivery to and dilution in receiving surface waters.

Surface water degradation processes are another important factor influencing waterbody pollutant concentrations. These depend heavily on temperature, residence time, oxygen availability, and the composition of the bacteria and vegetation community present in receiving surface waters.

3.4 Documented Environmental Impacts from Airport Deicing Pollutant Discharges

EPA searched publicly available literature for information on airport deicing pollutant discharges and their connection to environmental impacts. Literatures sources included the peer-reviewed literature, state reports, newspapers, government agency reports, and a variety of organization publications. This section describes the results of EPA's literature search that was completed in December of 2007. EPA compiled more than 90 individual documents describing environmental impacts from airport deicing discharges. In some cases, deicing pollutant discharges have been definitively linked to environmental impacts. In other cases, impact linkage to deicing pollutants is suggested, rather than definitive. Compiled articles describe a wide range of airport and discharge conditions.

Surface waters are often subject to multiple stressors (e.g., pollutants from airport activities other than deicing, other industrial discharges, invasive species). Determining the source(s) of a water's impairment can be difficult and requires complex analyses that have not yet been conducted and published. EPA has summarized suggested, as well as definitive, impact cases in this section because of the additional information they provide on potential environmental impacts from deicing pollutant discharges. Approximately half of the articles describe impacts with a definitive connection to airport deicing pollutant discharges.

The majority of the environmental impact documentation focuses on impacts observed in surface waters directly receiving airport deicing pollutant discharges. Wildlife impacts such as fish kills or other organism deaths are the most frequently described environmental impact. *Table 3-5* summarizes the total number of studies EPA found on different types of environmental impacts and that were categorized as having either a definitive or suggested connection to airport deicing discharges.

Table 3-5: Documented Environmental Impacts Associated with Airport Deicing Discharges

Impact	Connection to Airport Deicing Definitive	Connection to Airport Deicing Suggested	Total Number of Studies
COD, BOD, DO, Nutrients			
COD or BOD	11	5	16
DO	10	10	20
Nutrients	8	9	17
Wildlife Impacts			
Fish Kill	8	10	18
Other Organisms	25	20	45
Human Health Impacts			
Health	4	4	8
Drinking Water	1	7	8
Aesthetic Impacts			
Foam	4	6	10
Odor	14	17	31
Color	11	9	20
Violations			
Permit Violations	17	10	27

Though EPA's literature search was extensive, it is unlikely that EPA located all available documentation of environmental impacts from airport deicing discharges. There are probably environmental impacts from airport deicing discharges that have not yet been documented and published because of the time and effort often required to detect, analyze, and document environmental impacts from industrial discharges.

An additional limitation on EPA's literature compilation is its ability to reflect current conditions at individual airports. Since the publication of articles describing environmental impacts from certain airports, some of those airports have installed collection and treatment systems or otherwise changed their deicing practices in order to reduce deicing pollutant discharges. *Table 3-6* summarizes a number of improvements airports have undertaken to reduce their environmental impact in recent years. A number of these efforts have improved conditions in receiving surface waters.

Table 3-6: Airport Deicing System Improvements for In-scope Airports

Airport	Environmental Impacts	Deicing System Improvements	Date Improvement Implemented
Baltimore/Washington International Airport	Odor, foam and color issues, fish impacts, Clean Water Act violation	Deicing pads and drains	By winter 1997-98
Cincinnati/Northern Kentucky International Airport	Anoxia, Sphaerotilus overgrowth, color and odor issues, "dead" stream, high BOD and ammonia levels	Discharge routing to POTW, recycling system	1994-2004
Cleveland Hopkins International Airport	High ammonia levels, fish kills, color and odor issues	Deicing pads and basins	By 2004
Detroit Metropolitan Wayne County Airport	Odor and color issues, permit violations, fish kills	Construct sewer line to route discharges to POTW	By 2010
Des Moines International Airport	Odor and color issues, state water quality standard violations	Stormwater detention facility	Long-term plan as of 1998
General Mitchell International Airport	Color issues, fish kills, high glycol and BOD levels	Redesigned storm sewers	Pre-2006
Louisville International Airport	High ammonia and BOD levels, low DO levels, fish kills	No longer using urea	Pre-2002
Minneapolis-St. Paul International Airport	Low DO levels, odor and color issues, high BOD and glycol levels, permit violations	Sewer system improvements and deicing pads	1998-2001
Port Columbus International Airport	High nutrient levels, low DO levels, fish kills, aquatic species diversity loss	No longer using urea, construction of containment system	By 2002-2003

Source: Information gathered during EPA's literature search completed in December of 2007.

Despite these limitations, the literature compilation provides a diverse profile of the types of environmental impacts associated with airport deicing discharges. As air traffic and deicing product usage levels continue to increase in the U.S. these types of impacts will either reappear at previously affected airports or newly appear at airports where they had not been previously detected, unless application, collection, and treatment practices change. Environmental impacts from deicing discharges continue to persist at some level at many of the airports listed in *Table 3-6,* despite the sometimes significant efforts made to address them.

Sections 3.4.1 to *3.4.5* provide additional information on documented environmental impacts. For additional information on individual articles EPA compiled during the literature review, see *Table C-1* in *Appendix C. Section 3.5* provides information on the potential current extent of environmental impacts from airport deicing discharges.

3.4.1 Chemical Oxygen Demand, Biochemical Oxygen Demand, Dissolved Oxygen, and Nutrient Impacts

3.4.1.1 Chemical Oxygen Demand and Biochemical Oxygen Demand

The primary ingredients in ADFs and pavement deicers are organic compounds that serve as freezing point depressants. These organic compounds degrade after release to the environment, creating high chemical oxygen demand (COD) and biochemical oxygen demand (BOD) levels in surface waters. High COD and BOD levels in surface waters can lead to high levels of dissolved oxygen (DO) consumption as the organic matter degrades, potentially lowering DO concentrations below levels required for the health and survival of aquatic organisms (see *Section 2.2.1.2*). EPA documented COD and BOD problems for 13 individual airports in 16 articles, 11 of which were classified as being definitively connected to airport deicing discharges. Many of the information sources were state government reports and published journal articles.

In a newspaper article on impacts from Minneapolis-St. Paul International Airport's deicing operations, the Minnesota Pollution Control Agency's water quality supervisor is quoted as stating that the airport's deicing discharges represent the largest source of organic pollutants to the Minnesota River (Meersman 1993). During the course of the 1992-1993 deicing season, approximately 2,400 tons of glycol were discharged to the Minnesota River. State officials suspected that these discharges lower DO levels in the Minnesota River.

In 1998, the Kentucky Department of Environmental Protection determined that the Cincinnati/Northern Kentucky International Airport was responsible for elevated glycol levels and BOD issues observed in surface waters receiving stormwater discharges from the airport. These problems continued to persist, even after the airport implemented remediation actions (Kentucky Department of Environmental Protection 1998).

3.4.1.2 Dissolved Oxygen

As organic material, BOD, and COD levels increase in airport deicing discharges increases, the amount of dissolved oxygen (DO) required by surface water microorganisms to digest the material also increases. Biodegradation of organic material lowers DO levels in surface waters and can ultimately make them uninhabitable for aquatic life. EPA compiled 20 articles describing DO impacts from deicing activities at 13 airports. The impacts in 10 articles could be definitively connected to airport deicing discharges. The articles describe low levels of DO and anoxia in receiving waters.

The Columbia Slough receives deicing pollutant discharges from Portland International Airport and is a well-documented case of deicing pollutants lowering DO levels in a receiving water. In a technical report prepared for the City of Portland, the airport's deicing discharges were documented as contributing 79% of all organic material discharging to the Columbia Slough (Wells 1997). Low DO levels clearly coincide with cold weather deicing activities. A separate report written by the Oregon Department of Environmental Quality (1998) specifically states that the airport's deicing pollutants have lowered DO in the Slough.

3.4.1.3 Nutrients

The pavement deicer urea decays and forms ammonia in surface waters. High concentrations of ammonia can be toxic to many aquatic organisms and plants can use the nitrogen in ammonia to fuel extra growth. Bacteria can also convert ammonia to other nitrogen-containing compounds that plants can absorb as nutrients. Nitrogen in airport deicing discharges can encourage algal blooms and other biological overgrowths, followed by low DO levels or anoxia as the overgrowths die and decay. EPA found nutrient impact complaints in 17 articles, 8 of which EPA classified as definitively connected to airport deicing discharges. The 17 articles discuss 12 different airports. Most of the articles describe impacts from algal blooms and elevated surface water levels of ammonia and nitrates.

Two articles describe nutrient enrichment in surface waters receiving deicing discharges from Port Columbus International Airport (State of Ohio Environmental Protection Agency 1998, State of Ohio Environmental Protection Agency 2004). A third report, another Ohio Environmental Protection Agency publication, describes high ammonia and nitrate concentrations in receiving waters downstream of the airport and the discharge of significant quantities of glycol (State of Ohio Environmental Protection Agency 2003).

3.4.2 Wildlife Impacts

3.4.2.1 Fish Kills

As described in *Chapter 2,* ADFs and pavement deicers have toxic components that can harm or kill aquatic organisms when discharged in sufficient quantities to surface waters. As described in *Section 3.4.1,* ADFs and pavement deicers also contain high levels of organic matter and nutrients that, during degradation in surface waters, can lower DO concentrations to harmful or uninhabitable levels for aquatic life. Either of these pathways can result in acute fish death events known as fish kills. Eighteen of the articles documented in the literature review discussed fish kills. EPA classified impacts in 8 articles as definitively linked to airport deicing discharges. The 18 articles discussed fish kills downstream of 13 different airports and included newspaper articles, journal articles, and state government reports.

For example, in May 2001 at Detroit Metropolitan Wayne County Airport a stormwater collection pond primarily containing stormwater contaminated with ethylene and propylene glycol from deicing activities breached and discharged to the Frank and Poet Drain (Lochner 2006). Two days later, a fish kill was observed at the location where the Drain discharges to the Detroit River. EPA and the Federal Bureau of Investigation investigated the incident and charged the airport with violating the Clean Water Act after failing to report the discharge.

3.4.2.2 Other Organism Impacts

In addition to fish kills, airport deicing discharges have been linked to the death of other types of aquatic organisms and have been implicated in the sickening or deaths of other wildlife and pets that have come in contact with contaminated surface waters. Of the 45 articles EPA compiled in this category, 25 are definitively connected to airport deicing discharges. The 45 articles discuss 26 different airports. The following airports are discussed in 3 or more articles:

- Cincinnati/Northern Kentucky International Airport (6 articles);
- Baltimore/Washington International Airport (3 articles);
- Denver International Airport (3 articles); and
- General Mitchell International Airport (3 articles).

At Cincinnati/Northern Kentucky International Airport, Denver International Airport, and Buffalo-Niagara International Airport waters receiving deicing discharges are described as lifeless (Sierra Club 2004, Scanlon 1997, and Dawson 1994).

A number of studies conducted on the receiving waters located downstream from deicing outfalls at Baltimore/Washington International Airport report glycol concentrations high enough to kill daphnids and minnows (Hartwell et al. 1993, Fisher et al. 1995, Pelton 1997a).

3.4.3 Human Health, Aesthetic, and Other Aquatic Resource Use Impacts

3.4.3.1 Human Health

As discussed in *Chapter 2,* some ADF and pavement deicer components can be harmful to human beings exposed to sufficient quantities. Some people claim to have been sickened by strong chemical odors associated with some deicing-contaminated stormwaters. Human health impacts are documented for 6 airports in 8 articles. The articles include newspaper articles and reports from organizations. Impacts range from headaches and nausea due to odors to claims of kidney and other health problems, especially in children. The Alliance of Residents Concerning O'Hare (1997), a nonprofit organization of citizens residing nearby Chicago O'Hare International Airport, documented vomiting and other illness due to fumes from airport deicing discharges on a number of separate occasions. Residents state that, at times, streams in residential neighborhoods receiving airport deicing discharges have unnatural colors and emit odors that cause illness.

3.4.3.2 Drinking Water Contamination

EPA compiled 8 articles that discuss drinking water impacts from 5 airports. One article definitively connected impacts to airport deicing discharges and the other articles are suggestive of a connection.

Three of the articles discussed drinking water contamination issues near Baltimore Washington International Airport but did not definitively connect these impacts to airport deicing discharges.

At Hartsfield-Jackson Atlanta International Airport, 10 days after an ADF spill into a major source of drinking water, consumers complained of a sickeningly sweet taste and smell in their drinking water. Testing of samples taken three days after the complaints started did not indicate deicing fluid contamination. However, sampling immediately following the spill indicated that water flowing from the airport into the river that serves as the drinking water source contained 1,600 ppm of glycol.

3.4.3.3 Foam

Deicing chemicals can form visible foam in surface waters. EPA's compiled 10 articles that describe foam in surface waters downstream of 7 airports. The articles include journal articles, newspaper articles, and reports from organizations. Four articles definitively connect the presence of foam to airport deicing discharges. Foam complaints frequently co-occur with odor and color complaints. High levels of glycols were also typically found in surface waters containing visible foam.

At Baltimore/Washington International Airport, levels of ethylene glycol as high as 4,800 mg/L were detected in the Muddy Bridge Branch where foam had been frequently sighted (McDowell 1997). In 1997, the airport applied nearly 200,000 gallons of ADF to planes and it is estimated that as much as 68% may have entered nearby creeks (Pelton 1998). This discharge coincided with numerous complaints about pinkish foam present on downstream surface waters.

3.4.3.4 Odor

Deicing-contaminated surface waters are frequently described as having a sickeningly sweet chemical smell. EPA compiled 31 articles describing complaints of odors from surface waters located downstream from airport deicing outfalls. Of the 31 articles, EPA classified 14 as describing a definitive connection between airport deicing discharges and odor. The 31 articles describe 16 different airports. Several airports are described in multiple articles:

- Cincinnati/Northern Kentucky International Airport (5 articles);
- Baltimore/Washington International Airport (4 articles); and
- Cleveland Hopkins International Airport (3 articles).

Odor complaints are frequently associated with additional impacts such as organism human health, and aesthetic impacts. For example, all articles describing the odor complaints from Baltimore/Washington International Airport discharges also described visible foam, human illness complaints, and fish impacts

(McDowell 1997, Pelton 1997b, Pelton 1998). At Cincinnati/Northern Kentucky International Airport, allegations of discharge violations involving Elijah Creek coincided with unpleasant odors, surface water discoloration, and pollutant concentrations high enough to harm aquatic life (Klepal 2004, Sierra Club 2004). Residents also complained about chemical smells and discolored water in Gunpowder Creek, which also receives airport deicing discharges. Glycol levels in Gunpowder Creek were found to be up to 3.5 times higher than allowed by the airport's wastewater discharge permit (Kelly 2004).

3.4.3.5 Color

Manufacturers add dye to ADFs to help ADF users track their presence on aircraft and airfield surfaces and to help them distinguish Type I from Type IV fluids. Sufficient levels of dye can discolor surface waters. In addition, as described above, degradation of organic material associated with airport deicing discharges can lower DO levels in surface waters. Under anoxic conditions, reduction of iron and manganese ions to more soluble species can color surface waters (Zitomer 2001)

EPA found 20 articles describing 11 airports with unnatural colored surface waters downstream of airport deicing stormwater outfalls. EPA classified 11 of the articles as describing impacts definitively connected to airport deicing discharges. Five articles described impacts from Cincinnati/Northern Kentucky International Airport and 3 articles describe impacts from Baltimore/Washington International Airport. Color complaints frequently coincided with odor complaints.

At Des Moines International Airport, color and odor issues are discussed in documents describing Total Maximum Daily Loads (TMDLs) for receiving waters as well as in materials provided to local city council members (Iowa Department of Natural Resources 2005, Flannery 1998). The TMDL document describes ethylene glycol concentrations of 65 to 120 mg/L and propylene glycol concentrations of 210 to 490 mg/L near the airport outfall to Yeader Creek. These high glycol concentrations coincided with a greenish color and sweet sewage odor in Yeader Creek. Yeader Creek was determined to be severely polluted and in violation of Iowa Water Quality Standards. Local residents who live near the creek have lodged complaints with the Iowa Department of Natural Resources about the surface water's discoloration and odor.

3.4.4 Permit Violations

Permit violations were frequently described in articles compiled by EPA. Permit violations provide additional information on large quantities of airport deicing pollutants discharging to surface waters. EPA compiled 27 articles that describe discharge permit violations at 12 different airports. Several airports, including Cleveland Hopkins International Airport, Cincinnati/Northern Kentucky International Airport, and Baltimore/Washington International Airport were discussed in multiple articles. Seventeen articles describe direct discharge violations. Other articles describe unspecified violations or administrative violations such as failure to report an unauthorized discharge.

3.5 Potential Current Impacts to Impaired Waters and Other Resources

EPA evaluated the potential for airport deicing discharges to impact surface waters listed as impaired under Section 303(d) of the Clean Water Act as well as other aquatic resources located downstream of airport deicing stormwater outfalls. Listing of a surface water as impaired under Section 303(d) of the Clean Water Act is an official determination that a waterbody is unable to serve one or more of its designated uses such as drinking water supply, recreation, wildlife habitat, etc. because of pollution or other modifications. It is an indicator of a stressed ecosystem.

EPA examined the listing status of surface waters receiving airport deicing discharges for two reasons. First, to determine the extent to which airport deicing pollutants are being discharged to already stressed aquatic ecosystems and potentially contributing additional stress. Second, to determine which listed waterbodies may be impaired as a direct result of receiving airport deicing discharges.

EPA's analysis used a geographical information system (GIS) analysis of surface waters to which airports directly discharge deicing pollutants. EPA used this information to identify 303(d)-listed waters and aquatic resources that could potentially be affected by deicing discharges. EPA also examined existing Total Maximum Daily Load (TMDL) documents in order to identify airports that have officially been determined to be point sources contributing to surface water impairment.

3.5.1 303(d)-Listed Waters Receiving Airport Deicing Discharges

Based on airport outfall location information provided in response to EPA's Airport Deicing Questionnaire (US EPA 2006c), EPA indexed deicing outfall locations to the National Hydrography Dataset (NHD) Plus stream network. EPA used NHD Plus tools to determine surface waters within 10 miles downstream of airport outfalls. Once downstream waters were identified in NHD Plus, EPA overlaid their location information with the 2002 national GIS coverage of 303(d)-listed waters (http://www.epa.gov/waters/data/downloads.html#303d, accessed September 24, 2007) in order to determine whether any of the downstream waters are listed as impaired. EPA then linked identified impaired streams to EPA's Watershed Assessment, Tracking, and Environmental Results (WATERs) database (http://www.epa.gov/waters/data/index.html, accessed September 24, 2007) in order to determine the nature of the impairment. Of the 93 airports for which EPA has sufficient outfall location information to conduct this analysis, 36 discharge directly to a freshwater waterbody that is listed as impaired. *Table 3-7* summarizes the results of this analysis.

Table 3-7: 303(d) Impairment Categories for Fresh Waters Receiving Direct Airport Deicing Discharges from Surveyed Airports within Scope of the Final Rule

303(d) Impairment Category	Number of Airports with Impairment	Airport Deicing Pollutant Potentially Contributing to Impairment
Algal Growth	1	Yes
Ammonia	5	Yes
Cause Unknown	4	Yes
Cause Unknown - Impaired Biota	4	Yes
Chlorine	2	
Dioxins	2	
Fish Consumption Advisory - Pollutant Unspecified	1	Yes
Flow Alteration	4	
Habitat Alteration	6	
Mercury	2	
Metals (Other Than Mercury)	4	
Nutrients	7	Yes
Oil And Grease	1	
Organic Enrichment/Oxygen Depletion	12	Yes
Pathogens	18	
PCBs	6	
Pesticides	6	
pH	4	
Salinity/TDS/Sulfates/Chlorides	2	Yes
Sediment	6	
Temperature	2	
Total Toxicity	4	Yes
Toxic Organics	5	Yes
Turbidity	5	

Of the 28 in-scope airports directly discharging to impaired freshwater waterbodies, 21 discharge to waterbodies impaired by pollutants associated with airport deicing discharges. Because EPA had sufficient information for only 93 airports to conduct this analysis, additional airports could be discharging deicing pollutants to impaired waters.

Because NHD Plus does not provide information on marine waters, airport outfalls discharging directly to marine waters were not included in the GIS analysis described above. To assess whether any of the marine waters directly receiving airport deicing discharges are listed as impaired, EPA used information on receiving waters designated as marine from responses to EPA's Airport Deicing Questionnaire (US EPA 2006c) to search the WATERs database. *Table 3-8* summarizes the results of this analysis.

Table 3-8: 303(d) Impairment Categories for Marine Waters Receiving Direct Airport Deicing Discharges from Surveyed Airports within Scope of the Final Rule

303(d) Impairment Category	Number of Airports with Impairment	Airport Deicing Pollutant Potentially Contributing to Impairment
Aesthetically impaired waters	2	Yes
Dioxin	1	
Organic Enrichment/Oxygen Depletion	2	Yes
Floatables	1	
Mercury	1	
Metals (Other Than Mercury)	1	
Nutrients	2	Yes
Pathogens	5	
PCBs	2	
Pesticides	1	
pH	1	
Toxic Organics	3	Yes

Of the 6 in-scope airports discharging to impaired marine waters, 5 discharge to waters impaired for pollutants associated with airport deicing discharges. Because EPA had sufficient information for only 93 airports to conduct this analysis, additional airports could be discharging deicing pollutants to impaired marine waters.

Because states have not assessed all surface waters receiving deicing pollutant discharges from airports for impairment, additional waters beyond those described here could be impaired.

Several of the 303(d) impairment categories EPA identified during the analysis can derive from airport deicing pollutants. These categories include “aesthetically impaired waters,” “algal growth,” “ammonia,” “cause unknown,” “cause unknown-impaired biota,” “fish consumption advisory – pollutant unspecified,” “nutrients,” “organic enrichment/oxygen depletion,” “salinity/TDS/sulfates/chlorides,” “total toxicity,” and “toxic organics.” A 303(d) listing alone does not mean that airport deicing discharges are the cause of the waterbody impairments. However, 26 of the 34 in-scope airports discharging to impaired waters are discharging to waters impaired in a manner potentially associated with airport deicing pollutants. Even if these airports are not the root cause of the identified impairment, they contribute additional loadings of those pollutants by which the surface waters are already impaired.

Table 3-9 provides additional information on airports discharging directly to 303(d)-listed waters and associated impairments.

