Air Pollution Emissions from Tourist Activities in Klondike Gold Rush National Historical Park

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Abstract

Each summer, tens of thousands of people visit Klondike Gold Rush National Historical Park. During the height of the tourist season, up to five large cruise ships arrive daily in the Skagway harbor where they are met by tour buses and trains to take them on historical and scenic rides in the park and beyond. While docked in Skagway, each cruise ship continues to provide electrical power, heat and steam to passengers and crew by operating their engines and boilers for a period of 10 to 14 hours. Additionally, the waste generated in town is incinerated at the municipal incinerator. As a result, approximately 1,100 lbs/hr of nitrogen oxides (NO_x) and 800 lbs/hr of sulfur dioxide (SO_2) are emitted in Skagway, the majority of which is emitted by cruise ships. The amount of NO_x and SO_2 emitted by these ships is not directly related to the number of ships, but rather engine power output, fuel consumption rates, and fuel characteristics. Air pollution emission rates of visiting cruise ships are expected to decrease with the implementation of the Emission Control Area (ECA) recently adopted by the International Marine Organization (IMO).

Figure 1. Idling cruise ship emissions are visible during inversions.

Photograph by Rick Graw

Introduction

During the height of the 2008 tourist season, the National Park Service, together with the U.S. Forest Service, conducted a study of the effects of air pollution on the ecosystem of Klondike Gold Rush National Historical Park and the Tongass National Forest. To assess impacts of current and future scenarios, an air quality dispersion modeling analysis is being conducted. The dispersion model simulates the transport and dispersion from user-specified sources, and quantifies the concentration and deposition rates of these pollutants. Thus, the user must specify the emission rate and release characteristics of each emission source. This portion of the study presents the estimated emission rates of NO_x and SO_2 from cruise ships, buses, trains, and the municipal incinerator and offers some insights into their wide range of magnitude and contribution to total emissions.

Methods

Emissions were provided by individual emission source or estimated using emission factors and source-specific operating characteristics (e.g., fuel type, hours of operation, etc.). An emission factor is a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant (e.g., pounds of NO_x per gallon of fuel burned). Emission factors were obtained from the U.S. Environmental Protection Agency (*1996, 1997, 1998*), and the American Bus Association (*2006*). In the absence of direct measurements and emission factors, the International Maritime Organization (IMO) NO_x regulatory limit (*1997*) was used as a surrogate.

Results

Figure 2 illustrates the mean daily emission rate of NO_x and SO_2 from each emission source category and the variation throughout the week. Cruise ships were the greatest source of pollutants, emitting as much as 800 lbs/hr of NO_x and SO_2 each, during mid week, and decreasing dramatically on weekends. Trains were the next largest source of SO_2, emitting as much as 180 lbs/hr, but substantially less NO_x. The municipal incinerator and buses emitted relatively small amounts of NO_x and SO_2.

The amount of SO_2 and NO_x emitted from individual cruise ships varies substantially. Figures 3 and 4 illustrate the estimated hourly emission rates of SO_2 and NO_x, respectively, from 22 cruise ships and an Alaska Marine Highway ferry that visited Skagway during the study period. The ship names are listed along the bottom axis, in increasing order of capacity from left to right. The capacity, indicated by the red dots, ranged from 117 to 4,138 passengers and crew. The SO_2 emission rate (*Figure 3*) varied from 1 to 446 lbs/hr. The NO_x emission rates (*Figure 4*) varied from 11 to 314 lbs/hr.

While there is a general trend of increasing SO_2 emissions with ship capacity, there is wide variation amongst individual ships. The emission rate of SO_2 is determined from the sulfur content of the fuel, fuel

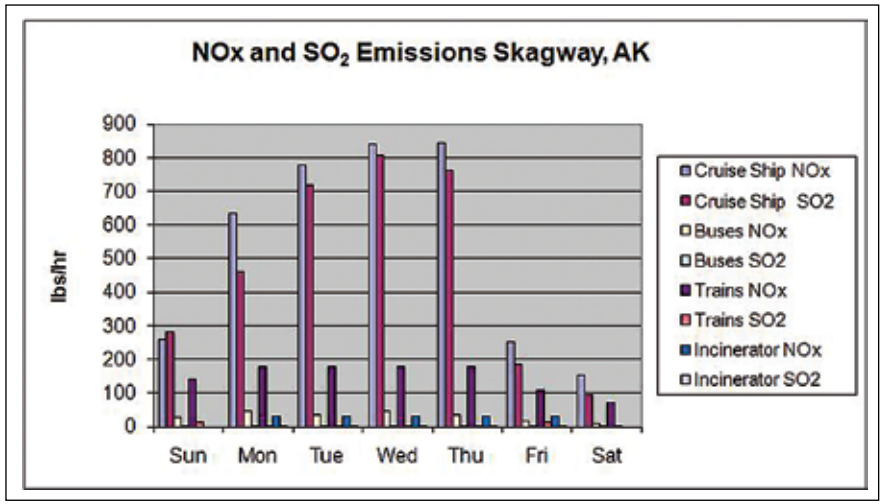

Figure 2. Daily variation in NO_x and SO_2 emissions in Skagway, during a typical week of the 2008 season.

density, and fuel consumption rate. Fuel consumption is related to the power and steam demands of each ship, as needed to provide electricity, heat, and hot water.