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type[1]	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
Austin Straubel International Airport	FW	Dutchman Creek	Ammonia	X
	FW	Dutchman Creek	Nutrients	X
	FW	Dutchman Creek	Nutrients (Phosphorus)	X
	FW	Dutchman Creek	Organic Enrichment/Oxygen Depletion	X
	FW	Dutchman Creek	Total Toxicity	X
Austin-Bergstrom International	FW	Colorado River Below Town Lake	Pathogens	
	FW	Onion Creek	Organic Enrichment/Oxygen Depletion	X
	FW	Onion Creek	Total Dissolved Solids	X
	FW	Onion Creek	Pathogens	
Birmingham International	FW	Village Creek	Ammonia	X
	FW	Village Creek	Nutrients	X
	FW	Village Creek	Organic Enrichment/Oxygen Depletion	X
	FW	Village Creek	Toxic Organics	X
	FW	Village Creek	Flow Alteration	
	FW	Village Creek	Metals (Other Than Mercury)	
	FW	Village Creek	pH	
	FW	Village Creek	Sediment	
	FW	Village Creek	Temperature	
Boeing Field/King County International	FW	Duwamish River	pH	
Bradley International	FW	Farmington River	Pathogens	
	FW	Stony Brook	Cause Unknown	X
Cincinnati/Northern Kentucky International	FW	Elijahs Creek	Toxic Organics	X
	FW	Elijahs Creek	Ammonia	X
	FW	Elijahs Creek	Dissolved Oxygen	X
	FW	Gunpowder Creek	Ammonia	X
	FW	Gunpowder Creek	Dissolved Oxygen	X

[1] FW – Freshwater
MW – Marine water

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type[1]	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
Cleveland-Hopkins International	FW	Rocky River	Ammonia	X
	FW	Rocky River	Nutrients	X
	FW	Rocky River	Organic Enrichment/Oxygen Depletion	X
	FW	Rocky River	Chlorine	
	FW	Rocky River	Flow Alteration	
	FW	Rocky River	Habitat Alteration	
	FW	Rocky River	Pathogens	
	FW	Rocky River	PCBs	
	FW	Rocky River	Sediment	
Des Moines International	FW	Yeader Creek	Salinity/TDS/Sulfates/Chlorides	X
	FW	Yeader Creek	Toxic Organics	X
	FW	Easter Lake	Nutrients (Phosphorus)	X
Detroit Metropolitan Wayne County	FW	Frank And Poet Drain	Cause Unknown - Impaired Biota	X
Eppley Airfield	FW	Missouri River	Pathogens	
	FW	Missouri River	PCBs	
	FW	Missouri River	Pesticides	
General Edward Lawrence Logan International	MW	Boston Inner Harbor	Toxic Organics	X
	MW	Boston Inner Harbor	Pathogens	
Hartsfield - Jackson Atlanta International	FW	Flint River	Pathogens	
Indianapolis International	FW	East Fork White Lick Creek	Cause Unknown - Impaired Biota	X
	FW	East Fork White Lick Creek	Pathogens	
	FW	East Fork White Lick Creek	PCBs	
	FW	State Ditch	Cause Unknown - Impaired Biota	X
	FW	State Ditch	Pathogens	
James M Cox Dayton International	FW	Stillwater River	Ammonia	X
	FW	Stillwater River	Nutrients	X
	FW	Stillwater River	Organic Enrichment/Oxygen Depletion	X
	FW	Stillwater River	Habitat Alteration	
	FW	Stillwater River	Pathogens	

[1] FW – Freshwater
MW – Marine water

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type[1]	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
John F Kennedy International	MW	Bergen Basin	Aesthetics	X
	MW	Bergen Basin	Dissolved Oxygen	X
	MW	Bergen Basin	Pathogens	
	MW	Jamaica Bay	Nutrients	X
	MW	Jamaica Bay	Dissolved Oxygen	X
	MW	Jamaica Bay	Pathogens	
	MW	Thurston Basin	Dissolved Oxygen	X
La Guardia	MW	Bowery Bay	Dissolved Oxygen	X
	MW	Bowery Bay	Pathogens	
	MW	Bowery Bay	PCBs	
	MW	Flushing Bay	Aesthetics	X
	MW	Flushing Bay	Dissolved Oxygen	X
	MW	Flushing Bay	PCBs	
	MW	Rikers Island Channel	Dissolved Oxygen	X
	MW	Rikers Island Channel	Pathogens	
	MW	Rikers Island Channel	PCBs	
Lafayette Regional	FW	Vermilion River	Nutrients	X
	FW	Vermilion River	Organic Enrichment/Oxygen Depletion	X
	FW	Vermilion River	Pathogens	
	FW	Vermilion River	Pesticides	
	FW	Vermilion River	Turbidity	
Louisville International-Standiford Field	FW	Southern Ditch	Organic Enrichment/Oxygen Depletion	X
	FW	Southern Ditch	Pathogens	
Minneapolis-St Paul International/Wold-Chamberlain	FW	Minnesota River	Organic Enrichment/Oxygen Depletion	X
	FW	Minnesota River	Mercury	
	FW	Minnesota River	Pathogens	
	FW	Minnesota River	PCBs	
	FW	Minnesota River	Turbidity	

[1] FW – Freshwater
MW – Marine water

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type[1]	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
Newark Liberty International	MW	Elizabeth Channel	Toxic Organics	X
	MW	Elizabeth Channel	Dioxin	
	MW	Elizabeth Channel	Floatables	
	MW	Elizabeth Channel	Metals	
	MW	Elizabeth Channel	Pathogens	
	MW	Elizabeth Channel	PCBs	
	MW	Newark Channel	Toxic Organics	X
	MW	Newark Channel	Dioxin	
	MW	Newark Channel	Floatables	
	MW	Newark Channel	Metals	
	MW	Newark Channel	Pathogens	
	MW	Newark Channel	PCBs	
Norman Y. Mineta San Jose International	FW	Los Gatos Creek	Pesticides	
Ontario International	FW	Cucamonga Creek	Pathogens	
Phoenix Sky Harbor International	FW	Salt River	Pesticides (Chlordane)	
	FW	Salt River	Pesticides (DDT Metabolites)	
	FW	Salt River	Pesticides (Dieldrin)	
	FW	Salt River	Pesticides (Toxaphene)	
	FW	Salt River	pH	
Piedmont Triad International	FW	Brush Creek	Habitat Alteration	
	FW	East Fork Deep River	Habitat Alteration	
	FW	East Fork Deep River	Pathogens	
	FW	East Fork Deep River	Turbidity	
	FW	Horsepen Creek	Sediment	

[1] FW – Freshwater
MW – Marine water

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type[1]	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
Port Columbus International	FW	Big Walnut Creek	Ammonia	X
	FW	Big Walnut Creek	Cause Unknown	X
	FW	Big Walnut Creek	Nutrients	X
	FW	Big Walnut Creek	Organic Enrichment/Oxygen Depletion	X
	FW	Big Walnut Creek	Total Toxicity	X
	FW	Big Walnut Creek	Toxic Organics	X
	FW	Big Walnut Creek	Flow Alteration	
	FW	Big Walnut Creek	Habitat Alteration	
	FW	Big Walnut Creek	Metals (Other Than Mercury) (Copper)	
	FW	Big Walnut Creek	Metals (Other Than Mercury)	
	FW	Big Walnut Creek	Pathogens	
	FW	Big Walnut Creek	Sediment	
	FW	Big Walnut Creek	Temperature	
	FW	Big Walnut Creek	Turbidity	
Portland International	FW	Columbia Slough	Algal Growth	X
	FW	Columbia Slough	Dioxins	
	FW	Columbia Slough	Metals (Other Than Mercury)	
	FW	Columbia Slough	Nutrients	X
	FW	Columbia Slough	Organic Enrichment/Oxygen Depletion	X
	FW	Columbia Slough	Pathogens	
	FW	Columbia Slough	PCBs	
	FW	Columbia Slough	Pesticides	
	FW	Columbia Slough	pH	
Rickenbacker International	FW	Walnut Creek	Cause Unknown	X
	FW	Walnut Creek	Fish Consumption Advisory - Pollutant Unspecified	X
	FW	Walnut Creek	Total Toxicity	X
	FW	Walnut Creek	Flow Alteration	
	FW	Walnut Creek	Habitat Alteration	
	FW	Walnut Creek	Pathogens	
	FW	Walnut Creek	PCBs	
	FW	Walnut Creek	Sediment	

[1] FW – Freshwater
MW – Marine water

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type[1]	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
Ronald Reagan Washington National	FW	Lower Anacostia River	Organic Enrichment/Oxygen Depletion	X
	FW	Lower Anacostia River	Toxic Organics (Bis(2-Ethylhexyl)Phthalate)	X
	FW	Lower Anacostia River	Toxic Organics (Chrysene)	X
	FW	Lower Anacostia River	Toxic Organics	X
	FW	Lower Anacostia River	Chlorine	
	FW	Lower Anacostia River	Dioxins	
	FW	Lower Anacostia River	Mercury	
	FW	Lower Anacostia River	Metals (Other Than Mercury) (Selenium)	
	FW	Lower Anacostia River	Metals (Other Than Mercury)	
	FW	Lower Anacostia River	Oil And Grease	
	FW	Lower Anacostia River	Pathogens	
	FW	Lower Anacostia River	Turbidity	
San Antonio International	FW	Salado Creek	Cause Unknown - Impaired Biota	X
	FW	Salado Creek	Organic Enrichment/Oxygen Depletion	X
	FW	Salado Creek	Pathogens	
	FW	Salado Creek	Pesticides	
Seattle-Tacoma International	MW	Puget Sound	Nutrients	X
	MW	Puget Sound	Toxic Organics	X
	MW	Puget Sound	Mercury	
	MW	Puget Sound	Pathogens	
	MW	Puget Sound	Pesticides	
	MW	Puget Sound	pH	
Theodore Francis Green State	FW	Buckeye Brook	Cause Unknown - Impaired Biota	X
	FW	Buckeye Brook	Pathogens	
Toledo Express	FW	Swan Creek	Total Toxicity	X
	FW	Swan Creek	Habitat Alteration	
	FW	Swan Creek	Sediment	
Wilkes-Barre/Scranton International	FW	Spring Brook	Cause Unknown	X

[1] FW – Freshwater
MW – Marine water

3.5.2 Airport Deicing Discharges Listed as TMDL Point Sources

To identify TMDLs that list airport deicing discharges as a point source contributing to a receiving waterbody's impairment, EPA searched the online TMDL document database (http://iaspub.epa.gov/waters/text_search.tmdl_search_form, accessed August 2, 2007). The EPA TMDL document database tracks information on waters listed by states as impaired under Section 303(d) of the Clean Water Act. The database provides information such as the identity of the pollutant causing the impairment, the source of the impairment, and the status of TMDL development for the impaired water body.

To date, EPA has identified 4 TMDL documents officially listing airport deicing discharges as point sources contributing to surface water impairment:

- Total Maximum Daily Load for Priority Organics Yeader, Creek, Polk County, Iowa;
- Total Maximum Daily Loads for Nutrients and Siltation, Easter Lake, Polk County, Iowa;
- Impacts of Deicing Fluids on Elijahs and Gunpowder Creeks, Boone County, Kentucky; and
- Columbia Slough Total Maximum Daily Loads for Dissolved Oxygen.

The state of Iowa has listed Yeader Creek as impaired by excessive levels of "priority organics" (glycol compounds) and identified Des Moines International Airport as the primary source. The TMDL describes Yeader Creek as a small stream (2 to 3 cubic feet per second flow). Waters immediately downstream from airport deicing stormwater outfalls had a greenish color, a wastewater odor, and no fish or macroinvertebrates. In addition, exposed substrate was an unusual rust-orange color and embedded substrate was an unusual black color, suggesting anaerobic conditions. The Yeader Creek TMDL describes two additional locations downstream as having pools of water the same nonalgal green color and with the "same odor of sewage and sweetener" as the waters immediately downstream of the airport deicing stormwater outfalls. The Yeader Creek TMDL established discharge limits for ethylene glycol and propylene glycol for airport deicing outdalls and set a benthic macroinvertebrate distribution target for the river to assess stream recovery.

The state of Iowa has listed Easter Lake as impaired for nutrients (i.e., phosphorus) and sediment. Although the Des Moines International Airport was identified as a contributing point sources for nutrient impairment, the airport's stormwater phosphorus load (110 pounds per year) was considered to be minor in comparison to other potential phosphorus sources in the watershed and the airport was not assigned a waste load reduction goal. The TMDL analysis did not consider the Des Moines International Airport to be a significant source of sediment to Easter Lake.

Elijahs and Gunpower Creeks are located immediately downstream from the Cincinnati/Northern Kentucky International Airport. Since the early 1990s the Kentucky Division of Water has documented low dissolved oxygen levels, evidence of ammonia toxicity, and extensive growth of *Sphaerotilus* bacteria in the creeks. In 1996, both streams were listed on Kentucky's 303(d) list of impaired waters and ranked as a high priority for TMDL development. The results of the TMDL analysis established discharge limits for BOD_5 and ammonia and required the airport to develop a Best Management Practices plan and a Groundwater Protection Plan.

The Columbia Slough, located downstream from the Portland International Airport in Oregon, is listed as impaired for multiple water quality parameters including bacteria, pH, dissolved oxygen, phosphorus, temperature, lead, and several toxic organics. The TMDL identified a complex list of pollution sources contributing to the Slough's impairment including combined sewer overflows, landfill leachate, airport deicing discharges, urban and industrial runoff, and other point sources in the watershed. Airport deicing discharges were identified as the primary pollution source for wintertime dissolved oxygen violations in the Slough. The TMDL established a range of BOD waste load allocations for airport deicing discharges to meet dissolved oxygen goals and also required the airport to perform additional waterbody monitoring.

3.5.3 Resources Located Downstream from Airport Deicing Discharge Outfalls

As a screening-level assessment, EPA evaluated the potential for airport deicing discharges to affect the following resources:

- Groundwater aquifers;
- Drinking water intakes from surface water sources;
- Federal lands;
- National, state, and local parks; and
- National Wildlife Refuge Areas (NWRAs).

EPA assessed the potential for airport deicing discharges to affect groundwater aquifers based on information provided in responses to EPA's *Airport Deicing Questionnaire* (US EPA 2006c). Individual airports' responses indicated whether or not airport grounds are located immediately above an aquifer, and whether or not the aquifer is a drinking water source. EPA assessed the remaining aquatic resources listed above for those surface waters located within 10 miles downstream of airport deicing outfalls, using the same GIS-based methodology described in *Section 3.5.1.* EPA overlaid the relevant NHD Plus stream segments over the following GIS coverages to determine whether downstream surface waters intersect with the GIS areas associated with each resource:

- Drinking water intake point file from EPA's Reach Address Database (RAD);
- National atlas of the U.S. federal land boundaries;
- Environmental Systems Research Institute (ESRI) U.S. Geographic Data Technology, Inc. (GDT) park landmarks (includes federal, state, and local parks in the U.S.); and
- U.S. Fish and Wildlife National Wildlife Refuge Area boundaries.

EPA analyzed aquatic resources within a distance of 10 miles downstream of airport deicing stormwater outfalls because, according to EPA's literature compilation, many documented impacts have taken place within this distance. Impacts could occur at distances beyond 10 miles downstream, but EPA has chosen 10 miles for this preliminary analysis.

Table 3-10 presents the results of the analysis for aquatic resources which could potentially be affected by airport deicing discharges. Because EPA has sufficient information to conduct this analysis for only airports EPA surveyed, the table below is not a complete list of airports discharging deicing pollutants to surface waters containing the resources listed above.

Table 3-10: Resources Potentially Impacted by Airport Deicing Discharges from Surveyed Airports within Scope of the Final Rule

Airport Name	Airport City	Airport State	Airport Grounds Above an Aquifer	Within 10 Miles Downstream from Airport Deicing Outfall			
				Drinking Water Intakes	Federal Lands	Parks	NWRAs
Albany International	Albany	NY		Yes		Yes	
Albuquerque International Sunport	Albuquerque	NM	DW				
Aspen-Pitkin Co/Sardy Field	Aspen	CO			Yes		
Austin Straubel International	Green Bay	WI	DW				
Austin-Bergstrom International	Austin	TX	Yes				
Baltimore-Washington International	Baltimore	MD	DW			Yes	
Bethel	Bethel	AK					
Birmingham International	Birmingham	AL	Yes			Yes	
Bismarck Municipal	Bismarck	ND					
Boeing Field/King County International	Seattle	WA	Yes			Yes	
Bradley International	Windsor Locks	CT	Yes			Yes	
Buffalo Niagara International	Buffalo	NY	Yes			Yes	
Central Wisconsin	Mosinee	WI					
Charlotte/Douglas International	Charlotte	NC	Yes			Yes	
Chicago O'Hare International	Chicago	IL	Yes			Yes	
Cincinnati/Northern Kentucky International	Covington	KY	Yes			Yes	
City of Colorado Springs Municipal	Colorado Springs	CO					
Cleveland-Hopkins International	Cleveland	OH				Yes	
Dallas Love Field	Dallas	TX	DW			Yes	
Dallas/Fort Worth International	Dallas-Fort Worth	TX				Yes	
Denver International	Denver	CO	Yes				
Des Moines International	Des Moines	IA	Yes	Yes		Yes	
Detroit Metropolitan Wayne County	Detroit	MI				Yes	
Eppley Airfield	Omaha	NE	DW	Yes			
Evansville Regional	Evansville	IN					
Fairbanks International	Fairbanks	AK	DW				
Fort Wayne International	Fort Wayne	IN	DW	Yes			
General Edward Lawrence Logan International	Boston	MA	Yes				
General Mitchell International	Milwaukee	WI				Yes	
George Bush Intercontinental Airport/Houston	Houston	TX	DW			Yes	
Gerald R. Ford International	Grand Rapids	MI					
Glacier Park International	Kalispell	MT	DW		Yes		
Greater Rochester International	Rochester	NY	Yes			Yes	
Hartsfield - Jackson Atlanta International	Atlanta	GA	Yes			Yes	
Indianapolis International	Indianapolis	IN	Yes			Yes	
James M Cox Dayton International	Dayton	OH					
John F Kennedy International	New York	NY			Yes	Yes	
Juneau International	Juneau	AK					

Table 3-10: Resources Potentially Impacted by Airport Deicing Discharges from Surveyed Airports within Scope of the Final Rule

				Within 10 Miles Downstream from Airport Deicing Outfall			
Airport Name	**Airport City**	**Airport State**	**Airport Grounds Above an Aquifer**	**Drinking Water Intakes**	**Federal Lands**	**Parks**	**NWRAs**
Kansas City International	Kansas City	MO		Yes			
La Guardia	New York	NY					
Lafayette Regional	Lafayette	LA	DW				
Lambert-St Louis International	St Louis	MO	Yes			Yes	
Louisville International-Standiford Field	Louisville	KY					
Lovell Field	Chattanooga	TN	Yes	Yes			
Manchester	Manchester	NH	Yes	Yes		Yes	
Mc Carran International	Las Vegas	NV	DW			Yes	
Memphis International	Memphis	TN	Yes				
Minneapolis-St Paul International/Wold-Chamberlain	Minneapolis	MN	Yes		Yes	Yes	
Montgomery Regional (Dannelly Field)	Montgomery	AL	Yes				
Nashville International	Nashville	TN		Yes		Yes	
Newark Liberty International	Newark	NJ	Yes				
Nome	Nome	AK	Yes				
Norfolk International	Norfolk	VA	Yes				
Norman Y. Mineta San Jose International	San Jose	CA			Yes	Yes	Yes
Northwest Arkansas Regional	Fayetteville/ Springdale	AR	Yes				
Ontario International	Ontario	CA					
Outagamie County Regional	Appleton	WI	DW				
Philadelphia International	Philadelphia	PA	DW				
Phoenix Sky Harbor International	Phoenix	AZ	DW				
Piedmont Triad International	Greensboro	NC	DW	Yes		Yes	
Pittsburgh International	Pittsburgh	PA		Yes			
Port Columbus International	Columbus	OH				Yes	
Portland International	Portland	OR	Yes				
Raleigh-Durham International	Raleigh/Durham	NC	DW			Yes	
Ralph Wien Memorial	Kotzebue	AK	Yes				
Rapid City Regional	Rapid City	SD	DW				
Redding Municipal	Redding	CA	DW			Yes	
Reno/Tahoe International	Reno	NV	DW				
Rickenbacker International	Columbus	OH	Yes				
Roanoke Regional/Woodrum Field	Roanoke	VA	Yes				
Rochester International	Rochester	MN	DW				
Ronald Reagan Washington National	Washington	DC	Yes		Yes	Yes	
Sacramento International	Sacramento	CA	DW	Yes		Yes	
Salt Lake City International	Salt Lake City	UT					
San Antonio International	San Antonio	TX				Yes	
Seattle-Tacoma International	Seattle	WA	DW			Yes	
Syracuse Hancock International	Syracuse	NY					

Table 3-10: Resources Potentially Impacted by Airport Deicing Discharges from Surveyed Airports within Scope of the Final Rule

Airport Name	Airport City	Airport State	Airport Grounds Above an Aquifer	Within 10 Miles Downstream from Airport Deicing Outfall			
				Drinking Water Intakes	Federal Lands	Parks	NWRAs
Ted Stevens Anchorage International	Anchorage	AK	Yes				
Theodore Francis Green State	Providence	RI	Yes			Yes	
Toledo Express	Toledo	OH	DW				
Tucson International	Tucson	AZ	Yes				
Washington Dulles International	Washington	DC	DW	Yes	Yes	Yes	
Wilkes-Barre/Scranton International	Wilkes-Barre/ Scranton	PA	Yes				
Will Rogers World	Oklahoma City	OK	DW				
Wilmington International	Wilmington	NC	DW				
Yeager	Charleston	WV		Yes			

DW = Aquifer is known by airport to be used for drinking water.

4 Benefits of Final Regulatory Options

This chapter summarizes the final regulatory options EPA evaluated and the environmental benefits EPA anticipates will result from each option. The benefits of reduced airport deicing pollutant discharges may be classified in three broad categories: human health, ecological and economic productivity benefits. EPA was not able to monetize benefits of the final regulatory options because of an imperfect understanding of the link between discharge reductions and benefit categories, and how society values some of the benefit events.

This chapter presents a summary of EPA's regulatory options *(Section 4.1),* a discussion of individual airports likely to be affected by the final options and associated pollutant discharge reductions *(Sections 4.2 and 4.3)*, and a qualitative assessment of expected ecological and human health and aquatic resource use benefits from reduced deicing pollutant discharges *(Section 4.4).*

4.1 Final Regulatory Options

EPA evaluated two different collection and treatment scenarios for aircraft deicing operation discharges from ADF application sites:

- **20% collection and treatment scenario -** uses glycol collection vehicles (GCVs) for deicing stormwater collection and anaerobic fluid bed (AFB) treatment for deicing stormwater treatment;
- **40% collection and treatment scenario -** uses GCVs in combination with plug-and-pump technology for deicing stormwater collection and AFB treatment for deicing stormwater treatment.

A complete description of these collection and treatment methods is available in EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010).

EPA also evaluated methods for control of deicing pollutant discharges from the airfield beyond ADF application sites. One approach EPA evaluated is to eliminate the use of urea as a pavement deicer and replace it with other, less environmentally harmful products. Other, less harmful products (e.g., potassium acetate, sodium acetate, and sodium formate) are available for substitution.

Table 4-1 provides a brief description of each of EPA's final regulatory options.

Table 4-1: Regulatory Options Evaluated for the Airport Deicing Category

Option	Option Description	Number of Airports Subject to Option
1	40 percent ADF collection requirement for large and medium ADF users (based on plug and pump with GCVs); numeric COD limitations for direct discharges of collected ADF (based on anaerobic treatment)	198
2	40 percent ADF collection requirement for the large ADF users (based on plug and pump with GCVs) and 20 percent ADF collection requirement for medium ADF users (based on GCVs); numeric COD limitations for direct discharges of collected ADF (based on anaerobic treatment)	198
3	Site-Specific Aircraft Deicing Discharge Controls	198

A complete description of how EPA constructed these regulatory options is available in the *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010).

4.2 Airports Affected by the Final Regulatory Options

EPA's survey collected data, for use in evaluating the airport deicing category, at all large and medium hub primary commercial airports, and a statistical subsample of small and nonhub primary commercial airports. To determine the airports within scope of the final regulatory options, EPA evaluated those airports for which survey information is available and then scaled up the resulting data using statistical weighting factors to represent conditions for the entire category. For additional information on the use of survey data and associated statistical weighting factors, see EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010).

For each regulatory option, EPA determined which individual airports are likely to fall within scope of the option. EPA then determined which surveyed airports are already in compliance with the option and which airports would likely need to take action to comply with the option.

For airports EPA surveyed, *Table 4-2* summarizes which options would likely require an airport to take action to address deicing discharges. For example, Albuquerque International Sunport falls within scope of Option 1 but, based on EPA's survey data, is believed to be already in compliance with both the 20% ADF collection and treatment and the urea restriction requirement. Therefore, for this airport under Option 1, EPA did not estimate additional technology requirements, compliance costs, or pollutant discharge reductions. Conversely, Charlotte-Douglas International Airport falls within scope of Option 1 and, based on EPA's survey information, is not believed to be in compliance with either the 20% ADF collection and treatment or the urea restriction requirement. For this airport, EPA evaluated GRV use and pavement deicer product substitution to reach compliance with Option 1's requirements. EPA also calculated associated compliance costs and pollutant discharge reductions.

Table 4-2: Surveyed Airports Affected by Final Regulatory Options

Airport Name	Option 1	Option 2	Option 3
Albuquerque Intl Sunport	X		
Austin Straubel International	X	X	X
Bethel	X	X	X
Boise Air Terminal/Gowen Fld	X	X	X
Bradley Intl	X	X	X
Central Wisconsin	X	X	X
Charlotte/Douglas Intl	X	X	X
Eppley Airfield	X	X	
Fairbanks Intl	X	X	X
Fort Wayne International	X	X	X
General Edward Lawrence Logan Intl	X	X	X
Glacier Park Intl	X	X	X
John F Kennedy Intl	X	X	
Juneau Intl	X	X	X
La Guardia	X	X	
Manchester	X	X	X
Memphis Intl	X	X	
Newark Liberty Intl	X	X	
Northwest Arkansas Regional	X	X	X
Piedmont Triad International	X	X	X
Port Columbus Intl	X	X	
Portland Intl	X		
Raleigh-Durham Intl	X	X	X
Ralph Wien Memorial	X	X	X
Reno/Tahoe International	X	X	X
Ronald Reagan Washington National	X	X	X
Salt Lake City Intl	X	X	X
Seattle-Tacoma Intl	X	X	
South Bend Regional	X	X	X
Spokane Intl	X	X	X
Stewart Intl	X	X	X
Ted Stevens Anchorage Intl	X	X	X
Yeager	X	X	X

Although EPA has insufficient information to determine what would happen under each regulatory option at each airport that was not surveyed, EPA was able to use statistical techniques to estimate the level to which each regulatory option would require airport deicing operation changes for the airport population determined to be within scope of the rule.

EPA's estimate of actions taken by individual airports under each regulatory option is based on data from EPA's Airport Deicing Questionnaire (2006c) and other publicly available data sources. Although current conditions at some individual airports may have changed since the survey was conducted, the overall results of the analysis provide a useful estimate of the level of action required by each regulatory option.

4.3 Environmental Benefits Anticipated under Final Regulatory Options

EPA expects that environmental benefits associated with each final regulatory option will accrue to society in several broad categories, including improved environmental quality, enhanced aquatic resource value for human use, reduced human health risks, and increased productivity in economic activities that are adversely affected by airport deicing pollutants discharges. This section provides a qualitative and quantitative discussion of benefits associated with the final regulatory options.

4.3.1 Airport Actions and Benefits under Final Regulatory Options

In assessing potential benefits from reducing airport deicing pollutant discharges, EPA used information on deicing pollutant environmental behavior, pollutant effects on the aquatic environment, human use of aquatic resources, and human health; deicing pollutant discharge levels under current conditions and under each final regulatory option; and characteristics of surface and ground water resources potentially affected by deicing pollutant discharges.

Table 4-3 and *Table 4-4* list the airports addressed by each regulatory option along with the following information:

- EPA's estimates of ammonia and COD discharge reductions associated with each airports ADF collection and treatment and pavement deicer substitution actions;
- Whether the airport discharges deicing pollutants directly to a water body listed as impaired under Section 303(d) of the Clean Water Act;
- Whether the airport property is above a groundwater aquifer and if that aquifer supplies drinking water (US EPA 2006c); and
- Information on aquatic resources (drinking water intakes, federal lands, and park lands) within 10 miles downstream of airport outfalls.[3]

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[3] Source files include the drinking water intake point file from EPA's Reach Address Database (RAD); national atlas of the U.S. federal land boundaries; ESRI U.S. GDT park landmarks (includes U.S. national, state, and local parks); and U.S. Fish and Wildlife NWRA boundaries.

Table 4-3. Option 1 – Airport Load Reductions and Environmental Benefits

Airport Name	Pavement Deicer Ammonia (pounds)	COD Discharge Reduction (pounds)		303(d) Listed Waters at the Outfall[1]	Above an Aquifer[2]	Within 10 Miles Downstream of Airport Outfall(s)		
		Aircraft Deicing Fluids	Pavement Deicers			Drinking Water Intake	Federal Lands	Park Lands
Albuquerque Intl Sunport	0	119,915	0		DW			
Austin Straubel International	25,387	0	69,240	P	DW			
Bethel	38,105	0	103,927					
Boise Air Terminal/Gowen Field	152,740	0	416,584		DW			
Bradley International	9,478	0	25,849	P	X			X
Central Wisconsin	69,856	0	190,526					
Charlotte/Douglas International	84,821	510,138	231,340		X			X
Eppley Airfield	0	412,933	0	X	DW	X		
Fairbanks International	187,883	0	512,432		DW			
Fort Wayne International	161,593	0	440,728		DW	X		
General Edward Lawrence Logan International	5,782	3,567,358	15,769	P	X			
Glacier Park International	189	0	514		DW		X	
John F Kennedy International	0	2,010,543	0	P			X	X
Juneau International	270,506	0	737,779					
La Guardia	0	1,644,524	0	P				
Manchester	20,844	669,225	56,851		X	X		X
Memphis International	0	759,100	0	X	X			
Newark Liberty International	0	4,197,448	0	P	X			
Northwest Arkansas Regional	10,186	0	27,782		X			
Piedmont Triad International	52,441	255,757	143,028	X	DW	X		X
Port Columbus International	0	1,141,588	0	P				X
Portland Intl	0	208,513	0		X			
Raleigh-Durham International	35,841	381,179	97,753		DW			X
Ralph Wien Memorial	5,659	0	15,435		X			
Reno/Tahoe International	6,330	138,835	17,265		DW			
Ronald Reagan Washington National	44,141	0	120,391	P	X		X	X
Salt Lake City International	634,519	0	1,730,588					
Seattle-Tacoma Intl	0	585,861	0		DW			X
South Bend Regional	18,358	0	50,070		DW			

[1] P = Impairment potentially linked to airport deicing.

[2] DW = Airport located above an aquifer used for drinking water.

Table 4-3. Option 1 – Airport Load Reductions and Environmental Benefits

Airport Name	Pavement Deicer Ammonia (pounds)	COD Discharge Reduction (pounds)		303(d) Listed Waters at the Outfall[1]	Above an Aquifer[2]	Within 10 Miles Downstream of Airport Outfall(s)		
		Aircraft Deicing Fluids	Pavement Deicers			Drinking Water Intake	Federal Lands	Park Lands
Spokane International	281,824	0	768,648		X			
Stewart International	85,905	0	234,299					
Ted Stevens Anchorage International	1,423,212	0	3,881,674		X			
Yeager	15,572	0	42,471			X		

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[1] P = Impairment potentially linked to airport deicing.
[2] DW = Airport located above an aquifer used for drinking water.

Table 4-4. Option 2 – Airport Load Reductions and Environmental Benefits

Airport Name	Pavement Deicer Ammonia (pounds)	COD Discharge Reduction (pounds)		303(d) Listed Waters at the Outfall[1]	Above an Aquifer[2]	Within 10 Miles Downstream of Airport Outfall(s)		
		Aircraft Deicing Fluids	Pavement Deicers			Drinking Water Intake	Federal Lands	Park Lands
Austin Straubel International	25,387	0	69,240	P	DW			
Bethel	38,105	0	103,927					
Boise Air Terminal/Gowen Field	152,740	0	416,584		DW			
Bradley International	9,478	0	25,849	P	X			X
Central Wisconsin	69,856	0	190,526					
Charlotte/Douglas International	84,821	255,069	231,340		X			X
Eppley Airfield	0	206,466	0	X	DW	X		
Fairbanks International	187,883	0	512,432		DW			
Fort Wayne International	161,593	0	440,728		DW	X		
General Edward Lawrence Logan International	5,782	1,783,679	15,769	P	X			
Glacier Park International	189	0	514		DW		X	
John F Kennedy International	0	1,005,272	0	P			X	X
Juneau International	270,506	0	737,779					
La Guardia	0	822,262	0	P				
Manchester	20,844	334,613	56,851		X	X		X
Memphis International	0	379,550	0	X	X			
Newark Liberty International	0	2,098,724	0	P	X			
Northwest Arkansas Regional	10,186	0	27,782		X			
Piedmont Triad International	52,441	127,879	143,028	X	DW	X		X
Port Columbus International		570,794	0	P				X
Raleigh-Durham International	35,841	190,589	97,753		DW			X
Ralph Wien Memorial	5,659	0	15,435		X			
Reno/Tahoe International	6,330	0	17,265		DW			
Ronald Reagan Washington National	44,141	0	120,391	P	X		X	X
Salt Lake City International	634,519	0	1,730,588					
Seattle-Tacoma Intl	0	292,931	0		DW			X
South Bend Regional	18,358	0	50,070		DW			
Spokane International	281,824	0	768,648		X			
Stewart International	85,905	0	234,299					
Ted Stevens Anchorage International	1,423,212	0	3,881,674		X			
Yeager	15,572	0	42,471			X		

[1] P = Impairment potentially linked to airport deicing.
[2] DW = Airport located above an aquifer used for drinking water.

Table 4-5. Option 3 – Airport Load Reductions and Environmental Benefits

Airport Name	Pavement Deicer Ammonia (pounds)	Pavement Deicers COD Discharge Reduction (pounds)	303(d) Listed Waters at the Outfall[1]	Above an Aquifer[2]	Within 10 Miles Downstream of Airport Outfall(s): Drinking Water Intake	Federal Lands	Park Lands
Austin Straubel International	25,387	69,240	P	DW			
Bethel	38,105	103,927					
Boise Air Terminal/Gowen Field	152,740	416,584		DW			
Bradley International	9,478	25,849	P	X			X
Central Wisconsin	69,856	190,526					
Charlotte/Douglas International	84,821	231,340		X			X
Fairbanks International	187,883	512,432		DW			
Fort Wayne International	161,593	440,728		DW	X		
General Edward Lawrence Logan International	5,782	15,769	P	X			
Glacier Park International	189	514		DW		X	
Juneau International	270,506	737,779					
Manchester	20,844	56,851		X	X		X
Northwest Arkansas Regional	10,186	27,782		X			
Piedmont Triad International	52,441	143,028	X	DW	X		X
Raleigh-Durham International	35,841	97,753		DW			X
Ralph Wien Memorial	5,659	15,435		X			
Reno/Tahoe International	6,330	17,265		DW			
Ronald Reagan Washington National	44,141	120,391	P	X		X	X
Salt Lake City International	634,519	1,730,588					
South Bend Regional	18,358	50,070		DW			
Spokane International	281,824	768,648		X			
Stewart International	85,905	234,299					
Ted Stevens Anchorage International	1,423,212	3,881,674		X			
Yeager	15,572	42,471			X		

[1] P = Impairment potentially linked to airport deicing.
[2] DW = Airport located above an aquifer used for drinking water.

Table 4-6 presents the total COD and ammonia discharge reductions associated with each of the regulatory options.

Table 4-6: Annual Pollutant Discharge Reductions under Regulatory Options

Regulatory Option	ADF COD (million pounds)	Pavement Deicer COD (million pounds)	Pavement Deicer Ammonia (million pounds)
Option 1	16.6	12.0	4.4
Option 2	13.8	12.0	4.4
Option 3	0	12.0	4.4

The totals for each regulatory option in *Table 4-6* are greater than the sum of the reductions presented for individual airports in *Table 4-3* and *Table 4-4*. This is because the totals in *Table 4-6* reflect discharge reductions associated with all airports in scope of the final regulatory options, whereas Table 4-3 and *Table 4-4* present reductions associated only with airports EPA surveyed. EPA calculated the discharge reductions associated with these airports by using statistical weighting factors associated with EPA's Airport Deicing Questionnaire (US EPA 2006c). For additional information on the calculation of discharge reductions associated with each regulatory option, see EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010).

Table 4-6 presents discharge reductions only for COD and ammonia. The final regulatory options will reduce discharges of other pollutants, as well (see *Chapter 2*), but EPA does not have sufficient information at this time to quantify those reductions.

4.4 Expected Ecological, Human Aquatic Resource Use, and Human Health Benefits

The final regulatory options will reduce discharges of chemical oxygen demand (COD), ammonia from urea pavement deicers, and other airport deicing product chemicals from selected airports. EPA anticipates that these discharge reductions will improve receiving water characteristics, including pollutant levels, aesthetic problems, aquatic community health, and utility for human needs and health.

4.4.1 Ecological Benefits

Ecological benefits from the regulation include protection of fresh- and saltwater plants, invertebrates, fish, and amphibians, and other aquatic organisms, as well as terrestrial wildlife and birds that prey on aquatic organisms exposed to airport deicing pollutants. The final regulation will reduce the presence and discharge of various pollutants to aquatic ecosystems currently under stress (e.g., 303(d) listed water bodies). The drop in pollutant discharges would help reestablish productive ecosystems in damaged waterways, protect resident species, including threatened and endangered species where present, and reduce the severity and frequency of fish kill events.

4.4.2 Human Health Benefits

As discussed in *Chapters 2 and 3* of this document, EPA identified several possible health risks and incidents of complaint by members of the public associated with certain ADF and pavement deicer components. To the extent current discharges contribute to human health risk, reducing airport deicing pollutant discharges to the nation's waterways will generate human health benefits by reducing risk of non-cancer and cancer toxic effects from fish and water consumption and contact.

Human health benefits are typically analyzed by estimating the change in the expected number of adverse human health events in the exposed population resulting from a reduction in effluent discharges. EPA, however, did not quantify changes in human health risk resulting from the final regulatory options due to unavailability of dose-response functions for many chemicals of potential concern and the complexity of many chemical's environmental behavior.

In concept, the value of these health effects to society is the monetary value that society is willing to pay to avoid the health effects, or the amount that society would need to be compensated to accept increases in the number of adverse health events. Willingness to pay (WTP) values are generally considered to provide a fairly comprehensive measure of society's valuation of the human and financial costs of illness associated with the costs of health care, losses in income, and pain and suffering of affected individuals and of their family and friends. Another measure that is typically used in assessing human health benefits is the cost of an illness. Cost of an illness is the direct medical costs of treating a health condition (e.g., reproductive problems), and can be used to value changes in health risk from reduced exposure to pollutants such as ethylene glycol.

4.4.3 Human Use of Aquatic Resource Benefits

Improvements in ecosystems and habitats and enhanced aesthetic quality of surface waters enhance human use and enjoyment of these areas. In particular, reducing instances of objectionable odors, colors, and foaming that have been frequently reported in surface waters affected by ADFs and pavement deicers is expected to enhance a broad range of recreational uses of the affected waterbodies, including swimming, boating, fishing, water skiing, and use of park lands adjacent to affected waterbodies. Improvements will also enhance quality of life for people who live near affected waterbodies. The regulation will also augment nonuse values (e.g., option, existence, and bequest values) of the affected water resources.

EPA's review of 45 surface water valuation studies conducted between 1981 and 2002 demonstrates that society places a significant value on improving and/or protecting its water resources. Total WTP (including use and non-use values) for water quality improvements over the sample of 45 studies ranged from $8.72 to $525.91, with a mean value of $120.54 (US EPA 2008c). WTP values from published studies vary widely depending on the study (e.g., methodology and sample size) and resource characteristics (e.g., water body characteristics, the magnitude of water quality improvements, the geographic scope of improvement). For example, WTP for reducing nutrient pollution and eutrophication impacts estimated by Shrestha and Alavapati (2004) ranges from to $84.15 to $106.71 (2008$, annualized). A study by Lindsey (1994) found that WTP to meet nutrient pollution reduction goals in the Chesapeake Bay ranged from $34.90 to $106.78 (2008$), depending upon the choice of outliers and protest bids excluded. Values for oil and toxic materials reductions were also available in the same review. A study by Phaneuf et al. (1998) found that WTP for a 20% reduction in toxins at fishery sites in North Carolina's Tar-Pamlico basin ranges from $14.59 to $193.46 (2008$), depending upon the models utilized. Based on the evidence from the published literature, EPA estimates that nonmarket benefits from water quality improvements resulting from reduced deicing pollutant discharges are likely to be substantial.

Reduced airport deicing discharges should improve groundwater and drinking water sources located under or near airports subject to regulation. Drinking water contaminated by deicing pollutants may pose health risks or have an unpleasant taste and odor which may cause concerns regarding potential adverse health effects. Protection of groundwater sources from contamination by airport deicing pollutants is of particular concern because households that use private wells usually do not treat or regularly test their drinking water for contamination.

The appropriate measure of the economic value of clean groundwater achieved through a ban on MTBE use in gasoline is option price. This measure is commonly used when uncertainty is present in the analysis. Option price is defined as an individual's maximum WTP to secure the option to use a resource or commodity in the future (Desvousges et al. 1987 and Freeman 2003). Option price is a measure of the total economic value an individual places on protecting groundwater quality. Protecting groundwater quality provides a number of services to groundwater users, including avoidance of higher drinking water costs (e.g., avoided treatment or replacement costs), elimination of potential health concerns associated with consumption of bad tasting water, general aesthetic enjoyment derived from a clean environment, and any nonuse values associated with protecting groundwater quality (e.g., bequest value, existence value).

Based on the meta-analysis of groundwater valuation studies, WTP values for protection of groundwater from contamination by pollutants other then nitrates and pesticides (i.e., "Other" pollutants) range from \$154.74 to \$235.25 for residential wells. For small public water supply systems, household WTP values range from \$78 to \$122.03, and for public water supply systems, household WTP values range from \$78 to \$233.99 (2008\$) (US EPA 2001). All are annual values.

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Appendix A: Detailed Characterization of Airport Deicing Products

Table A-1: Surveyed U.S. Commercial Airports- Chemical Pavement Deicer Usage

Pavement Deicer Chemical	2002/2003 Total Surveyed Airport Usage (tons/year)	2003/2004 Total Surveyed Airport Usage (tons/year)	2004/2005 Total Surveyed Airport Usage (tons/year)	Average Total Surveyed Airport Usage (tons/year)[1]	Percentage of Chemical Usage
Potassium acetate	22,803	20,267	20,029	21,185	65
Propylene glycol-based fluids	3,317	4,147	2,884	3,089	9
Urea (airside)	3,015	3,804	4,031	3,620	11
Sodium acetate	2,815	3,195	2,663	2,888	9
Sodium formate	1,663	694	1,359	1,290	4
Ethylene glycol-based fluids	1,038	465	691	731	2

[1] Based on the 90 airports reporting airfield deicing chemical use. The 3 year average is not a straight average of the total annual amounts; the average for each airport was evaluated and calculated separately.

Source: EPA Airport Deicing Questionnaire (2006c). For additional details, see EPA (2010).

Table A-2: Chelating Agents

Characteristics	Ethylene diamine tetra acetic acid (EDTA)	Diethylene triamine penta acetic acid (DTPA , DTAA)
CASRN	60-00-4	67-43-6
Formula	$C_{10}H_{16}N_2O_8$	$C_{14}H_{23}N_3O_{10}$
Water solubility, g/L	1.0	4.8
Log K_{OW}	-3.86	-4.91
Log K_{OC}	1.99	
Henry's Law constant (atm-m^3/mole)	$7.69x10^{-16}$	
Vapor pressure (mm Hg)	$2x10^{-12}$	
Environmental partitioning summary	Both volatilization and adsorption to soils and particulates are expected to be negligible.	
Degradation summary	Both aerobic and anaerobic biodegradation are negligible for un-complexed EDTA. Photolysis of EDTA complexed with Fe(III) is likely to be the primary route of degradation, but only where exposed to bright light. Otherwise, degradation appears to be minimal.[a]	Relatively resistant to biodegradation, especially where the microbial community is unacclimated.
Degradation products		
Half-life	In the upper layer of surface water directly exposed to the sun, the half-life of EDTA*Fe(III) was approximately 11 minutes.	
Transport rate summary	EDTA is highly mobile in soil, sediment, and water.	DTPA is expected to be highly mobile in soil, sediment, and water.
Mixture effects	Both of these substances can increase the mobility of potentially toxic metals. They readily form complexes with metal ions, bringing them into the soluble phase in soils, sediments, and water. This property is being investigated and exploited for extracting and phytoremediating toxic metals.[a]	
Additional notes	Degradation of uncomplexed EDTA appears to be minimal; photolysis of metal-complexed EDTA could be rapid in the presence of direct sunlight, and this may be the primary route of degradation. EDTA is commonly detected in surface water; it is not removed by standard wastewater or drinking water treatment processes, but may be degraded by UV treatment of drinking water.[a] Most characteristics of these compounds are expected to be similar.	

Source: Oviedo and Rodriguez (2003).
Blank cells indicate information not readily available to EPA at this time.

Table A-3: Freezing Point Depressants: Sugars

Characteristics	Dulcitol	Mannitol	Sorbitol
CASRN	608-66-2	69-65-8	50-70-4
Formula	$C_6H_{14}O_6$	C6H14O6	$C_6H_{14}O_6$
Water solubility, g/L	31		Freely soluble up to 83%
Log K_{OW}			-2.2
Log K_{OC}			0.30
Henry's Law constant (atm-m^3/mole)			7.3×10^{-13}
Vapor pressure (mm Hg)			4.9×10^{-9}
Environmental partitioning summary	Not expected to volatilize or to adsorb to soils or particulates.		
Half-life			
Degradation summary	Biodegradation, the primary route of degradation, is expected to be very rapid. Hydrolysis and photolysis are not expected.		
Degradation products	Carbon dioxide, water, and microbial biomass.		
Transport rate summary	All of these substances may be highly mobile in water and soil, but biodegradation is likely to limit the distance of transport in surface water, groundwater, and soil.		
Mixture effects			
Degradation products	CO_2		
Additional notes	Characteristics of these sugar alcohols are likely to be relatively similar.		

Blank cells indicate information not readily available to EPA at this time.

Table A-4: Freezing Point Depressants: Acetates

Characteristics	Potassium acetate	Sodium acetate
CASRN	127-08-2	127-09-3 (anhydrous)
Formula	$C_2H_3KO_2$	$C_2H_3NaO_2$
Water solubility, g/L		1,190 at 0° C
Log K_{OW}		
Log K_{OC}	-3.72	
Henry's Law constant (atm-m^3/mole)		
Vapor pressure (mm Hg)		7.08×10^{-7}
Environmental partitioning summary	These substances are not expected to volatilize. They are quite soluble in water. Depending on site-specific factors, the inorganic ions may adsorb or complex with soil or water constituents, but may also remain dissolved in surface water and groundwater. Acetate should be rapidly biodegraded under aerobic conditions in surface water, groundwater, and soil.	
Half-life		
Degradation summary		
Degradation products	The cations calcium, magnesium, potassium, and sodium are liberated, and acetate degradation produces bicarbonate, carbon dioxide, and water[a].	
Transport rate summary	Depends on a combination of degradation rate and interaction with soils/sediments. May be very site-specific.	
Mixture effects	Formate can decrease the breakdown of acetate in anaerobic environments.	
Additional notes		

Source: D'Itri (1992).
Blank cells indicate information not readily available to EPA at this time.

Table A-5: Freezing Point Depressants: Formates and Lactates

Characteristics	Potassium formate	Sodium formate	Ethyl lactate	Sodium lactate
CASRN	590-29-4	141-53-7	97-64-3	72-17-3
Formula	$CH_2O_2.K$	$CH_2O_2.Na$	$C_5H_{10}O_3$	$C_3H_6O_3.Na$
Water solubility, g/L	3,310 at 18° C	972 at 20° C	Miscible with water	1,000
Log K_{OW}			-0.18	
Log K_{OC}			1	
Henry's Law constant (atm-m^3/mole)			5.8×10^{-7}	
Vapor pressure (mm Hg)			3.75	
Environmental partitioning summary	These substances are not expected to volatilize. They are quite soluble in water, and may be expected to ionize freely. Depending on site-specific factors, the inorganic ions may adsorb or complex with soil or water constituents but may also remain dissolved in surface water and groundwater.			
Half-life			In water: hydrolysis: 72 days at pH 7; 7 days at pH 8.	
Degradation summary	Formate is slowly hydrolyzed in water, and can be anaerobically degraded by methanogens.		Hydrolysis to ethanol and lactate in surface waters may be an important degradation pathway.	
Degradation products	Release of potassium and sodium cations and microbial biomass.			
Transport rate summary	Depends on a combination of degradation rate and interaction with soils/sediments. May be very site-specific.			
Mixture effects	60% ethyl lactate has a strong cosolvency effect and can increase the solubility of dense non-aqueous phase liquid (DNAPL) compounds by orders of magnitude.			
Additional notes				

Redox Tech (2008) and US NLM (2008).
Schauer et al. (1982) and Redox Tech (2008).
Blank cells indicate information not readily available to EPA at this time.

Table A-6: Freezing Point Depressants: Other

Characteristics	Sodium pyrrolidone carboxylate	Glycerol	Isopropanol	Proline	Erythritol	Pentaerythritol
CASRN	54571-67-4	56-81-5	67-63-0	147-85-3	149-32-6	115-77-5
Formula	$C_5H_7NO_3$.Na	$C_3H_8O_3$	C_3H_8O	$C_5H_9NO_2$	$C_4H_{10}O_4$	$C_5H_{12}O_4$
Water solubility, g/L		Freely soluble	1000	1620	610	72.3
Log K_{OW}		-1.76	0.05	-2.54	-2.29	-1.69
Log K_{OC}			1.4			
Henry's Law constant (atm-m^3/mole)		1.73×10^{-8}	8.10×10^{-6}	1.92×10^{-9}		4.1×10^{-10}
Vapor pressure (mm Hg)		$1.58 \mathrm{X} 10^{-4}$	45.4	3.77×10^{-9}		15.1
Environmental partitioning summary		Volatilizes more slowly than water. Should not adsorb to soil or particulates.	Volatilization is expected to be an important route of removal from soil and water. Should not adsorb to soil or particulates.			Readily forms complexes with metal ions; this is likely to retard its mobility in soils and sediments.
Half-lives		Atmospheric degradation: 33 h to 3.2 d.	Volatilization from river: 57 h; from lake: 29 d. Aerobic degradation in sludge: <1 d to 48 d.			
Degradation summary		Rapid, both aerobic and anaerobic.	Rapid, both aerobic and anaerobic.			3 to 15 days lag time before significant degradation begins.
Degradation products						
Transport rate summary		Should move very rapidly through soil and water, but range may be limited by rapid degradation.				
Mixture effects						
Additional notes	With the exception of the erythritols, these chemicals are not expected to share similar properties.					

Blank cells indicate information not readily available to EPA at this time.

Table A-7: Freezing Point Depressants: Ethylene Glycols

Characteristics	Poly-ethylene glycol, molecular weight from 62 to 106	Ethylene glycol	Diethylene glycol[a]	Triethylene glycol
CASRN	25322-68-3	107-21-1	111-46-6	112-27-6
Formula	$(C_2H_4O).(H_2O)n$	$C_2H_6O_2$	$C_4H_{10}O_3$	$C_6H_{14}O_4$
Water solubility, g/L	Freely soluble	Freely soluble	Freely soluble	Freely soluble
Log K_{OW}		-1.36	1.47	-1.98
Log K_{OC}		1 (K_{OC})	1 (K_{OC})	1
Henry's Law constant (atm-cu m^3/mole)		6.00×10^{-8}	2×10^{-9}	3.2×10^{-11}
Vapor pressure (mm Hg)		0.092	1	1.32×10^{-3}
Environmental partitioning summary	Volatilization is not expected to be an important pathway for these glycols. Very high mobility is expected for all glycols in soil, sediment, and water. Experimentally determined adsorption of ethylene glycol to four soils (two clay, two sandy clay) ranged from 0-0.5%. Tracer experiments have shown that ethylene glycol moves through soil with water.			
Half-lives		Atmospheric half-life: 50 h at 25º C.	Atmospheric half-life: 13 h.	
Degradation summary		Very rapid degradation rates in soil, sediment, and water. Soils: 90 to 100% degradation of ethylene glycol was observed in various field soils in 2 to 12 days (temperatures not known); ethylene glycol in aircraft deicing or anti-icing fluid formulation was completely degraded in runway-side soils within 29 days at 8° C. Water: Hydrolysis and photolysis are not expected to be significant. Ethylene glycol in river water degraded completely in three days at 20º C and in 5 to 14 days at 8º C. Aerobic degradation of ethylene glycol may be essentially complete in less than one to four days under optimal conditions in water or treatment systems, but the impact of the full theoretical biological oxygen demand may not be observed for several weeks.	Water: Diethylene glycol in aerobic river water showed little degradation during winter.	Soils: Triethylene glycol in aerobic soil was completely degraded within 7 to 11 days.
Degradation lag time	For unacclimated microbial communities, there is often a lag of several days before glycol degradation begins.			
Transport rate summary	Expected to have very high mobility in soil, sediment, and water.			
Mixture effects	Triazoles decrease the degradation rate of glycols. Low temperatures may also greatly decrease the degradation rates of glycols.			

Table A-7: Freezing Point Depressants: Ethylene Glycols

Characteristics	Poly-ethylene glycol, molecular weight from 62 to 106	Ethylene glycol	Diethylene glycol[a]	Triethylene glycol
Additional notes	Ethylene glycols are expected to share somewhat similar properties, except for polyethylene glycols. Formulated polyethylene glycol products contain different mixtures of polymers, and the properties of the products will vary based on the size and shape of the polymers they contain. All of these substances are expected to be rapidly degraded under aerobic and anaerobic conditions.			

a. Not currently used in the U.S.

Blank cells indicate information not readily available to EPA at this time.

Table A-8: Freezing Point Depressants: Propylene Glycols

Characteristics	Propylene glycol	1,3-Propylene glycol	1, 1'-oxybis-2-propanol (dipropylene glycol)
CASRN	57-55-6	504-63-2	25265-71-8
Formula	$C_3H_8O_2$		$C_6H_{14}O_3$
Water solubility, g/L	Freely soluble	Freely soluble	Freely soluble
Log K_{OW}	-0.92	-1.04	-1.486
Log K_{OC}	0.90		1 (K_{OC})
Henry's Law constant (atm-m^3/mole)	$1.3x10^{-8}$	$1,74x10^{-7}$	$5.6x10^{-9}$
Vapor pressure (mm Hg)	0.13	0.0441	0.032
Environmental partitioning summary	Very high mobility in soils, sediments, and water. Not expected to volatilize readily.		
Half-lives			
Degradation summary	Propylene glycol was not observed to degrade at 4º C, and only degraded at 20 C in soil that was rich in organic matter[a].		
Degradation lag time	For unacclimated microbial communities, there is often a lag of several days before glycol degradation begins.		
Transport rate summary			
Mixture effects			
Additional notes			

Source: Jaesche et al. (2006).
Blank cells indicate information not readily available to EPA at this time.

Table A-9: Freezing Point Depressants: Urea and Metabolites

Characteristics	Urea	Ammonia
CASRN	57-13-6	7664-41-7
Formula	CH_4N_2O	H_3N
Water solubility, g/L	545	"31%"
Log K_{OW}	-2.11	0.23
Log K_{OC}	0.903	
Henry's Law constant (atm-m^3/mole)		1.61×10^{-5}
Vapor pressure (mm Hg)	1.2×10^{-5}	7.51×10^{3}
Environmental partitioning summary		
Half-lives		
Degradation summary		
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes		

Blank cells indicate information not readily available to EPA at this time.

Table A-10: Thickeners: Acrylic Acid Polymers

Characteristics	Carbomer	Carbopol 672	Carbopol 934	Carbopol 1610	Carbopol 1621	Carbopol 1622	Polymer of acrylic acid
CASRN	Trade name	Trade name	9007-16-3	Trade name	Trade name	Trade name	79-10-7
Formula	polymer of acrylic acid	polymer of acrylic acid	polymer of acrylic acid	polymer of acrylic acid	polymer of acrylic acid	polymer of acrylic acid	polymer of acrylic acid
Water solubility, g/L							$1x10^3$
Log K_{OW}							0.35
Log K_{OC}							1.63
Henry's Law constant (atm-m^3/mole)							$3.2x10^{-7}$
Vapor pressure (mm Hg)							3.97
Environmental partitioning summary	Not expected to volatilize from water or moist soil. Slow volatilization from dry soil is possible. Not expected to adsorb to soils or particulates; potential for transport in soil is high.						
Half-lives							
Degradation summary	Non-polymerized (monomeric) acrylic acid readily biodegrades both aerobically and anaerobically; it reached 68% of its theoretical BOD in 2 weeks using an activated sludge inoculum, and in a 42-day anaerobic screening study using a sewage seed inoculum, 71% of acrylic acid was degraded. However, biodegradability decreases with increasing number of polymerized units and increasing formula molecular weight, dropping off sharply between MWs 700 and 1,000, and for polymers with more than seven units[a]. It appears that monomers and dimers of acrylic acid are completely biodegradable, but there are indications polymers of three to seven units are incompletely biodegraded[a].						
Degradation lag time							
Transport rate summary							
Mixture effects							
Additional notes	May be contaminated by low-ppm levels of metals.						

Source: Larson et al. (1997).
Blank cells indicate information not readily available to EPA at this time.

Table A-11: Thickeners: Natural Gums

Characteristics	Kappa-carrageenan	Iota-carrageenan	Welan gum	Xanthan gum
CASRN	Mixture	9062-07-1	Mixture	11138-66-2
Formula				
Water solubility, g/L	10			
Log K_{OW}				
Log K_{OC}				
Henry's Law constant ($atm\text{-}m^3/mole$)				
Vapor pressure (mm Hg)				
Environmental partitioning summary				
Half-lives				
Degradation summary				
Degradation lag time				
Transport rate summary				
Mixture effects				
Additional notes	Naturally-derived high-molecular-weight polysaccharide gums. Tend to be highly water soluble, and are expected to be biodegradable, although biodegradation information was not available.			

Blank cells indicate information not readily available to EPA at this time.

Table A-12: Thickeners: Other

Characteristics	Hydroxyethylcellulose
CASRN	9004-62-0
Formula	C_2-H_6-O_2.x-Unspecified
Water solubility g/L	Freely soluble
Log KOW	
Log KOC	
Henry's Law constant (atm-m^3/mole)	
Vapor pressure (mm Hg)	
Environmental partitioning summary	
Half-lives	
Degradation summary	Cellulose gums are generally slowly biodegraded. Reported values for the biological oxygen demand of two samples of hydroxyethyl cellulose are 7,000 & 18,000 ppm, respectively, after 5 days of incubation.
Degradation lag time	
Transport rate summary	
Mixture effects	
Additional notes	

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Table A-13: Surfactants: Alcohol Ethoxylates

Characteristics	Decyl alcohol ethoxylate	Lauryl alcohol ethoxylate	Lauryl alcohol phosphoric acid - ester ethoxylate
CASRN	26183-52-8	Category	-
Formula	CH3(CH2)n(OCH2 CH2)yOH[a]	CH3(CH2)n(OCH2 CH2)yOH[a]	CH3(CH2)n(OCH2 CH2)yOH[a]
Water solubility, g/L			
Log K_{OW}			
Log K_{OC}	In general, log K_d is a better predictor of behavior than Kow for these substances[a]. Log K_d, as with the other physicochemical parameters, varies by ethoxymer. The formula below, as given by Belanger et al. (2006) permits the calculation of an estimated log K_d. log Kd = 0.331 * (alkyl chain length) – 0.009 * (ethoxylate chain length) – 1.126		
Henry's Law constant (atm-m^3/mole)			
Vapor pressure (mm Hg)			
Environmental partitioning summary	Sorption may be important, and is likely to vary by ethoxymer.		
Half-lives			
Degradation summary	Aerobic degradation may be rapid.		
Degradation lag time			
Transport rate summary			
Mixture effects			
Additional notes			

Source: Belanger et al. (2006).
Blank cells indicate information not readily available to EPA at this time.

Table A-14: Surfactants: Alkylbenzene Sulfonates

Characteristics	Sodium alkylbenzene sulfonate	Siponate A-2466, sodium dodecylbenzene sulfonate	Siponate DDB-40, sodium dodecylbenzene sulfonate	Siponate DS, sodium dodecylbenzene sulfonate	Sandocorin 8132, sodium dodecylbenzene sulfonate
CASRN	68411-30-3	Trade name	Trade name	Trade name	Trade name
Formula					
Water solubility, g/L					
Log K_{OW}					
Log K_{OC}					
Henry’s Law constant (atm-m^3/mole)					
Vapor pressure (mm Hg)					
Environmental partitioning summary					
Half-lives					
Degradation summary					
Degradation lag time					
Transport rate summary					
Mixture effects					
Additional notes					

Blank cells indicate information not readily available to EPA at this time.

Table A-15: Surfactants: Alcohol Ethoxylates

Characteristics	Alcohol ethoxylates	Tergitol TMN-10, branched secondary alcohol ethoxylate	Aliphatic alcohol ethoxylates
CASRN	Category	Trade name	Category
Formula			
Water solubility, g/L			
Log K_{OW}			
Log K_{OC}			
Henry's Law constant (atm-m^3/mole)			
Vapor pressure (mm Hg)			
Environmental partitioning summary			
Half-lives			
Degradation summary			
Degradation lag time			
Transport rate summary			
Mixture effects			
Additional notes			

Blank cells indicate information not readily available to EPA at this time.

Table A-16: Surfactants: Alkylphenol Ethoxylates

Characteristics	Alkylphenol ethoxylates	Octylphenol ethoxylates	Nonylphenol ethoxylates
CASRN	Category	Category	Category
Formula			C_9H_{19}-$C_6H_4O(CH_2CH_2O)_nH$[a]
Water solubility, g/L	All are highly soluble in water, but solubility varies by ethoxymer[a].		
Log K_{OW}			
Log K_{OC}			
Henry's Law constant (atm-m^3/mole)			
Vapor pressure (mm Hg)			
Environmental partitioning summary	Not expected to volatilize. Likely to partition to organic matter or minerals in soil, but this tendency varies by ethoxymer, and migration through the soil has been observed. In water, as in soil, may sorb to organic matter or particulates[a].		
Half-lives	3-26 d under ideal aerobic conditions with acclimated community[b]		
Degradation summary	Degradation varies by ethoxymer, and tends to produce some recalcitrant compounds[a].		
Degradation lag time			
Transport rate summary			
Mixture effects	Surfactants can increase the solubility and transport of less soluble substances.		
Additional notes	These are all categories; therefore, the specific physical properties vary by ethoxymer. Alkylphenol ethoxylates are antifoaming agents[c]. Degradation of these compounds can produce more persistent octyl- and nonylphenols.		

Blank cells indicate information not readily available to EPA at this time.

a. Environment Canada (2002).

b. Staples et al. (2001).

c. Bennie et al. (1997).

Table A-17: Surfactant Breakdown Products: Alkylphenols

Characteristics	Octylphenol	Nonylphenol
CASRN	Category	25154-52-3 (category)
Formula	$C_{14}H_{22}O$	
Water solubility, g/L		$5.43\text{x}10^{-3a}$
Log K_{OW}	4.12[b]	4.1-4.7[a]
Log K_{OC}	4.01 to 4.65[b]	
Henry's Law constant (atm-m^3/mole)		$1.09\text{x}10^{-4a}$
Vapor pressure (mm Hg)		$3.4\text{x}10^{-5a}$
Environmental partitioning summary	Unlikely to volatilize from soils. Likely to partition to sediments and soil minerals[b].	Although volatility is low, can volatilize from water and result in high atmospheric concentrations. Unlikely to volatilize from soils. Likely to partition to sediments and mineral particles in water and soil, but can still leach through soils[a].
Half-lives	7-50 d in river water[c].	2.4 hours to 0.74 d in water. Photolytic half-life in upper layer of surface water is 10-15 hours; in deeper layers, it is much slower. In a sediment mesocosm, a half-life of 66 days was observed[a].
Degradation summary	Relatively rapid degradation in aerobic river water[c]. Highly recalcitrant to anaerobic degradation in sediments[c].	A biphasic degradation profile has been observed in soils, with relatively rapid initial degradation of 30-50% of applied nonylphenol degrading in the first several weeks, and the remainder degrading with a half-life of approximately 90 days[a].
Degradation lag time		
Transport rate summary	Can leach through soils[b].	Can leach through soils[a].
Mixture effects		
Additional notes		

Blank cells indicate information not readily available to EPA at this time.

a. Environment Canada (2002).

b. Isobe et al. (2001).

c. Christiansen et al. (2002).

Table A-18: Surfactants: Diamines

Characteristics	Oleic acid diamine	Oleyl propylene diamine	Palmitic acid diamine
CASRN	Category	Category	Category
Formula			
Water solubility, g/L			
Log K_{OW}			
Log K_{OC}			
Henry's Law constant (atm-m^3/mole)			
Vapor pressure (mm Hg)			
Environmental partitioning summary			
Half-lives			
Degradation summary			
Degradation lag time			
Transport rate summary			
Mixture effects			
Additional notes			

Blank cells indicate information not readily available to EPA at this time.

Table A-19: Surfactants: Polyethylene Oxide Monomer and Polymer

Characteristics	Ethylene oxide	Ethylene oxide / propylene oxide block copolymers
CASRN	75-21-8	Category
Formula	C_2H_4O	
Water solubility, g/L	Miscible with water	
Log K_{OW}	-0.3	
Log K_{OC}	n/a	
Henry's Law constant (atm-m^3/mole)	1.48X10-4	
Vapor pressure (mm Hg)	1314	
Environmental partitioning summary	Expected to volatilize rapidly from soil. It does not adsorb well to soil, and would be expected to leach readily. In water, volatilization will occur in hours to days.	
Half-lives	Atmospheric half-life estimated at 211 days. The volatilization half-lives of ethylene oxide in a model river and lake are 5.9 hr and 3.8 days, respectively. The half-life for hydrolysis is 9-14 days. In a river die-away test, the rate of degradation was not significantly different than for hydrolysis.	
Degradation summary	Hydrolysis may also be an important mechanism of removal from water. Biodegradation appears to occur more slowly than volatilization, but data are extremely limited. Expected to degrade by hydrolysis in groundwater. Products of degradation by hydrolysis are biodegradable (ethylene glycol and ethylene chlorohydrin).	
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes		

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Table A-20: Surfactants: Other Nonionic Detergents

Characteristics	Emerest 2660 (OEG-12 oleate) (=Polyoxyethylene monoleate)	Emsorb 6900 (peg-20 sorbitan oleate) (=glycol (polysorbate 80))
CASRN	9004-96-0	9005-65-6
Formula	(C_2H_4O) mult-$C_{18}H_{34}O_2$	
Water solubility, g/L	Very soluble	Highly soluble
Log K_{OW}		
Log K_{OC}		
Henry's Law constant (atm-m^3/mole)		
Vapor pressure (mm Hg)		
Environmental partitioning summary		
Half-lives		
Degradation summary		
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes		

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Table A-21: Corrosion Inhibitors and Flame Retardants: Tolyltriazoles

Characteristics	Tolyltriazole	Cobratec TT-50S, tolyltriazole solution
CASRN	29385-43-1	Trade name
Formula	$C_7H_7N_3$	
Water solubility, g/L		
Log K_{OW}		
Log K_{OC}		
Henry's Law constant (atm-m^3/mole)		
Vapor pressure (mm Hg)		
Environmental partitioning summary	Mobile in groundwater.	
Half-lives		
Degradation summary	Unlikely to be readily degradable.	
Degradation lag time		
Transport rate summary		
Mixture effects	Even at very low concentrations, triazoles have been observed to sharply decrease the biodegradability of other components in mixtures.	
Additional notes		

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Table A-22: Corrosion Inhibitors and Flame Retardants: Other Triazoles

Characteristics	Triazoles	Benzyltriazole	Benzotriazole	5-Methyl-1H-Benzotriazole	4-methyl-1H-benzotriazole
CASRN	37306-44-8	-	95-14-7	136-85-6	29878-31-7
Formula	$C_2H_3N_3$		$C_6H_5N_3$	$C_7H_7N_3$	$C_7H_7N_3$
Water solubility, g/L			19.8		
Log K_{OW}			1.44		
Log K_{OC}					
Henry's Law constant (atm-m^3/mole)			3.17×10^{-7}		
Vapor pressure (mm Hg)			4.0×10^{-2}		
Environmental partitioning summary			Expected to be highly mobile in soil. Also, it may protonate in some environmental matrices, and the cationic form should bind to organic material and clays. Volatilization is not expected.		
Half-lives			Half-life for atmospheric degradation by reaction with hydroxyl radicals is estimated at 16 days. May also be subject to direct photolysis.		
Degradation summary			Persists in the environment; apparently not biodegradable.	5-tolyltriazole is much better (aerobically) degradable than the 4-tolyltriazole isomer (in river water samples).[b]	
Degradation lag time					
Transport rate summary					
Mixture effects	Even at very low concentrations, triazoles have been observed to sharply decrease the biodegradability of other components in mixtures.				
Additional notes	Benzotriazole and methylbenzotriazole have been detected in groundwater near an airport, at concentrations in excess of those known to be toxic to microbiota, fish, and invertebrates.[a]				

Blank cells indicate information not readily available to EPA at this time.

a. Cancilla et al. (1998)

b. Weiss and Reemtsma (2005).

Table A-23: Corrosion Inhibitors: Alcohols

Characteristics	Propargyl alcohol
CASRN	107-19-7
Formula	C_3H_4O
Water solubility, g/L	Miscible with water
Log K_{OW}	-0.38
Log K_{OC}	
Henry's Law constant (atm-m^3/mole)	1.1x10-6
Vapor pressure (mm Hg)	15.6
Environmental partitioning summary	Should be highly mobile in soil, and volatilize readily from both moist and dry soils. In water, propargyl alcohol is not expected to adsorb to sediments or suspended solids. Volatilization from the water's surface is expected.
Half-lives	The half-life of propargyl alcohol in an alkaline sandy silt loam (61.5% sand, 31.1% silt, 7.4% clay, pH 7.8, 3.25% organic carbon) was 12.6 days. The half-life in an acidic sandy loam (68% sand, 23.4% silt, 8.6% clay, pH 4.8, 0.94% organic carbon) was 13 days. Modeled volatilization half-lives for a river and lake are 16 and 176 days, respectively. The modeled atmospheric half-life due to degradation by hydroxyl radicals is 37 hours.
Degradation summary	Aerobic degradation in soils is expected, based on the results above, and is also likely in water.
Degradation lag time	
Transport rate summary	
Mixture effects	
Additional notes	

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Table A-24: Corrosion Inhibitors: Nitrite, Nitrate, and Silicate Salts

Characteristics	Sodium nitrate	Sodium nitrite	Sodium silicate	Potassium silicate
CASRN	7631-99-4	7632-00-0	13870-28-5	10006-28-7
Formula	$HNO_3.Na$	$HNO_2.Na$		K_2SiO_3
Water solubility, g/L	912	848	Almost insoluble in cold water; soluble in water with heat and pressure	
Log K_{OW}				
Log K_{OC}				
Henry's Law constant (atm-m^3/mole)				
Vapor pressure (mm Hg)				
Environmental partitioning summary	Nitrite does not volatilize from soil or water.	Nitrate does not volatilize from soil or water.		
Half-lives				
Degradation summary	Aerobically degraded to nitrate.			
Degradation lag time				
Transport rate summary				
Mixture effects				
Additional notes				

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Table A-25: Corrosion Inhibitors: Other Inorganics

Characteristics	Potassium phosphate	Borax
CASRN	7778-53-2	1303-96-4
Formula	$H_3O_4P.3K$	$B_4Na_2O_7.10H_2O$
Water solubility, g/L		593
Log K_{OW}		
Log K_{OC}		
Henry's Law constant (atm-m^3/mole)		
Vapor pressure (mm Hg)		Approximately zero.
Environmental partitioning summary		Not expected to volatilize from soils or water.
Half-lives		
Degradation summary		Persists in soil for a year or more, depending on soil type and rainfall.
Degradation lag time		
Transport rate summary		High mobility in soil with high rainfall; otherwise, sorbs to minerals in soils.
Mixture effects		Biostatic and antiseptic; biodegradation not reported. May inhibit degradation of other substances in mixtures due to antimicrobial activity.
Additional notes		

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Table A-26: Corrosion Inhibitors: Other Organics

Characteristics	Sodium benzoate	Phosphate esters	Thiourea
CASRN	532-32-1	Category	62-56-6
Formula	$C_7H_5NaO_2$		CH_4N_2S
Water solubility, g/L	556		
Log K_{OW}			-1.08
Log K_{OC}			
Henry's Law constant (atm-m^3/mole)			1.98×10^{-9}
Vapor pressure (mm Hg)	3.67×10^{-9}		
Environmental partitioning summary			Is not expected to adsorb to suspended solids and sediment in water. Not expected to volatilize from any medium.
Half-lives			
Degradation summary			Thiourea can degrade in soil by both chemical and microbial degradation, although high levels of thiourea may suppress microbial activity for extended periods of time. In one soil degradation study, thiourea persisted in excess of 15 weeks.
Degradation lag time			
Transport rate summary			Expected to be highly mobile in soils.
Mixture effects			May delay degradation of other components of mixtures due to antimicrobial activity.
Additional notes		((RO)3PO) Phosphoric acids with alkyl or aryl alcohols.	

Blank cells indicate information not readily available to EPA at this time.

Table A-27: Corrosion Inhibitors: Ethanolamines			
Characteristics	**Monoethanolamine**	**Diethanolamine**	**Triethanolamine**
CASRN	141-43-5	111-42-2	102-71-6
Formula	C_2H_7NO	$C_4H_{11}NO_2$	$C_6H_{15}NO_3$
Water solubility, g/L	$1x10^3$	Freely soluble	Freely soluble
Log K_{OW}	-1.31	-1.43	-1
Log K_{OC}			
Henry's Law constant (atm-m^3/mole)	$3.25x10^{-8}$	$3.9x10^{-11}$	$7.1x10^{-13}$
Vapor pressure (mm Hg)	0.404	$1.4x10^{-4}$	$3.59x10^{-6}$
Environmental partitioning summary	Expected to ionize under most environmental conditions (pH 5 to 9), which would favor adsorption to clays and organic matter. Not expected to volatilize from soils or water.		
Half-lives		Days to weeks	
Degradation summary	Biodegradation may be an important pathway of degradation.	Rapid biodegradation expected, following lag time. Aerobic degradation observed.	Aerobic degradation observed.
Degradation lag time	5 d		15 d
Transport rate summary	Binding to clays and organic matter should restrict mobility of ionized ethanolamines in soil. Unionized forms are predicted to be very mobile in soils. In water, they may be transported with particulates.		
Mixture effects			
Additional notes	Degrades to nitrogen dioxide and ammonia.	N-Nitrosodiethanolamine is a degradation product	

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Table A-28: pH Buffers, Phosphate-Based

Characteristics	Dipotassium phosphate	Disodium phosphate (Sodium hydrogen phosphate)
CASRN	7758-11-4	7558-79-4
Formula	$H_3O_4P.2K$	$H_3O_4P.2Na$
Water solubility, g/L	Freely soluble	Freely soluble
Log K_{OW}		
Log K_{OC}		
Henry's Law constant (atm-m^3/mole)		
Vapor pressure (mm Hg)		
Environmental partitioning summary		
Half-lives		
Degradation summary		
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes		

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Table A-29: pH Reducers

Characteristics	Potassium hydroxide	Sodium hydroxide
CASRN	1310-58-3	1310-73-2
Formula	HKO	HNaO
Water solubility, g/L	Freely soluble	Freely soluble
Log K_{OW}		Too low to be measured
Log K_{OC}		
Henry's Law constant (atm-m^3/mole)		
Vapor pressure (mm Hg)		
Environmental partitioning summary		
Half-lives		
Degradation summary		
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes		

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Table A-30: Antifoamers: Silicones

Characteristics	DC 1520, silicone antifoam	Foamban	SAG 1000	SAG 7133
CASRN	Trade name	Category	Trade name	Trade name
Formula				
Water solubility, g/L				
Log K_{OW}				
Log K_{OC}				
Henry's Law constant (atm-m^3/mole)				
Vapor pressure (mm Hg)				
Environmental partitioning summary				
Half-lives				
Degradation summary				
Degradation lag time				
Transport rate summary				
Mixture effects				
Additional notes				

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Table A-31: Antifoamers: Silicones and Other Substances

Characteristics	**Siltech E-2202**	**Dimethyl polysiloxane**	**AF-9020, polydimethylsiloxane**	**1-dodecanol**
CASRN	Trade name	9016-00-6	63148-62-9	112-53-8
Formula		$(C_2H_6OSi)x-$	$(C_2H_6OSi)n$	$C_{12}H_{26}O$
Water solubility, g/L				0.004
Log K_{OW}				5.13
Log K_{OC}				$1.5x10^{+4}$ (Koc)
Henry's Law constant (atm-m^3/mole)				$2.22x10^{-5}$
Vapor pressure (mm Hg)				$8.48x10^{-4}$
Environmental partitioning summary				Expected to have slight mobility in soil and volatilize from wet soils; not expected to volatilize from dry soils. Likely to adsorb to suspended solids and sediment and volatilize from water surfaces. Should exist as a vapor in the atmosphere.
Half-lives				Vapor-phase 1-dodecanol is degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 21 hours.
Degradation summary				Does not degrade anaerobically. Atmospheric degradation via hydroxyl radicals. No environmental hydrolysis.
Degradation lag time				
Transport rate summary				Immobile in soil.
Mixture effects				
Additional notes				

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Table A-32: Dyes

Characteristics	Eosin orange, tetrabromofluorescein	FD&C blue #1, alphazurine
CASRN	17372-87-1	3844-45-9
Formula	$C_{20}H_8Br_4O_5.2Na$	
Water solubility, g/L		
Log K_{OW}	4.8	
Log K_{OC}		
Henry's Law constant (atm-m^3/mole)		
Vapor pressure (mm Hg)		
Environmental partitioning summary		
Half-lives		
Degradation summary		
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes	May discolor receiving waters.	

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Table A-33: Additional Dyes

Characteristics	FD&C yellow #5, tartrazine	Malonyl green, C.I. Pigment Yellow 34	Shilling green
CASRN	1934-21-0	Trade name	Trade name
Formula	$C_{16}H_9N_4Na_3O_9S_2$		
Water solubility, g/L			
Log K_{OW}			
Log K_{OC}			
Henry’s Law constant (atm-m^3/mole)			
Vapor pressure (mm Hg)			
Environmental partitioning summary			
Half-lives			
Degradation summary			
Degradation lag time			
Transport rate summary			
Mixture effects			
Additional notes			

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Table A-34: Hydrophobic Agents

Characteristics	N-Dodecane[a]	Mineral oil	White mineral oil (10 cSt)
CASRN	112-40-3[a]	Mixture	Mixture
Formula			
Water solubility, g/L		Insoluble in water	
Log K_{OW}		n/a	
Log K_{OC}			
Henry's Law constant (atm-m^3/mole)			
Vapor pressure (mm Hg)	$1.3x10^{-1}$[a]		
Environmental partitioning summary			
Half-lives	1.1 days in the atmosphere; degraded via gas-phase reaction with hydroxyl radicals [a]		
Degradation summary			
Degradation lag time			
Transport rate summary			
Mixture effects			
Additional notes			

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a. Chemfate database (2008).

Table A-35: Solvents

Characteristics	Ethylbenzene	Toluene	M- and P-Xylene	Trichloroethylene	Methyl ethyl ketone
CASRN	100-41-4	108-88-3	108-38-3	79-01-6	78-93-3
Formula	C_8H_{10}	C_7H_8	C_8H_{10}	C_2HC_{l3}	C_4H_8O
Water solubility, g/L	0.0014 @ 15 degrees C		Insoluble in water	1.280	353 @ 10 Deg C
Log K_{OW}	3.15		3.15	2.61	0.29
Log K_{OC}					
Henry's Law constant (atm-m^3/mole)	7.88×10^{-3}		0.0069	9.85×10^{-3}	4.7×10^{-5}
Vapor pressure (mm Hg)	9.6		8.84	69	91
Environmental partitioning summary	Volatilization from moist and dry soil surfaces is expected. In aquatic environments BTEX compounds will adsorb to suspended solids and sediments and will volatilize from surface water. BTEX compounds will exist as vapors in the atmosphere.			High mobility in soils and volatilization from both moist and dry soils are expected. In aquatic environments, these compounds do not adsorb to suspended solids and sediments. Volatilization is an important process. In the atmosphere, these compounds exist solely in the vapor phase.	
Half-lives	The atmospheric half-life is 55 hours. Aquatic volatilization half-life is estimated at between 1.1 and 99 hours.		The atmospheric half-life of this compound is about 27 hours. Aquatic volatilization half-life is estimated at between 3 and 99 hours.	The half-life for the reaction with hydroxyl radicals in air is estimated to be 7 days. There is a wide range of degradation half-lives under anaerobic conditions. An approximate average half-life is 1 year.	The half-life for the reaction with hydroxyl radicals in air is estimated to be about 14 days.
Degradation summary	Biodegradation occurs under both aerobic and anaerobic conditions. Abiotic degradation is primarily photolytic. Ethylbenzene was degraded in aerobic conditions within 10-16 days, and in conditions of low initial oxygen, it was rapidly degraded in 21 days until the available oxygen was depleted.	Biodegradation occurs under both aerobic and anaerobic conditions. Abiotic degradation is primarily photolytic.		Trichloroethylene is not degraded aerobically. It is degraded anaerobically under methanogenic conditions.	Aerobic degradation is the main degradation pathway. Atmospheric degradation pathways include photodecomposition and degradation by reaction with hydroxyl radicals.
Degradation lag time					

Table A-35: Solvents					
Characteristics	**Ethylbenzene**	**Toluene**	**M- and P-Xylene**	**Trichloroethylene**	**Methyl ethyl ketone**
Transport rate summary	Moderate to low mobility in soil.				
Mixture effects					
Additional notes					

Blank cells indicate information not readily available to EPA at this time.

Table A-36: Solvents: Alcohols and Other Solvents

Characteristics	Acetone	Methylene chloride	1.3-Butanediol	Butyne-1,4-diol	Glycol ethers
CASRN	67-64-1	75-09-2	107-88-0	110-65-6	110-80-5, 111-76-2, 107-98-2
Formula	C_3H_6O	CH_2C_{l2}	$C_4H_{10}O_2$	$C_4H_6O_2$	
Water solubility, g/L	Miscible in water	13	Miscible in water	3,740	Miscible in water
Log K_{OW}	-0.24	1.25	-0.29	-0.93	
Log K_{OC}			0.114		
Henry's Law constant (atm-m^3/mole)	$3.97x10^{-5}$	$3.25X10^{-3x}$	$2.30x10^{-7}$	$1.684x10^{-11}$	
Vapor pressure (mm Hg)	231	435	0.06	$5.56x10^{-4}$	
Environmental partitioning summary	Very high mobility in soil, volatilization expected from moist or dry soil surfaces and from water. These compounds exist in the atmosphere solely as vapors.		In the atmosphere, degradation will occur via hydroxyl radicals. Biodegradation in soils and water is likely. Volatilization from moist soils and water is expected. Biodegradation is likely to be an important degradation pathway.		
Half-lives			An atmospheric half-life of about 1.2 days at an atmospheric concentration of $5x10^{+5}$ hydroxyl radicals per cm^3 is estimated.	An atmospheric half-life of about 11 hours at an atmospheric concentration of $5x10^{+5}$ hydroxyl radicals per cm^3 is estimated.	
Degradation summary	Volatilization is the primary mechanism for removal from aquatic environments. Acetone degrades under both aerobic and anaerobic conditions. Methylene chloride biodegradation may occur in soils or contaminated aquifers under reducing conditions. Acetone undergoes photodegradation in the atmosphere, and not hydrolysis. Methylene chloride is not directly photooxidized; it does undergo hydrolysis in the atmosphere and terrestrial environments.		Aerobic biodegradation occurs. There is not enough data to determine rates. Anaerobic degradation information is not available. Abiotically degraded by hydrolysis in the atmosphere (via hydroxyl radicals). Aquatic hydrolysis is not expected for 1,3-butanediol and information was not found for butyne-1,4-diol.		

Table A-36: Solvents: Alcohols and Other Solvents

Characteristics	Acetone	Methylene chloride	1.3-Butanediol	Butyne-1,4-diol	Glycol ethers
Degradation lag time					
Transport rate summary	Highly mobile in soil.	Highly mobile in soil; adsorbs strongly to peat moss, less strongly to clay, slightly to dolomite sandstone, and not at all to sand.	Highly mobile in soil.		
Mixture effects					
Additional notes					

Blank cells indicate information not readily available to EPA at this time.

Table A-37: Plasticizers and Other Miscellaneous Substances

Characteristics	Di-N-Butyl Phthalate	Bis (2-ethylhexyl) phthalate	Dioxane	3,5,5-Trimethylhexanoic Acid
CASRN	84-74-2	117-81-7	123-91-1	3302-10-1
Formula	$C_{16}H_{22}O_4$	$C_{24}H_{38}O_4$	C4H8O2	$C_9H_{18}O_2$
Water solubility, g/L	0.013	Less than 0.01% in water	Miscible with water	
Log K_{OW}	4.9	7.6	-0.27	
Log K_{OC}				
Henry's Law constant (atm-m^3/mole)	$4.5x10^{-6}$	$1.3x10^{-7}$	$4.8x10^{-6}$	
Vapor pressure (mm Hg)	$2.01x10^{-5}$	$7.23x10^{-8}$	38.1	
Environmental partitioning summary	Expected to volatilize from moist soil surfaces but not dry soil surfaces. Will adsorb to suspended solids and sediment in water and is expected to volatilize from water surfaces. It has a low bioconcentration potential. Exists as both a vapor and particulate in the atmosphere.	Not expected to volatilize from soil surfaces. Expected to adsorb to suspended solids and sediments in water and volatilize from water surfaces. Will exist as both a vapor and particulate in the atmosphere.	Expected to volatilize from moist and possibly dry soil surfaces. Not expected to adsorb to suspended solids and sediments. It is expected to volatilize from water surfaces. Exists solely as a vapor in the atmosphere.	
Half-lives	The half-life for hydroxyl radical degradation in air is estimated to be 42 hours. Particulates may be removed by wet and dry deposition.	An aerobic biodegradation half-life of 60 to 70 hours is expected in groundwater. The half-life for hydroxyl radical degradation in air is estimated to be about 18 hours. Particulates may be removed by wet and dry deposition. Observed biological half-lives for bis(2-ethylhexyl) phthalate under aerobic conditions are as follows: pure culture (Penicillium lilacum), 30 days; river water, 4.5 weeks; hydrosoil, 14 days; activated sludge, 17 days; and soil, 31 to 98 days.	The half-life for hydroxyl radical degradation in air is estimated to be 35 hours.	

Table A-37: Plasticizers and Other Miscellaneous Substances

Characteristics	Di-N-Butyl Phthalate	Bis (2-ethylhexyl) phthalate	Dioxane	3,5,5-Trimethylhexanoic Acid
Degradation summary	Aerobic and anaerobic biodegradation. Will hydrolyze in the environment. Degraded in the atmosphere by reaction with hydroxyl radicals.	Hydrolysis is not an important degradation pathway. Rapid biodegradation will occur under aerobic conditions in aquatic environments. Some biodegradation may occur in soils. Degraded in the atmosphere by hydroxyl radicals.	Considered recalcitrant/ resistant to biodegradation. Degraded by hydroxyl radicals in the atmosphere.	
Degradation lag time				
Transport rate summary	Low mobility in soil.	Immobile in soil.	Very high mobility in soil.	
Mixture effects				
Additional notes			A contaminant of technical grade ethylene glycol, and is an animal carcinogen	

Blank cells indicate information not readily available to EPA at this time.
Chemfate Database (2008).
Sills and Blakeslee (1992).

Table A-38: Degradation Products

Characteristics	Methane	Acetaldehyde	Nitrous acids	Ethanol	Nitrosamines
CASRN	74-82-8	75-07-0	7782-77-6	64-17-5	Category
Formula	CH_4	C_2H_4O	HNO_2	C_2H_6O	$R_1N(-R_2)-N=O$
Water solubility, g/L	0.022	1,000		Miscible	
Log K_{OW}	1.09	-0.17		-0.31	
Log K_{OC}					
Henry's Law constant (atm-m^3/mole)	0.66	$6.67x10^{-5}$		$5x10^{-6}$	
Vapor pressure (mm Hg)	$4.66x10^5$	902		59.3	
Environmental partitioning summary	Volatilization from moist soil surfaces is an important process. Not expected to adsorb to suspended solids and sediments. Volatilization from water surfaces is a dominant fate process in aqueous systems.	Volatilization from moist soil surfaces is expected to be an important fate process; some volatilization may occur from dry soil surfaces. Not expected to adsorb to suspended solids and sediments. Volatilization from water is expected. In the atmosphere, exists as a gas under ambient conditions.		Volatilization from moist soil surfaces is an important fate process; volatilization from dry soil may occur. Volatilization occurs from water surfaces; ethanol does not adsorb to suspended solids and sediment. It is unlikely to be persistent in aquatic environments. Exists solely as a vapor in the atmosphere.	
Half-lives	Volatilization half-lives for a model river and model lake are both 2 hours. The biodegradation half-life of methane was estimated to range from 70 days to infinity. The half-life for the hydroxyl radical reaction in air is estimated to be about 6 years.	Volatilization half-lives for a model river and model lake are 6.5 hrs and 5.3 days, respectively. The half-life for atmospheric reaction with hydroxyl radicals is estimated to be 24 hrs. The half-life in the atmosphere due to photolysis is reported as 8.4 hours and 16 hours.		Volatilization half-lives for a model river and model lake are 3 and 39 days, respectively. The half-life for the hydroxyl radical reaction in air is estimated to be 5 days.	

Table A-38: Degradation Products

Characteristics	Methane	Acetaldehyde	Nitrous acids	Ethanol	Nitrosamines
Degradation summary	Aerobic degradation is an important mechanism in moist soils.	Rapidlybiodegrades in the environment under aerobic and anaerobic conditions. Degraded in the atmosphere by hydroxyl radicals and photolysis.		Aerobic and anaerobic biodegradation are important fate processes. Degraded in the atmosphere by photochemically-produced hydroxyl radicals.	
Degradation lag time					
Transport rate summary	High mobility in soil.	Very highly mobile in soil.		Very high mobility in soil.	
Mixture effects					
Additional notes					

Blank cells indicate information not readily available to EPA at this time.

Table A-39: Emulsifiers and Other Miscellaneous Substances

Characteristics	Propanoic acid	Hexanoic acid	Butanoic acid	Polyamines	Chloroform
CASRN	79-09-4	142-62-1	107-92-6	Category	67-66-3
Formula	$C_3H_6O_2$	$C_6H_{12}O_2$	$C_4H_8O_2$		CHC_{l3}
Water solubility, g/L	1,000	10.3	60.0		7.710
Log K_{OW}	0.33	1.92	0.79		1.97
Log K_{OC}					
Henry's Law constant (atm-m^3/mole)	$4.45x10^{-7}$	$7.58x10^{-7}$	$5.35x10^{-7}$		$3.67x10^{-3}$
Vapor pressure (mm Hg)	3.53	0.0435	1.65		197
Environmental partitioning summary	These compounds exist as anions in the soil, making them highly mobile. They do not readily volatilize from most soils and may volatilize from dry soils (especially hexanoic acid and Butanoic acid). In aquatic environments these compounds will exist as anions and will not adsorb to suspended solids and sediments. Volatilization from water surfaces is not an important fate process. These compounds exist as vapors in the atmosphere.				Volatilization from moist soil surfaces is expected to be an important fate process; volatilization from dry soil surfaces may occur. Not expected to adsorb to suspended solids and sediment in water. Volatilization from water surfaces will occur. Exists as a vapor in the atmosphere and is degraded by hydroxyl radicals.
Half-lives	The half-life for the hydroxyl radical reaction in air is estimated to be 13 days. Anaerobic degradation in groundwater occurs with a half life of approximately 21 days.	The half-life for the hydroxyl radical reaction in air is estimated to be 3 days.	The half-life for the hydroxyl radical reaction in air is estimated to be 7 days.		Chloroform was found to have a half-life of 0.3 days when applied 1 cm deep into soil and 1.4 days when applied 10 cm deep. Volatilization half-lives for a model river and model lake are 1.3 hrs and 4.4 days, respectively. The half-life for the hydroxyl radical reaction in air is estimated to be 151 days.

Table A-39: Emulsifiers and Other Miscellaneous Substances

Characteristics	Propanoic acid	Hexanoic acid	Butanoic acid	Polyamines	Chloroform
Degradation summary	These compounds are readily biodegradable under both aerobic and anaerobic conditions. Anaerobic degradation occurs with methanogenesis. Atmospheric degradation occurs via reaction with photochemically-produced hydroxyl radicals.				Chloroform is biodegradeable anaerobically by methanotrophic bacteria.
Degradation lag time					
Transport rate summary	Very high mobility in soil.				Moderate mobility in soil. Poorly retained by aquifer material.
Mixture effects					
Additional notes					

Blank cells indicate information not readily available to EPA at this time.

Table A-40: Ecological Toxicity Values for Airport Deicing Product Components

CASRN	Chemical Name	Study Species	Concentration Type	Concentration (mg/L)
102-71-6	Triethanolamine	Fathead minnow	LC_{50} (96 hr)	11,800
107-19-7	Propargyl alcohol	Fathead minnow	LC_{50} (96 hr)	1.53
107-21-1	Ethylene glycol	Rainbow trout	LC_{50} (96 hr)	>18,500
		Fathead minnow	NOEC (growth, 7 day)	15,380
		Waterflea-*Ceriodaphnia dubia*	NOEC (reproduction, 7 day)	3,469
		Green algae	EC_{50} (96 hr)	7,900
		Duckweed	LOEC (96 hr, frond growth)	10,000
110-65-6	Butyne-1,4-diol	Fathead minnow	LC_{50} (96 hr)	53.6
111-42-2	Diethanolamine	Fathead minnow	LC_{50} (96 hr)	4,710
111-46-6	Diethylene glycol	Fathead minnow	LC_{50} (96 hr)	75,200
112-27-6	Triethylene glycol	Fathead minnow	LC_{50} (96 hr)	77,400
112-53-8	1-dodecanol	Algae	LC_{50}	0.97
		Fathead minnow	LC_{50} (96 hr)	1.01
		Harpacticoid	LC_{50}	0.9
		Northern leopard frog - *Rana pipiens*	LC_{50}	0.88
115-77-5	Pentaerythritol	Waterflea-Daphnia magna	EC_{50} (24 hr)	38,900
127-08-2	Potassium acetate	Fathead minnow	LC_{50}	>500
			LC_{50} (7 day)	>1,500
		Rainbow trout	LC_{50} (96 hr)	>2,100
		Waterflea	LC_{50} (48 hr)	>3,000
127-09-3	Sodium acetate	Fathead minnow	LC_{50} (48 hr)	2,750
			LC_{50} (120 hr)	13,330
		Waterflea	LC_{50} (48 hr)	2,400
1310-58-3	Potassium hydroxide	Guppy	LC_{50} (24 hr)	165
1310-73-2	Sodium hydroxide	Western mosquitofish	LC_{50} (96 hr)	125
136-85-6	Tolyltriazole	Bluegill	LC_{50}	31
		Waterflea	LC_{50}	74
		Microtox® (bacteria)	EC_{50} (5 min)	6
		Microtox® (bacteria)	EC_{50} (15 min)	6
141-43-5	Monoethanolamine	Rainbow trout	LC_{50} (96 hr)	150
141-53-7	Sodium formate	Bluegill	LC_{50} (24 hr)	5,000
		Waterflea	EC_{50} (24 hr)	4,800
			EC_{50} (48 hr)	4,400
			EC_0 (24 hr)	3,300
			EC_0 (48 hr)	3,200
		Zebrafish	LC_{50} (96 hr)	100

Table A-40: Ecological Toxicity Values for Airport Deicing Product Components

CASRN	Chemical Name	Study Species	Concentration Type	Concentration (mg/L)
1934-21-0	FD&C Yellow #5 (constituents)	Fish (species not specified)	LC_{50} (72 hr)	>1,000
25265-71-8	Dipropylene glycol	Goldfish	LC_{50} (24 hr)	>5,000
25322-68-3	Polyethylene glycol, m.w. from 62 to 106	Rainbow trout	LC_{50} (96 hr)	>20,000
504-63-2	1,3-Propylene glycol	Goldfish	LC_{50} (24 hr)	>5,000
56-81-5	Glycerol	Rainbow trout	LC_{50} (96 hr)	54
57-13-6	Urea	Guppy	LC_{50} (96 hr)	17,500
		Fish-*Barilius barna*	LC_{50} (96 hr)	>9,100
		Mozambique tilapia-*Tilapia moassambica*	LC_{50} (96 hr)	22,500
		Carp	LC_{50} (48 hr)	>10,000
		Waterflea	EC_{50} (24 hr)	>10,000
		Mosquito	LC_{50} (4 hr)	60,000
		Freshwater snail	LC_{50} (24 hr)	14,241-30,060
57-55-6	Propylene Glycol	Fathead minnow	LC_{50} (96 hr)	55,770
			NOEC (growth, 7 day)	<11,530
		Goldfish	LC_{50}	5,000
		Waterflea-*Daphnia magna*	LC_{50}	8,000
		Waterflea-*Ceriodaphnia dubia*	NOEC (reproduction, 7 day)	13,020
62-56-6	Thiourea	Waterflea-*Daphnia magna*	LC_{50} (48 hr)	9
7558-79-4	Disodium phosphate (aka sodium hydrogen phosphate)	Waterflea-*Daphnia magna*	LC_{50} (48 hr)	3,580
7631-99-4	Sodium nitrate	Rainbow trout	LC_{50} (96 hr)	1,658
7664-41-7	Ammonia	Fathead minnow	LC_{50} (96 hr)	0.73-8.2
		Goldfish	LC_{50} (24-96 hr)	2-2.5
		Rainbow trout	LC_{50} (24 hr)	0.068-3.58
		Waterflea	LC_{50} (48 hr)	187-189
		Various	EPA National Recommended Water Quality Criteria	Temp., life-stage, time-dependent.
7778-53-2	Potassium phosphate	Western mosquitofish	LC_{50} (96 hr)	750
79-10-7	Acrylic acid	Green algae	EC_{50} (96 hr)	0.17
			EC_3 (7 day)	18
		Waterflea	EC_{50} (24 hr, immobilization)	765
		Rainbow trout	NOEC (96 hr)	6.3
95-14-7	Benzotriazole	Microtox ® (bacteria)	EC_{50} (5 min)	41
			EC_{50} (15 min)	42
97-64-3	Ethyl lactate	Zebrafish	LC_{50} (96 hr)	320
(25154-52-3)	Nonylphenol	Fish	LC_{50}	0.17-1.4
		Invertebrates	LC_{50}	0.17-1.4

Table A-40: Ecological Toxicity Values for Airport Deicing Product Components

CASRN	Chemical Name	Study Species	Concentration Type	Concentration (mg/L)
		Waterflea-*Daphnia magna*	Life-Cycle Chronic Value	0.02262
		Fathead minnow	Early Life Stage Chronic Value	0.01018
(Multiple)	Nonylphenol ethoxylate	Fathead minnow	LC_{50}	3.75
		Other fishes	LC_{50}	4.7-29.2
		Calanoid copepod	LC_{50}	2.8
		Polychaete worm	LC_{50}	3.78
(Multiple)	Octylphenol	Fish	LC_{50}	0.17-1.4
		Invertebrates	LC_{50}	0.02-3
(Multiple)	Octylphenol ethoxylate	Algae	LC_{50}	0.027-2.5
		Rainbow trout	LC_{50}	7.2
		Polychaete worm	LC_{50}	7.1
(Multiple)	Alcohol ethoxylates	Bluegill	EC_{10} (C9-11EO6)	3.882
		Fathead minnow (egg, juvenile)	NOEC (C9-11EO6, reproduction)	0.730
		Green algae	EC_{10} (C12E2, growth)	0.030
		Waterflea-*Daphnia magna*	EC_{10} (C14-15EO7)	0.255
(Unknown)	Sodium	Ionic sodium can cause ion imbalance in aquatic organisms.		
(Unknown)	Potassium	Ionic potassium can cause ion imbalance in aquatic organisms.		
(Unknown)	Xanthan Gum	Rainbow trout	LC_{50} (96 hr)	420
(Unknown)	Polyacrylic Acid	Bluegill	LC_{50} (96 hr)	1,290

Sources: EPA (2000); Environment Canada (2008a); EPA (2005); Environment Canada (2001); IPCS (1997).

Table A-41: Human Health Effects of Airport Deicing Product Components as Reported in IRIS, EPA NRWQC, EPA Drinking Water MCLs, and RSEI

CASRN	Pollutant Name	EPA NRWQC Values Water & Organism (µg/L)	EPA NRWQC Values Organism only (µg/L)	EPA Drinking Water MCL (mg/L)	RfD (mg/kg/day)	RfC (mg/m^3)	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	Drinking Water Slope Factor $(\mu g/L)^{-1}$
100-41-4	Ethylbenzene	530	2,100	0.7	0.1	1			
107-19-7	Propargyl alcohol				0.002				
107-21-1	Ethylene glycol				2	0.4			
108-88-3	Toluene	1,300	15,000	1	0.08	5			
111-42-2	Diethanolamine				0.0014	0.003			
117-81-7	Bis (2-ethylhexyl) phthalate	1.2	2.2	0.006	0.02	0.07			$4x10^{-7}$
123-91-1	Dioxane				0.1	3	0.011	0.0077	$3.1x10^{-7}$
62-56-6	Thiourea						1		
75-07-0	Acetaldehyde					0.009		0.0022	
75-21-8	Ethylene oxide					0.03	0.222	0.088	
7664-41-7	Ammonia					0.1			
84-74-2	Di-N-Butyl Phthalate	2,000	4,500		0.1				

Sources: EPA (2006b); EPA (2007); EPA (2008d); EPA (2008e).

Table A-42: Acetate	
	Fate and Transport
CASRN	No CASRN
Formula	$C_2H_3O_2$
Environmental partitioning summary	Acetates are not expected to volatilize. They are quite soluble in water. Acetate should rapidly biodegrade under aerobic conditions in surface water, groundwater, and soil.
Degradation products	Acetate degradation produces bicarbonate, carbon dioxide, and water.
Transport rate summary	Depends on a combination of degradation rate and interaction with soils/sediments. May be very site-specific.
	Human Health Effects
Exposure Limit	
MCL	
NOAEL	
LOAEL	
Exposure Routes	
Target Organs	
Symptoms	
	Ecological Effects
COD (g per 100 lbs)	11,850-15,500 (in various compounds)
In the aquatic environment, acetate may lower dissolved oxygen levels as it derades because of its COD content. Acetate-containing pavement deicers, including potassium acetate and sodium acetate, may be toxic at sufficiently high concentrations. Specific toxicity values range from a 48-hour LC_{50} of 2,400 mg/L for the waterflea to a 120-hour LC_{50} of 13,330 mg/L for the fathead minnow (*Pimephales promelas*) (both for sodium acetate).	
Blank cells indicate information not readily available to EPA at this time.	

Table A-43: Alcohol Ethoxylates	
	Fate and Transport
CASRN	64-17-5
Formula	$CH_3(CH_2)_n(OCH_2\ CH_2)_yOH$
Log K_{OC}	In general, log K_d is a better predictor of behavior than Kow for these substances[a]. Log K_d, as with the other physicochemical parameters, varies by ethoxymer. The formula below, as given by Belanger et al. (2006) permits the calculation of an estimated log K_d. log Kd = 0.331 * (alkyl chain length) – 0.009 * (ethoxylate chain length) – 1.126
Environmental partitioning summary	Sorption may be important, and is likely to vary by ethoxymer.
Degradation summary	Aerobic degradation may be rapid.
	Human Health Effects
Exposure Limit	
MCL	
NOAEL	
LD50 (rat)	
Exposure Routes	Inhalation, ingestion, skin and/or eye contact
Target Organs	Eyes, skin, respiratory system, central nervous system, liver, blood, reproductive system
Symptoms	Irritation to eyes, skin, nose; headache, drowsiness, lassitude (weakness, exhaustion), narcosis; cough; liver damage; anemia; reproductive effects, teratogenic effects, gastrointestinal irritation
	Ecological Effects
Alcohol ethoxylates have toxicity levels similar to those of nonylphenol ethoxylates and octylphenol ethoxylates. Alcohol ethoxylate degradation by-products are less toxic and less persistent than those of nonylphenol ethoxylates and octylphenol ethoxylates. Alcohol ethoxylate toxicity values range from an EC_{10} (duration unspecified) of 0.030 mg/L for growth effects in green algae to an EC_{10} (duration unspecified) of 3.882 mg/L in the bluegill (*Lepomis macrochirus*).	

Blank cells indicate information not readily available to EPA at this time.

Table A-44: Dyes	
Fate and Transport	
Eosin orange, tetrabromofluorescein	17372-87-1
FD&C blue #1, alphazurine	3844-45-9
FD&C yellow #5, tartrazine	1934-21-0
Malonyl green, C.I. Pigment Yellow 34	Trade name
Shilling green	Trade name
See *Table A-32* and *Table A-33* in *Appendix A*	
Human Health Effects	
Exposure Limit	
MCL	
NOAEL	
LOAEL	
Exposure Routes	Ingestion, inhalation, dermal contact
Target Organs	Bladder, stomach, kidneys, brain, mouth, esophagus, liver, gallbladder, bile duct, pancreas
Symptoms	Coughing, abdominal pain, pain and redness of the eyes, various cancers
Ecological Effects	
Ecological toxicity information for many dyes used in deicing products is unavailable. Available data on dye toxicity indicates a wide variability in toxicity levels. The most toxic component of FD&C Yellow #5 is toxic at concentrations of 200 mg/L to fish. Toxicity values for eosin orange range from 620 mg/L to 2,200 mg/L for fish. C.I. Pigment Yellow 34 may have high toxicity due to chromate and lead components, but no studies have yet quantified this toxicity level.	
Blank cells indicate information not readily available to EPA at this time.	

Table A-45: Ethylene Glycol	
	Fate and Transport
CASRN	107-21-1
Formula	$C_2H_6O_2$
Water solubility, g/L	Freely soluble
Log K_{OW}	-1.36
Log K_{OC}	1 (K_{OC})
Henry's Law constant (atm-m^3/mole)	6.00×10^{-8}
Vapor pressure (mm Hg)	0.092
Environmental partitioning summary	Volatilization is not expected to be an important pathway for ethylene glycol. Very high mobility is expected for ethylene glycol in soil, sediment, and water. Experimentally determined adsorption of ethylene glycol to four soils (two clay, two sandy clay) ranged from 0-0.5%. Tracer experiments have shown that ethylene glycol moves through soil with water.
Half-lives	Atmospheric half-life: 50 h at 25º C.
Degradation summary	Very rapid degradation rates in soil, sediment, and water. Soils: 90 to 100% degradation of ethylene glycol was observed in various field soils in 2-12 days (temperatures not known); ethylene glycol in aircraft deicing or anti-icing fluid formulation was completely degraded in runway-side soils within 29 days at 8° C. Water: Hydrolysis and photolysis are not expected to be significant. Ethylene glycol in river water degraded completely in three days at 20º C and in 5 to 14 days at 8º C. Aerobic degradation of ethylene glycol may be essentially complete in less than one to four days under optimal conditions in water or treatment systems, but the impact of the full theoretical biological oxygen demand may not be observed for several weeks.
Degradation lag time	With unacclimated microbial communities there is often a lag of several days before glycol degradation begins.
Transport rate summary	Expected to have very high mobility in soil, sediment, and water.
Mixture effects	Triazoles decrease the degradation rate of glycols. Low temperatures may also greatly decrease the degradation rates of glycols.
Additional notes	Ethylene glycols are expected to share somewhat similar properties, except for polyethylene glycols. Formulated polyethylene glycol products contain different mixtures of polymers, and the properties of the products will vary based on the size and shape of the polymers they contain. All of these substances are expected to be rapidly degraded under aerobic and anaerobic conditions.

Table A-45: Ethylene Glycol	
Human Health Effects	
Exposure Limit	Ceiling 50 ppm
MCL	
NOAEL	
RfD	2 mg/kg*day
Exposure Routes	Inhalation, ingestion, skin and/or eye contact
Target Organs	Eyes, skin, respiratory system, central nervous system
Symptoms	Irritation eyes, skin, nose, throat; nausea, vomiting, abdominal pain, lassitude (weakness, exhaustion); dizziness, stupor, convulsions, central nervous system depression; skin sensitization
Ecological Effects	
Ethylene glycol has high COD content and can depress dissolved oxygen levels in aquatic environments. Ethylene glycol is also acutely and chronically toxic to aquatic organisms at higher concentrations. Toxicity values range from a 7-day NOEC for reproductive effects of 3,469 mg/L in the waterflea (*Ceriodaphnia dubia)* to a 96-hr LC_{50} of greater than 18,500 mg/L in the rainbow trout (*Oncorhynchus mykiss*).	

Blank cells indicate information not readily available to EPA at this time.

Table A-46: Formate	
	Fate and Transport
CASRN	No CASRN
Formula	CH_2O_2
Environmental partitioning summary	Formates are not expected to volatilize. They are quite soluble in water, and may be expected to ionize freely. Depending on site-specific factors, the inorganic ions may adsorb or complex with soil or water constituents or remain dissolved in surface water or groundwater.
Degradation summary	Formate is slowly hydrolyzed in water and can be anaerobically degraded by methanogens.
Transport rate summary	Depends on a combination of degradation rate and interaction with soil and sediments. May be very site-specific.
	Human Health Effects
Exposure Limit	
MCL	
NOAEL	
LOAEL	
Exposure Routes	
Target Organs	
Symptoms	
	Ecological Effects
COD (g per 100 lbs)	**4,300 (in sodium formate)**
Formates may impact the aquatic environment due to their COD content. Formate-containing compounds used as pavement deicers, including sodium formate and potassium formate, can be toxic at sufficient concentrations. Known toxicity values range from a 96-hr LC_{50} of 100 mg/L for zebrafish (*Danio rerio*) to a 24-hr LC_{50} of 5,000 mg/L for bluegill (*Lepomis macrochirus*).	

Blank cells indicate information not readily available to EPA at this time.

Table A-47: Nonylphenol and Nonylphenol Ethoxylates

	Fate and Transport	
	Nonylphenol	**Nonylphenol Ethoxylates**
CASRN	25154-52-3	9016-45-9
Formula		C_9H_{19}-$C_6H_4O(CH_2CH_2O)_nH$[a]
Water solubility, g/L	$5.43x10^{-3}$	All are highly soluble in water, but solubility varies by ethoxymer.
Log K_{OW}	4.1-4.7	
Henry's Law constant (atm-m^3/mole)	$1.09x10^{-4}$	
Vapor pressure (mm Hg)	$3.4x10^{-5}$	
Environmental partitioning summary	Not expected to volatilize. Likely to partition to organic matter or minerals in soil, but this tendency varies by ethoxymer, and migration through the soil has been observed. In water, as in soil, may sorb to organic matter or particulates.	Although volatility is low, can volatilize from water and result in high atmospheric concentrations. Unlikely to volatilize from soils. Likely to partition to sediments and mineral particles in water and soil but can still leach through soils.
Half-lives	3-26 days under ideal aerobic conditions with acclimated microbial community	2.4 hours to 0.74 days in water. Photolytic half-life in upper layer of surface water is 10-15 hours; in deeper layers, it is much slower. In a sediment mesocosm, a half-life of 66 days was observed.[a]
Degradation summary	A biphasic degradation profile has been observed in soils, with relatively rapid initial degradation of 30-50% of applied nonylphenol degrading in the first several weeks, and the remainder degrading with a half-life of approximately 90 days[a].	Degradation varies by ethoxymer, and tends to produce some recalcitrant compounds
Transport rate summary		Can leach through soils.
Mixture effects		Surfactants can increase the solubility and transport of less soluble substances.
Additional notes		Specific physical properties vary by ethoxymer.

Table A-47: Nonylphenol and Nonylphenol Ethoxylates	
Human Health Effects	
Exposure Limit	
MCL	
NOAEL	10 mg/kg*day
LOAEL	50 mg/kg*day
Exposure Routes	Inhalation, ingestion, skin and/or eye contact
Target Organs	Upper respiratory system, kidneys, skin, eyes, digestive system
Symptoms	Skin and eye irritation, tissue decay, swelling, mottled kidneys, lethargy, coughing, wheezing, shortness of breath, headache, nausea, diarrhea, vomiting, sore throat, burning sensation, shortness of breath, labored breathing, abdominal pain, shock, collapse
Ecological Effects	
Nonylphenol ethoxylates are moderately toxic to aquatic life, but do not persist for long periods of time in water. Available acute toxicity data indicate harmful effects to aquatic life in a range of 2.8 mg/L (LC_{50}, duration unknown for a calanoid copepod) to 29.2 mg/L for an unspecified species of fish.	
Nonylphenol, a degradation product of nonylphenol ethoxylates, is more toxic to aquatic organisms than nonylphenol ethoxylates. It persists in the aquatic environment and potentially bioaccumulates in aquatic organisms. Toxicity values range from an “early life stage chronic value” for adverse impacts established by Environment Canada of 0.01 mg/L to an LC_{50} value from a study of unspecified fish species of 1.4 mg/L.	
Blank cells indicate information not readily available to EPA at this time.	

Table A-48: Polyacrylic Acid	
Fate and Transport	
CASRN	79-10-7
Water solubility, g/L	1×10^3
Log K_{OW}	0.35
Log K_{OC}	1.63
Henry's Law constant (atm-m^3/mole)	3.2×10^{-7}
Vapor pressure (mm Hg)	3.97
Environmental partitioning summary	Not expected to volatilize from water or moist soil. Slow volatilization from dry soil is possible. Not expected to adsorb to soils or particulates; potential for transport in soil is high.
Degradation summary	Non-polymerized (monomeric) acrylic acid readily biodegrades both aerobically and anaerobically; it reached 68% of its theoretical BOD in two weeks using an activated sludge inoculum, and in a 42 day anaerobic screening study using a sewage seed inoculum, 71% of acrylic acid was degraded. Biodegradability decreases with increasing number of polymerized units and increasing formula molecular weight, dropping off sharply between MWs 700 and 1,000, and for polymers with more than seven units. It appears that monomers and dimers of acrylic acid are completely biodegradable, but there are indications polymers of three to seven units are incompletely biodegraded.
Additional notes	May be contaminated by low-ppm levels of metals.
Human Health Effects	
Exposure Limit	TWA 2 ppm (6 mg/m^3) [skin]
MCL	
NOAEL	140mg/kg/day
LOAEL	15 mg/m^3
Exposure Routes	Inhalation, skin absorption, ingestion, skin and/or eye contact
Target Organs	Eyes, skin, respiratory system
Symptoms	Irritation eyes, skin, respiratory system; eye, skin burns; skin sensitization; in animals: lung, liver, kidney injury
Ecological Effects	
Acrylic acid toxicity values range from a 96-hour EC_{50} of 0.17 mg/L for green algae to a 24-hour EC_{50} for immobilization effects in the waterflea of 765 mg/L. A 7-day EC3 for chronic effects in green algae was measured as 0.17 mg/L.	
Blank cells indicate information not readily available to EPA at this time.	

Table A-49: Potassium	
Fate and Transport	
CASRN	No CASRN
Environmental partitioning summary	Potassium is present in the airport pavement deicers potassium acetate and potassium formate. These materials are not expected to volatilize. These materials are quite soluble in water and can be expected to ionize freely. Depending on site-specific factors, the inorganic ions may adsorb or complex with soil or water constituents or remain dissolved in surface water or groundwater.
Degradation products	Potassium is liberated from potassium acetate and potassium formate through ionization.
Transport rate summary	Depends on a combination of degradation rate and interaction with soils and sediments. May be very site-specific.
Human Health Effects	
Exposure Limit	4,700 mg/day
MCL	
NOAEL	
LOAEL	
Exposure Routes	Ingestion
Target Organs	Circulatory system, kidneys, central nervous system
Symptoms	Listlessness, fatigue, gas pains, constipation, insomnia, low blood sugar, weak muscles and a slow, irregular pulse
Ecological Effects	
Potassium can affect aquatic ecosystems by creating ion imbalances in surface waters and aquatic organisms.	

Blank cells indicate information not readily available to EPA at this time.

Table A-50: Propylene Glycol

Fate and Transport	
CASRN	57-55-6
Formula	$C_3H_8O_2$
Water solubility, g/L	Freely soluble
Log K_{OW}	-0.92
Log K_{OC}	0.90
Henry's Law constant (atm-m^3/mole)	1.3×10^{-8}
Vapor pressure (mm Hg)	0.13
Environmental partitioning summary	Very high mobility in soils, sediments, and water. Not expected to volatilize readily.
Degradation summary	Propylene glycol was not observed to degrade at 4ºC and only degraded at 20ºC in soil that was rich in organic matter.
Degradation lag time	For unacclimated microbial communities, there is often a lag of several days before glycol degradation begins.
Human Health Effects	
Exposure Limit	
MCL	
NOAEL	
LD50 (rat)	30,000 mg/kg
Exposure Routes	Ingestion, injection
Target Organs	Skin, water balance, circulatory system, kidneys
Symptoms	Hyperosmolality, lactic acidosis (the build-up of lactic acid in the body), intravascular hemolysis (the rupturing of blood vessels), central nervous system depression, seizures, coma, hypoglycemia (low blood sugar) and renal failure (all as associated with burn creams).
Ecological Effects	
Propylene glycol has a high COD content and can depress dissolved oxygen levels in aquatic environments. Propylene glycol exhibits acute and chronic toxicity to aquatic life only at higher concentrations. Toxicity values range from an LC_{50} (time unknown) of 5,000 mg/L in goldfish (*Carassius gibelio*) to a 96-hr LC_{50} of 55,770 mg/L in fathead minnow (*Pimephales promelas*).	

Blank cells indicate information not readily available to EPA at this time.

Table A-51: Sodium

Fate and Transport	
CASRN	No CASRN
Environmental partitioning summary	Sodium is present in the airport pavement deicers sodium acetate and sodium formate. These materials are not expected to volatilize. These materials are quite soluble in water and can be expected to ionize freely. Depending on site-specific factors, the inorganic ions may adsorb or complex with soil or water constituents or remain dissolved in surface water or groundwater.
Degradation products	Sodium is liberated from sodium acetate and sodium formate through ionization.
Transport rate summary	Depends on a combination of degradation rate and interaction with soils and sediments. May be very site-specific.
Human Health Effects	
Exposure Limit	2,300 mg/day
MCL	
NOAEL	
LOAEL	
Exposure Routes	Ingestion, possibly inhalation
Target Organs	Circulatory system, mineral balances
Symptoms	High blood pressure, loss of calcium
Ecological Effects	
Sodium can affect aquatic ecosystems by creating ion imbalances in surface waters and aquatic organisms.	
Blank cells indicate information not readily available to EPA at this time.	

Table A-52: Tolyltriazoles, Benzotriazoles, Methyl-substituted Benzotriazole	
Fate and Transport	
CASRN	No CASRN
Formula	$C_7H_7N_3$ (tolyltriazole)
Environmental partitioning summary	Mobile in groundwater.
Degradation summary	Unlikely to be readily degradable.
Mixture effects	Even at very low concentrations, triazoles have been observed to sharply decrease the biodegradability of other components in mixtures.
Human Health Effects	
Exposure Limit	
MCL	
NOAEL	
LD50 (rat)	600-675 mg/kg
Exposure Routes	
Target Organs	
Symptoms	
Ecological Effects	
Tolyltriazole, a methylated benzotriazole used in aircraft deicing fluid formulations, exhibits moderate acute toxicity in aquatic organisms. Toxicity values range from a 5-minute Microtox® assay value of 6 mg/L for effects on microbial organisms to an LC_{50} (duration unspecified) of 74 mg/L in the waterflea.	
Other benzotriazoles have not been studied as thoroughly as tolyltriazole. Microtox® studies with 5- and 15-minute durations have established values of 41 and 42 mg/L, respectively, for effects on microbial organisms.	
Blank cells indicate information not readily available to EPA at this time.	

Table A-53: Urea and Ammonia

	Fate and Transport	
	Urea	**Ammonia**
CASRN	57-13-6	7664-41-7
Formula	CH_4N_2O	H_3N
Water solubility, g/L	545	"31%"
Log K_{OW}	-2.11	0.23
Log K_{OC}	0.903	
Henry's Law constant (atm-m^3/mole)		$1.61x10^{-5}$
	Human Health Effects	
Exposure Limit	TWA 25 ppm (18 mg/m^3) ST 35 ppm (27 mg/m^3)	
MCL		
NOAEL		
LOAEL		
Exposure Routes	Inhalation, ingestion (solution), skin and/or eye contact (solution/liquid)	
Target Organs	Eyes, skin, respiratory system	
Symptoms	Irritation to eyes, nose, throat; dyspnea (breathing difficulty), wheezing, chest pain; pulmonary edema; pink frothy sputum; skin burns, vesiculation; liquid: frostbite	
	Ecological Effects	
Ammonia is a common by-product of urea degradation and is highly toxic to some aquatic organisms. EPA has established National Recommended Water Quality Criteria for ammonia which vary with pH, temperature, and aquatic organism life stage. LC_{50} values for ammonia range from a 24-hr value for rainbow trout (*Oncorhynchus mykiss*) of 0.068 mg/L to a 48-hr LC_{50} for the waterflea of 189 mg/L.		

Blank cells indicate information not readily available to EPA at this time.

Appendix B: Surveyed Airports within Scope for EPA's Regulatory Options for Airport Deicing Operations

Table B-1: Surved Airports within Scope for EPA's Regulatory Options for Airport Deicing Operations

Airport Name	Airport City	Airport State	Service Level	Confirmed Deicing Operations[1]	Annual Non-propeller-driven aircraft Departures[2]	SOFP Days[3]
Albany International	Albany	NY	Small Hub	Y	25,156	36
Albuquerque International Sunport	Albuquerque	NM	Medium Hub	Y	40,969	3
Aspen-Pitkin Co/Sardy Field	Aspen	CO	Non-Hub	Y	2,495	53.5
Austin Straubel International	Green Bay	WI	Small Hub	Y	9,706	31
Austin-Bergstrom International	Austin	TX	Medium Hub	Y	49,601	4
Baltimore-Washington International	Baltimore	MD	Large Hub	Y	114,673	12
Bethel	Bethel	AK	Non-Hub	Y	1,287	55
Birmingham International	Birmingham	AL	Small Hub	Y	29,510	1.5
Bismarck Muni	Bismarck	ND	Non-Hub	Y	3,139	36
Bob Hope	Burbank	CA	Medium Hub	Y	30,411	0
Boeing Field/King County International	Seattle	WA	Non-Hub	Y	3,204	4
Boise Air Terminal/Gowen Fld	Boise	ID	Small Hub	Y	20,888	16
Bradley International	Windsor Locks	CT	Medium Hub	Y	46,878	31
Buffalo Niagara International	Buffalo	NY	Medium Hub	Y	36,429	48.5
Central Wisconsin	Mosinee	WI	Non-Hub	Y	2,781	36
Charlotte/Douglas International	Charlotte	NC	Large Hub	Y	183,722	5.5
Cherry Capital	Traverse City	MI	Non-Hub	Y	5,369	68.5
Chicago Midway International	Chicago	IL	Large Hub	Y	93,123	26
Chicago O'Hare International	Chicago	IL	Large Hub	Y	475,988	26
Cincinnati/Northern Kentucky International	Covington	KY	Large Hub	Y	236,650	17
City of Colorado Springs Municipal	Colorado Springs	CO	Small Hub	Y	19,526	16
Cleveland-Hopkins International	Cleveland	OH	Medium Hub	Y	104,136	36
Dallas Love Field	Dallas	TX	Medium Hub	Y	44,023	8
Dallas/Fort Worth International	Dallas-Fort Worth	TX	Large Hub	Y	345,029	8
Denver International	Denver	CO	Large Hub	Y	222,922	26
Des Moines International	Des Moines	IA	Small Hub	Y	21,871	31
Detroit Metropolitan Wayne County	Detroit	MI	Large Hub	Y	224,328	31
El Paso International	El Paso	TX	Small Hub	Y	26,200	8
Eppley Airfield	Omaha	NE	Medium Hub	Y	31,175	26

Table B-1: Surved Airports within Scope for EPA's Regulatory Options for Airport Deicing Operations

Airport Name	Airport City	Airport State	Service Level	Confirmed Deicing Operations[1]	Annual Non-propeller-driven aircraft Departures[2]	SOFP Days[3]
Evansville Regional	Evansville	IN	Non-Hub	Y	7,404	12
Fairbanks International	Fairbanks	AK	Small Hub	Y	6,094	89
Fort Wayne International	Fort Wayne	IN	Non-Hub	Y	13,109	31
General Edward Lawrence Logan International	Boston	MA	Large Hub	Y	162,635	26
General Mitchell International	Milwaukee	WI	Medium Hub	Y	66,798	31
George Bush Intercontinental Arpt/Houston	Houston	TX	Large Hub	Y	244,359	4
Gerald R. Ford International	Grand Rapids	MI	Small Hub	Y	20,854	48.5
Glacier Park International	Kalispell	MT	Non-Hub	Y	3,820	36
Greater Rochester International	Rochester	NY	Small Hub	Y	29,129	43.5
Gulfport-Biloxi International	Gulfport	MS	Small Hub	Y	6,805	4
Hartsfield - Jackson Atlanta International	Atlanta	GA	Large Hub	Y	454,832	1.5
Helena Regional	Helena	MT	Non-Hub	Y	2,839	14.5
Indianapolis International	Indianapolis	IN	Medium Hub	Y	76,351	21
Jackson Hole	Jackson	WY	Non-Hub	Y	1,687	49.5
Jacksonville International	Jacksonville	FL	Medium Hub	Y	36,849	1.5
James M Cox Dayton International	Dayton	OH	Small Hub	Y	34,024	26
John F Kennedy International	New York	NY	Large Hub	Y	162,809	12
John Wayne Airport-Orange County	Santa Ana	CA	Medium Hub	Y	49,807	0
Juneau International	Juneau	AK	Small Hub	Y	5,035	21
Kansas City International	Kansas City	MO	Medium Hub	Y	73,758	27
Ketchikan	Ketchikan	AK	Non-Hub	[4]	2,815	55
La Guardia	New York	NY	Large Hub	Y	166,496	12
Lafayette Regional	Lafayette	LA	Non-Hub	Y	4,205	4
Lambert-St Louis International	St Louis	MO	Large Hub	Y	106,572	17
Long Island Mac Arthur	Islip	NY	Small Hub	Y	12,210	16
Louis Armstrong New Orleans International	New Orleans	LA	Medium Hub	Y	59,063	4
Louisville International-Standiford Field	Louisville	KY	Medium Hub	Y	64,780	12
Lovell Field	Chattanooga	TN	Non-Hub	Y	6,156	1.5
Manchester	Manchester	NH	Medium Hub	Y	31,195	36
Mc Carran International	Las Vegas	NV	Large Hub	Y	187,365	0
Memphis International	Memphis	TN	Medium Hub	Y	152,698	8
Metropolitan Oakland International	Oakland	CA	Large Hub	Y	85,964	0
Minneapolis-St Paul International/Wold-Chamberlain	Minneapolis	MN	Large Hub	Y	219,293	41
Montgomery Regional (Dannelly Field)	Montgomery	AL	Non-Hub	Y	4,266	0

Table B-1: Surved Airports within Scope for EPA's Regulatory Options for Airport Deicing Operations

Airport Name	Airport City	Airport State	Service Level	Confirmed Deicing Operations[1]	Annual Non-propeller-driven aircraft Departures[2]	SOFP Days[3]
Nashville International	Nashville	TN	Medium Hub	Y	74,189	5.5
Newark Liberty International	Newark	NJ	Large Hub	Y	207,698	16
Nome	Nome	AK	Non-Hub	Y	1,324	55
Norfolk International	Norfolk	VA	Medium Hub	Y	32,957	5.5
Norman Y. Mineta San Jose International	San Jose	CA	Medium Hub	Y	64,101	0
Northwest Arkansas Regional	Fayetteville/Springdale	AR	Small Hub	Y	16,783	14.5
Ontario International	Ontario	CA	Medium Hub	Y	43,364	0
Outagamie County Regional	Appleton	WI	Non-Hub	Y	8,842	36
Palm Beach International	West Palm Beach	FL	Medium Hub	Y	31,169	0
Pensacola Regional	Pensacola	FL	Small Hub	Y	14,164	1.5
Philadelphia International	Philadelphia	PA	Large Hub	Y	205,128	12
Phoenix Sky Harbor International	Phoenix	AZ	Large Hub	Y	220,200	0
Piedmont Triad International	Greensboro	NC	Small Hub	Y	34,001	14.5
Pittsburgh International	Pittsburgh	PA	Large Hub	Y	89,337	31
Port Columbus International	Columbus	OH	Medium Hub	Y	57,358	26
Portland International	Portland	OR	Medium Hub	Y	61,238	4
Raleigh-Durham International	Raleigh/Durham	NC	Medium Hub	Y	83,276	9.5
Ralph Wien Memorial	Kotzebue	AK	Non-Hub	Y	1,274	55
Rapid City Regional	Rapid City	SD	Non-Hub	Y	3,659	21
Reno/Tahoe International	Reno	NV	Medium Hub	Y	31,378	9.5
Richmond International	Richmond	VA	Small Hub	Y	33,089	12
Rickenbacker International	Columbus	OH	Non-Hub	Y	2,330	26
Roanoke Regional/Woodrum Field	Roanoke	VA	Non-Hub	Y	7,245	16
Rochester International	Rochester	MN	Non-Hub	Y	4,990	46
Ronald Reagan Washington National	Washington	DC	Large Hub	Y	130,879	12
Sacramento International	Sacramento	CA	Medium Hub	Y	51,515	0
Salt Lake City International	Salt Lake City	UT	Large Hub	Y	140,566	14.5
San Antonio International	San Antonio	TX	Medium Hub	Y	46,181	4
San Diego International	San Diego	CA	Large Hub	Y	80,108	0
San Francisco International	San Francisco	CA	Large Hub	Y	137,328	0
Seattle-Tacoma International	Seattle	WA	Large Hub	Y	114,607	1.5
South Bend Regional	South Bend	IN	Small Hub	Y	8,562	48.5
Southwest Florida International	Fort Myers	FL	Medium Hub	Y	32,000	0
Spokane International	Spokane	WA	Small Hub	Y	16,034	31

Table B-1: Surved Airports within Scope for EPA's Regulatory Options for Airport Deicing Operations

Airport Name	Airport City	Airport State	Service Level	Confirmed Deicing Operations[1]	Annual Non-propeller-driven aircraft Departures[2]	SOFP Days[3]
Stewart International	Newburgh	NY	Non-Hub	Y	6,314	26
Syracuse Hancock International	Syracuse	NY	Small Hub	Y	23,609	43.5
Tampa International	Tampa	FL	Large Hub	Y	85,166	0
Ted Stevens Anchorage International	Anchorage	AK	Medium Hub	Y	61,035	55
Theodore Francis Green State	Providence	RI	Medium Hub	Y	37,606	21
Toledo Express	Toledo	OH	Non-Hub	Y	10,559	36
Tucson International	Tucson	AZ	Medium Hub	Y	26,666	0
Washington Dulles International	Washington	DC	Large Hub	Y	225,552	17
Wilkes-Barre/Scranton International	Wilkes-Barre/Scranton	PA	Non-Hub	Y	4,789	26
Will Rogers World	Oklahoma City	OK	Small Hub	Y	29,664	14.5
William P Hobby	Houston	TX	Medium Hub	Y	57,448	4
Wilmington International	Wilmington	NC	Non-Hub	Y	6,330	4
Yeager	Charleston	WV	Non-Hub	Y	8,003	16

[1] Y =Airport stated in response to EPA Airport Deicing Questionnaire (EPA 2006c) that it conducts deicing operations.

[2] "Annual non-propeller-driven aircraft departures" derived from data from Federal Aviation Administration for the 2004/2005 winter deicing season

[3] Snow or Freezing Precipitation (SOFP) days data is based on National Oceanic and Atomospheric Administration data from 1971 – 1990.

[4] Ketchikan was sent an airport questionnaire but did not respond.

Appendix C: Documented Impacts from Airport Deicing Discharges

Table C-1: Documented Impacts from Airport Deicing Discharges

Airport Name	Article Year	Article	Waterbody Name	BOD, DO, Nutrients[1]	Wildlife Impacts[2]	Human Health Impacts[3]	Aesthetic Impacts[4]	Permit Violations	Other[5]
Airborne Airpark	1998	Hannah, James. 1998. De-Icing Chemicals for Planes Killing Creek, Professor Says. Cleveland Plain Dealer, June 7.	Lytle Creek		F,O	H	Od	X	
Airborne Airpark	2000	State of Ohio Environmental Protection Agency. 2000. Biological and Water Quality Study of the Little Miami River Basin, 1998. OEPA Technical Report Number MAS/1999-12-3. Columbus, OH.	Lytle Creek, Little Miami River, Cowan Creek, Indian Run	D	O				S
Baltimore Washington International Airport	1993	Hartwell, S.I., D.M. Jordahl, E.B. May. 1993. Toxicity of Aircraft De-Icer and Anti-Icer Solutions to Aquatic Organisms. Chesapeake Bay Research and Monitoring Division. CBRM-TX-93-1	Sawmill Creek, Muddy Bridge Branch		O		Co		
Baltimore Washington International Airport	1997	McDowell, A. Scott. 1997. Hayes, Seay, Mattern and Mattern. Letter communication to Stephen Debreceny.	Patapsco Aquifer	D,B,N		DW			
Baltimore Washington International Airport	1995	Fisher, D.J., M.H. Knott, S.D. Turley, B.S. Turley, L.T. Yonkos and G.P. Ziegler. 1995. The Acute Whole Effluent Toxicity of Storm Water from an International Airport. Environmental Toxicology and Chemistry. 14(6): 1103-1111.	Kitten Branch of Stony Run, Muddy Bridge Branch of Sawmill Creek	B,N	O		Co		
Baltimore Washington International Airport	1997	Pelton, Tom. 1997. EPA Probing Allegation of BWI Runoff; Polluting Chemicals Seeping Into Creek, Environmentalists Say; Airport Cooperating; Public's Health Is Not In Danger, According to State. Baltimore Sun, April 23.	Sawmill Creek				Fo,Od	X	

[1] B = BOD; D = DO; N = Nutrients
[2] F = Fish Kill; O = Other Organism Impacts
[3] H = Human Health; DW = Drinking Water
[4] Fo = Foam; Od = Odor; Co = Color
[5] G = Groundwater; S = Sediment

Table C-1: Documented Impacts from Airport Deicing Discharges

Airport Name	Article Year	Article	Waterbody Name	BOD, DO, Nutrients[1]	Wildlife Impacts[2]	Human Health Impacts[3]	Aesthetic Impacts[4]	Permit Violations	Other[5]
Baltimore Washington International Airport	1997	Pelton, Tom. 1997. De-Icing Fluid Used at BWI Fouls Waters; MD.'s Pride in System Ignores Pollution Data From Other Agencies; BWI is 'Economic Engine'; 11th-Hour Clearance Gives Airport Time, $1.6 Million for Drains. Baltimore Sun, August 9.	Sawmill Creek		O		Fo,O, Co	X	
Baltimore Washington International Airport	1997	McDowell, A.S. 1997. Sawmill Creek - Watershed "Restoration" Project. Allwood Community Association Site Inspection, March.	Sawmill Creek			DW,H	Fo,Od		
Baltimore Washington International Airport	1998	Pelton, Tom. 1998. BWI Violated Water Act, Group Claims; Environmentalists File Notice of Intent to Sue; De-Icing Chemicals at Issue; Airport Maintains it Has Tried to Keep Pollution Contained. Baltimore Sun, January 8.	Kitten Branch of Stony Run, Muddy Bridge Branch of Sawmill Creek				Fo,Od	X	
Baltimore Washington International Airport	2001	Ayres, E. 2001. Airports and cities: Can they coexist? San Diego Earth Times, September.	unnamed aquifer			DW			
Bangor International Airport	2003	New England Grassroots Environment Fund. 2003. Annual Report. Montpelier, Vermont.	Birch Stream			H			
Bangor International Airport	2006	State of Maine Department of Environmental Protection. 2006. 2006 Integrated Water Quality Monitoring and Assessment Report. Report DEPLW0817.	Birch Stream	B	O				
Bradley International Airport	2003	Farmington River Watershed Association. 2003. State of the Farmington River Watershed Report. August.	Rainbow Brook, Seymour Hollow Brook	D					
Bradley International Airport	2004	State of Connecticut Department of Environmental Protection. 2004. List of Connecticut waterbodies not meeting water quality standards.	Rainbow Brook, Seymour Hollow Brook	D	O				
Buffalo Niagara International Airport	1994	Dawson, Dick. 1994. Contaminant Testing Sought at Ellicott Creek Amherst Councilwoman Fears Runoff of De-Icer Fluids from Airport. Buffalo News, May 11.	Ellicott Creek		O		Fo,O, Co		

[1] B = BOD; D = DO; N = Nutrients
[2] F = Fish Kill; O = Other Organism Impacts
[3] H = Human Health; DW = Drinking Water
[4] Fo = Foam; Od = Odor; Co = Color
[5] G = Groundwater; S = Sediment

Table C-1: Documented Impacts from Airport Deicing Discharges

Airport Name	Article Year	Article	Waterbody Name	BOD, DO, Nutrients[1]	Wildlife Impacts[2]	Human Health Impacts[3]	Aesthetic Impacts[4]	Permit Violations	Other[5]
Chicago O'Hare International Airport	1997	Alliance of Residents Concerning O'Hare, Inc. 1997. O'Hare Found to be Major Water Polluter. ARCO Flight Tracks, May.	Des Planes River, ground water, Bensenville Ditch, Willow Creek, Crystal Creek		F,O	H	Fo,O, Co		G
Chicago O'Hare International Airport	1997	Cowan, P.F. 1997. Water Pollution-Chicago International Airport. Alliance of Residents Concerning O'Hare, Inc., May 28.	Des Planes River, Bensenville Ditch, Willow Creek, Crystal Creek		F,O	H	Od,Co		
Chicago O'Hare International Airport	1998	Worthington, R. 1998. Group Claims O'Hare Fails to Report on De-Icing Toxins. Chicago Tribune, January 9.	unnamed receiving waters						
Cincinnati/Northern Kentucky International Airport	1992	Associated Press. 1992. Cincinnati Airport Cited by State. Cleveland Plain Dealer, June 8.	Elijah Creek		O		Od,Co	X	
Cincinnati/Northern Kentucky International Airport	2003	Alliance of Residents Concerning O'Hare, Inc. 2003. Comments from the Alliance of Residents Concerning O'Hare, Inc. to the Federal Aviation Administration regarding the Draft FAA Five-Year Strategic Plan "Flight Plan" 2004-2008 by Jack Saporito. August 5.	Gunpowder Creek, Elijah's Creek		O		Od,Co	X	
Cincinnati/Northern Kentucky International Airport	2004	Kelly, B.R. and D. Klepal. 2004. Silent Streams. The Cincinnati Enquirer, March 7.	Gunpowder and Elijah Creeks		O		Od,Co	X	
Cincinnati/Northern Kentucky International Airport	2004	Sierra Club. 2004. Water Sentinels: Rescuing the river that wouldn't freeze. Annual Report.	Gunpowder Creek, Elijah's Creek		O		Od,Co		
Cincinnati/Northern Kentucky International Airport	2004	Klepal, Dan. 2004. Airport Pollution Provokes Ire: Residents fault state for going easy on de-icing runoff. The Cincinnati Enquirer, September 10.	Gunpowder and Elijah Creeks	D			Od,Co		
Cincinnati/Northern Kentucky International Airport	2004	KPDES Permit # KY0082864. Kentucky Department for Environmental Protection. Expiration: July 31, 2007.	Elijahs Creek, Gunpowder Creek						

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Airport Name	Article Year	Article	Waterbody Name	BOD, DO, Nutrients[1]	Wildlife Impacts[2]	Human Health Impacts[3]	Aesthetic Impacts[4]	Permit Violations	Other[5]
Cincinnati/Northern Kentucky International Airport	2006	Sierra Club. 2006. An Interview with Tim Guilfoile. August.	Gunpowder Creek		O				
Cincinnati/Northern Kentucky International Airport		Impacts of Deicing Fluids on Elijahs and Gunpowder Creeks, Boone County, Kentucky. Kentucky Department for Environmental Protection.	Elijahs Creek, Gunpowder Creek	D,B,N	O			X	
Cleveland Hopkins International Airport	2001	NPDES Permit # OH0122068. Ohio Environmental Protection Agency. Expiration: October 31, 2006.	Rocky River, Abrams and Silver Creek		O			X	G
Cleveland Hopkins International Airport	1991	Miller, Alan. 1991. De-Icing's Fatal Effect Not Plain. Columbus Dispatch, January 6.	Rocky River						
Cleveland Hopkins International Airport	2001	Kuehner, John C. 2001. Airport ordered to reduce discharge. The Plain Dealer, November 1.	Rocky River, Abram Creek, Silver Creek		F		Od,Co	X	
Cleveland Hopkins International Airport	2001	Egan, D'arcy. 2001. Rocky River fishing in danger as pollutants keep pouring in. The Plain Dealer, October 21.	Rocky River, Lake Erie		O		Od		
Cleveland Hopkins International Airport	2006	Richardson, David C. 2006. Deicing by Design: Cleveland Gets a New Pad. Stormwater. 7(7).	Abrams Creek, Rocky River		F		Od	X	
Dallas/Fort Worth International Airport	2006	Corsi, S.R., G.R. Harwell, S.W. Geis, and D. Bergman. 2006. Impacts of aircraft deicer and anti-icer runoff on receiving waters from Dallas/Fort Worth International Airport, Texas, U.S.A. Environ Toxicol Chem. 25(11):2890-2900	Trigg Lake and Big Bear Creek		O				
Denver International Airport	1997	Scanlon, Bill. 1997. DIA Pollutes Creek / De-Icer Washing off Runways Kills Life in Stream That Flows Toward Barr Lake Bird Sanctuary. Rocky Mountain News, April 22.	Third Creek, Barr Lake		O		Od		S
Denver International Airport	1997	Eddy, Mark. 1997. Airport Deicer Pollutes Creek. Denver Post, April 22.	Third Creek, Barr Lake	D	O		Od,Co		
Denver International Airport	1997	Dafforn, Erik. 1997. 'Til Hill and Valley are Ringing. Wabash Magazine. Summer.	unnamed creek						
Denver International Airport	2001	Ayres, E. 2001. Airports and cities: Can they coexist? San Diego Earth Times, September.	Barr Lake		O				

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Denver International Airport	2005	Meyerhoff, R., N. Rowan, J. Kieler, J. Barrilleaux, R. Albrecht, and S. Morea. 2005. Development of Site-Specific Dissolved Oxygen Standards in Surface Waters at Denver International Airport. TMDL 2005 Specialty Conference. Water Environment Federation.	Second, Third and Box Elder Creeks	D					S
Des Moines International Airport	1998	Flannery, William. 1998. Status on Recovery of Aircraft Deicing Fluid Operations at the Airport. City Council Communication 98-052. February 16.	Yeader Creek				Od,Co	X	
Des Moines International Airport	2004	Iowa Department of Natural Resources. 2004. Total Maximum Daily Loads For Nutrients and Siltation: Easter Lake, Polk County, Iowa.	Easter Lake	N					
Des Moines International Airport	2005	Iowa Department of Natural Resources. 2005. Total Maximum Daily Load For Priority Organics: Yeader Creek, Polk County, Iowa.	Yeader Creek	B	O		Fo,O, Co	X	S
Detroit Metropolitan Wayne County Airport	1990	Askari, Emilia. 1990. State Probes Airport in Pollution Allegations. Detroit Free Press, August 30.	Detroit River						
Detroit Metropolitan Wayne County Airport	2001	Environmental News Service. 2006. Wayne County Airport Admits De-Icing Chemical Discharge. June 14.	Detroit River	D			Od,Co	X	
Detroit Metropolitan Wayne County Airport	2006	Lochner, Paul. 2006. Wayne County Airport Authority Pleads Guilty to Violation of Clean Water Act. Department of Justice Press Release. June 8.	Frank and Poet Drain		F		Od,Co	X	
General Mitchell International Airport	2001	Corsi, S.R., N.L. Booth, and D.W. Hall. 2001. Aircraft and Runway Deicers at General Mitchell International Airport, Milwaukee, Wisconsin, USA. 1. Biochemical Oxygen Demand and Dissolved Oxygen in Receiving Streams. Environ. Toxicol. Chem. 20(7):1474-1482	Wilson Park Creek, Kinnickinnic River	B	O				
General Mitchell International Airport	2001	Corsi, S.R., D.W. Hall, and S.W. Geis. 2001. Aircraft and Runway Deicers at General Mitchell International Airport, Milwaukee, Wisconsin, USA. 2. Toxicity of Aircraft and Runway Deicers. Environ. Toxicol. Chem. 20(7):1483-1490.	Wilson Park Creek, Kinnickinnic River	N	O				

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General Mitchell International Airport	2003	Cancilla, D.A., J.C. Baird, S.W. Geis, and S.R. Corsi. 2003. Studies of the Environmental Fate and Effect of Aircraft Deicing Fluids: Detection of 5-methyl-1H-benzotraizole in the fathead minnow (*Pimephales promelas*). Environ. Toxicol. Chem. 22(1):134-140	Wilson Park Creek, Kinnickinnic River		F,O				
General Mitchell International Airport	2006	Sandler, Larry. 2006. Environmental group challenges airport's wastewater permit: Mitchell discharges too much deicing fluid into creek, it says. Milwaukee Journal Sentinel, January 25.	Wilson Creek				Co		
Hartsfield-Jackson Atlanta International Airport	2002	Hamrick, Dave. 2002. Officials unanimous: Our water is safe. The Citizen, February 13.	Flint River			H,DW	Od		
Hartsfield-Jackson Atlanta International Airport	2002	Hamrick, Dave. 2002. EPD: 'We blew it': State agency took 4 days to respond to calls that deicing fluid had been spilled into the Flint River; airport manager promises new procedures will prevent future spills. The Citizen, February 13.	Flint River			DW			
Indianapolis International Airport	1997	Stahl, J.R., T.P. Simon, and E.O. Edberg. 1997. A Preliminary Appraisal of the Biological Integrity of the East Fork White Lick Creek in the West Fork White River Watershed Using Fish Community Assessment. IDEM/32/03/013/1997. December 12.	White Lick Creek		O				
James M. Cox Dayton International Airport	1991	Miller, Alan. 1991. De-Icing's Fatal Effect Not Plain. Columbus Dispatch, January 6.	Mill Creek		F				
James M. Cox Dayton International Airport	1995	State of Ohio Environmental Protection Agency. 1995. Biological and Water Quality Study of Mill Creek: Dayton International Airport, Miami and Montgomery Counties, Ohio. OEPA Technical Report MAS/1995-2-2. Columbus, OH.	Mill Creek	B,N	F,O				
James M. Cox Dayton International Airport	1998	Associated Press. 1998. Panel Settles De-Icing Suit with Homeowners. Cleveland Plain Dealer, March 28.	Mill Creek			DW			G

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James M. Cox Dayton International Airport	2001	State of Ohio Environmental Protection Agency. 2001. Biological and Water Quality Study of the Stillwater River Basin, 1999, Darke, Miami and Montgomery Counties. OEPA Technical Report Number MAS/2001-12-8. Columbus, OH	Mill Creek	B,N	O				
Kansas City International Airport	2007	Missouri Department of Conservation. 2007. Platte River Watershed: Water Quality and Use. <mdc.mo.gov/fish/watershed/platte/watqual/>	Todd Creek		F				
Lambert-St. Louis International Airport	1995	Uhlenbrock, Tom. 1995. Up A Creek Runoff of De-Icer from Lamber Field Pits Airport Against U.S. St. Louis Post Dispatch, February 5.	Coldwater Creek				Od		
Louisville International - Standiford Field	2002	KPDES Permit # KY0092185. Kentucky Department for Environmental Protection. Expiration: December 31, 2007.	Northern Ditch, Fern Creek	D,N	F				
Manchester Airport	2003	CAA News Channel. 2003. New Hampshire Brook to be Tested for Chemicals. The Union Leader and New Hampshire Sunday News, January 27.	Little Cohas Brook				Fo,Od		
Manchester Airport	2006	Kibbe, Cindy. Planes, trains and automobiles: What are southern N.H.'s transportation options? NHBR Daily, April 14.	Merrimack River				Od		
Minneapolis/St. Paul International Airport	2004	Larson, Catherine. 2004. Lower Minnesota River Model Project Proposal. Proposal to Develop an Advanced Water-Quality Model of the Minnesota River, Jordan to the mouth, and Conduct River Monitoring and Studies to Support the Model. January 15.	Minnesota River	B				X	
Minneapolis/St. Paul International Airport	2004	Mikkelson, Stephen. 2004. Water Quality Violations to Cost Metropolitan Airports Commission $69,076. Minnesota Pollution Control Agency News Release. November 2.	Lower Minnesota River	D				X	

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Minneapolis/St. Paul International Airport	2005	Environmental News Service. 2005. Minnesota Halts Jet Fuel Leaks, Spills at Twin Cities Airport. Environmental News System. March 18.	Minnesota River, Snelling Lake, Mother Lake				Od,Co	X	
Minneapolis/St. Paul International Airport	1993	Meersman, Tom. 1993. New Rules for Airport De-Icers Amount of Chemicals Flushed into River Will be Reduced. Minneapolis Star Tribune, September 29.	Minnesota River	D,B					
Minneapolis/St. Paul International Airport	1993	Meersman, Tom. 1993. FAA-Mandated Plane De-Icing Puts Minnesota River at Risk. Minneapolis Star Tribune, March 10.	Minnesota River						
Minneapolis/St. Paul International Airport	2001	Mills, Karren. 2001. Minneapolis airport saw big jump in runoff from de-icer into Minnesota River. CAA News Channel, May 19.	Minnesota River					X	
Newcastle International Airport	1995	Turnbull, D.A. and J.R. Bevan. 1995. The Impact of Airport De-Icing on a River: The case of the Ouseburn, Newcastle Upon Tyne. Environ. Pollut. 88:321-332.	Ouseburn River	B,N	O				S
Pease Air Force Base	1999	Agency for Toxic Substances and Disease Registry. 1999. Public Health Assessment: Pease Air Force Base, Portsmouth, Rockingham County, New Hampshire. Department of Health and Human Services. September 30.	groundwater	N		DW			G
Pittsburgh International Airport	1996	Hopey, Don. 1996. Airport Gets Criticism for Disposal of De-Icer. Pittsburgh Post-Gazette, October 28.	McClarens, Enlow and Montour Runs	N	F	H	Od	X	
Pittsburgh International Airport	1998	Hopey, Don. 1998. Airport Ordered Again to Keep De-Icers Out of Streams. Pittsburgh Post-Gazette, January 31.	McClarens, Enlow and Montour Runs		F	H	Od	X	
Pittsburgh International Airport	1998	Koryak, M. L.J. Stafford, R.J. Reilly, R.H. Hoskin and M.H. Haberman. 1998. The Impact of Airport Deicing Runoff on Water Quality and Aquatic Life in a Pennsylvania Stream. J. Freshwater Ecol. 13(3): 287-298.	Montour Run and tributaries	B,N	O				

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Port Columbus International Airport	1998	State of Ohio Environmental Protection Agency. 1998. Biological and Water Quality Study of Mason Run, 1996, Franklin County, Columbus, Ohio. OEPA Technical Report MAS/1996-12-6. Columbus, OH.	Mason Run, Turkey Run, Big Walnut Creek	D,N	F,O				
Port Columbus International Airport	2003	State of Ohio Environmental Protection Agency: Division of Surface Water. Biological and Water Quality Study of Big Walnut Creek Basin. 2003. OEPA Technical Report DSW/EAS 2003-11-10. Columbus, OH.	Big Walnut Creek, Alum Creek and Blacklick Creek watersheds	D,B,N					
Port Columbus International Airport	2004	NPDES Permit # OH0124311. Ohio Environmental Protection Agency. Expiration: July 31, 2007.	Big Walnut Creek, Mason Run	N	O				
Portland International Airport	1997	Wells, Scott. 1997. The Columbia Slough. Prepared for the City of Portland Bureau of Environmental Services. Technical Report EWR-2-97. (March)	Columbia Slough	D,B					
Portland International Airport	1998	Oregon Department of Environmental Quality. 1998. Columbia Slough Total Maximum Daily Loads (TMDLs) For: Chlorophyll a, Dissolved Oxygen, pH, Phosphorus, Bacteria, DDE/DDT, PCBs, Pb, Dieldrin and 2,3,7,8 TCDD	Columbia Slough	D	O				
Portland International Airport,	1998	Stewart, Bill. 1998. Airport Juggles Safety, Pollution Concerns. The Oregonian, February 2	Columbia Slough	D					
Portland International Airport	2005	Johnson, Steve. 2005. Port Plans study to Enhance Airport Deicing Storm Water Collection System. Port of Portland News Release, September 26.	Columbia River					X	
Portland International Airport	2006	Associated Press. 2006. Portland airport's de-icing system harms fish. USA Today, October 17.	Columbia River		O			X	
Raleigh-Durham International Airport	2000	RDU Airport Changes its Runway Deicing Chemical. 2000. The Umstead Coalition Newsletter, November 29.	Big Lake, Sycamore Lake	N					

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Rickenbacker International Airport	1996	State of Ohio Environmental Protection Agency: Division of Surface Water. 1996. Biological and Water Quality Study of Lower Big Walnut Creek and Walnut Creek Tributaries. Prepared for State of Ohio Environmental Protection Agency: Division of Emergency and Remedial Response, Columbus, OH.	Walnut Creek, Big Walnut Creek and tributaries		O				
Seattle-Tacoma International Airport	1993	Roberts, C.R. 1993. Airport Antifreeze May Be Toting Chill of Death to Miller Creek. Tacoma News Tribune, January 26.	Miller Creek		O				
Seattle-Tacoma International Airport	1995	Taylor, Rob. 1995. Lawsuit Filed Over Stream Pollution From Sea-Tac Airport. Seattle Post-Intelligencer, August 15.	Des Moines Creek, Miller Creek, Puget Sound					X	
Seattle-Tacoma International Airport	2003	Lange, Larry. 2003. Sea-Tac blamed for fish deaths. Seattle Post-Intelligencer, April 14.	Miller Creek, Puget Sound		F			X	
Spokane International	2002	NPDES Permit # SO3004373. State of Washington Department of Ecology. Expiration: September 20, 2007.	unnamed aquifer						G
Stapleton International Airport	1996	Pillard, D.A. Assessment of Benthic Macroinvertebrate and Fish Communities in a Stream Receiving Storm Water Runoff from a Large Airport. J. Freshwater Ecol. 11(1):51-59.	Sand Creek		O				
Stockholm Arlanda Airport	1993	O'Conner, R. and Douglas, K. 1993 Cleaning up after the big chill: Thousands of rivers and streams are harmed by the de-icing chemicals that keep aircraft flying through the winter. Now airports are being forced to curb this damaging pollution. New Scient	unnamed receiving waters	D					
Syracuse Hancock International Airport	1999	Atlantic States Legal Foundation, Inc. 1999. Litigation Update. Atlantic States Legal Foundation, Inc. Newsletter.	Bear Trap Creek, Ley Creek					X	
Syracuse Hancock International Airport	2000	Beartrap Creek Reclamation Project Description. GL2000-045	Beartrap Creek		O				

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Syracuse Hancock International Airport	2003	Onondaga Lake Partnership. 2003. Izaak Walton League's Efforts Lead to Restored Beartrap Creek. Reflections. 1(3): 6.	Beartrap Creek		O				
Ted Stevens Anchorage International Airport	1990	Wohlforth, Charles. 1990. Toxic Runoff Adds to Lake Hood Pollution. Anchorage Daily News, May 4.	Lake Hood		O				
Ted Stevens Anchorage International Airport	1991	Pytte, Alyson. 1991. Chemicals Lace Airport Soil Finding Pollution is Easy; Who Pays for Cleanup is the Problem. Anchorage Daily News, September 8.	Lake Hood	N			Od		G
Ted Stevens Anchorage International Airport	2007	deMarban, Alex. 2007. Lake mower clears paths for floatplanes. Anchorage Daily News, August 13.	Lake Hood		O		Co		
Theodore Francis Green State Airport	2004	RIPDES Permit # RI0021598. Rhode Island Department of Environmental Management. Expiration January 1, 2010.	unnamed tributaries of Warwick Pond and Buckeye Brook, and Tuscatucket Brook	D	O		Fo,Od		
Toronto Pearson International Airport	1989	Legislative Assembly of Ontario. Storm Water. Transcript of the July 6, 1989 meeting.	Etobicoke Creek, Mimico Creek, Lake Ontario	B	O			X	S
Unknown international North American airport	1998	Cancilla, D.A., J. Martinez, and G.C. van Aggelen. 1998. Detection of Aircraft Deicing/Antiicing Fluid Additives in a Perched Water Monitoring Well at an International Airport. Environ. Sci. Technol. 32: 3834-3835.	unnamed well		O				G
Victoria International Airport	2003	Reay Watershed: 2003 Fish Kill. <www.peninsulastreams.org/watersheds/reay.shtml>.	Reay Creek		F				
Victoria International Airport	2004	Dickson, Louise. 2004. Polluted creek killing fish: Reclamation work wasted as second major kill wipes out run. Times Colonist. November 1.	North Saanich Creek		F				
Westchester County Airport	1997	Conetta, A., R. Bracchitta, and P. Sherrer. 1997. Storm Water Management and Control of Aircraft Deicing Runoff at Westchester County Airport. Environmental Regulation and Permitting.	Rye Lake, Blind Brook	B					

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Westchester County Airport	1999	Switzenbaum, M.S., S. Veltman, T. Schoenberg, C.M. Durand, D. Mericas and B. Wagoner. 1999. Best Management Practices for Airport Deicing Stormwater. Publication No. 173.	Blind Brook	D	F		Fo		
Westchester County Airport	1999	Associated Press. 1999. De-icing Chemical Found in Westchester Reservoir. New York Times, January 14.	Kensico Reservoir			DW			

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