Interestingly, ships with similar capacity may have widely varying emission rates of SO_2. Consider the following two ships: Princess Cruise Lines' *Diamond Princess*, with a capacity of 4,138 passengers and crew, and Royal Caribbean's *Serenade of the Seas*, with a capacity of 3,300 passengers and crew. The *Diamond Princess* has a fuel consumption rate of 1,144 gal/hr, whereas the *Serenade of the Seas* has a fuel consumption rate of 745 gal/hr. The two ships also use different fuels containing widely varying amounts of sulfur (2.5% sulfur by weight compared with 0.05% sulfur by weight). As a result, the Diamond Princess emits 446 lbs/hr of SO_2, whereas the Serenade of the Seas emits only 5 lbs/hr of SO_2.

As the case with SO_2, NO_x emissions generally increase with ship size, but vary widely amongst cruise ship. Emissions of NO_x result from both fuel-bound nitrogen and the nitrogen contained in the combustion air. The emission rate of NO_x is a function of the fuel type and rate of fuel combustion, which increase in proportion to power demand.

Discussion and Conclusions

Cruise ships account for the majority of NO_x and SO_2 emissions in Skagway, but vary in amounts depending upon the number of ships docked in port. However, the amount of NO_x and SO_2 emitted by each ship can vary greatly, depending upon engine power demands, fuel type, fuel consumption rates, and the sulfur content of the fuel.

Emissions from cruise ships are regulated by the IMO. Recently, IMO adopted the U.S.-Canadian petition to establish all waters within 200 nautical miles of the U.S. and Canadian coast line as an Emission Control Area (*EPA 2010*). As a result, emissions from these large vessels will be regulated to reduce SO_2 and NO_x in the future.

Management Implications

In recent years, park managers have considered the air pollution impacts from the increasing number of cruise ships visiting Alaska parks. While it seems appropriate from a management perspective that limiting the number of ships would limit the air pollution impacts, an investigation into the emissions released from cruise ships has found cruise ships can vary widely in the amount of SO_2 and NO_x emitted. The study found that emissions of air pollutants from cruise ships are dependent upon engine power demands, fuel characteristics, fuel consumption rates, and applicable regulations. Thus, these insights offer new options for addressing concerns about air pollution while not necessarily limiting the number of cruise ships visiting parks. Additional modeling efforts may be able to refine the relationships between emissions, air quality, and impacts to natural resources.

A full report of the Air Pollution Emission Inventory from Skagway, Alaska, during the 2008 tourist season can be found on the Alaska Department of Environmental Conservation web site at http://dec.alaska.gov/water/cruise_ships/pdfs/Skagway2008_Final_Emissions_Report.pdf.

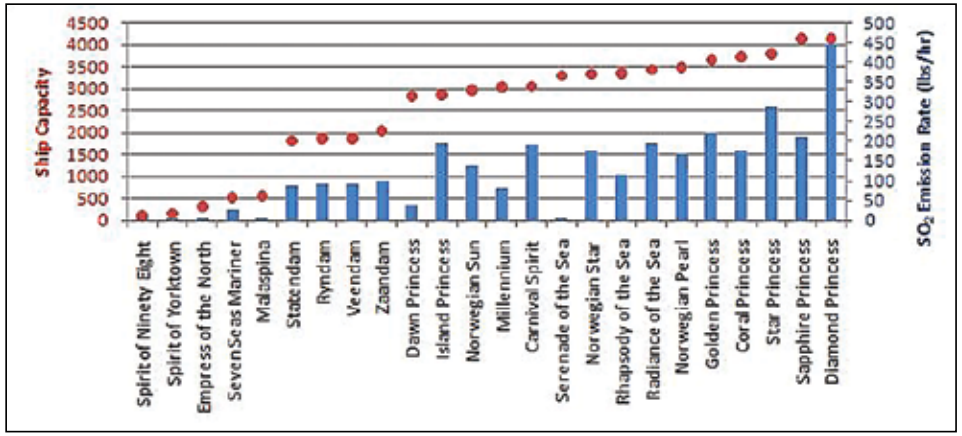

Figure 3. Emission rates of SO_2 from cruise ships and an Alaska Marine Highway ferry (*Malaspina*).

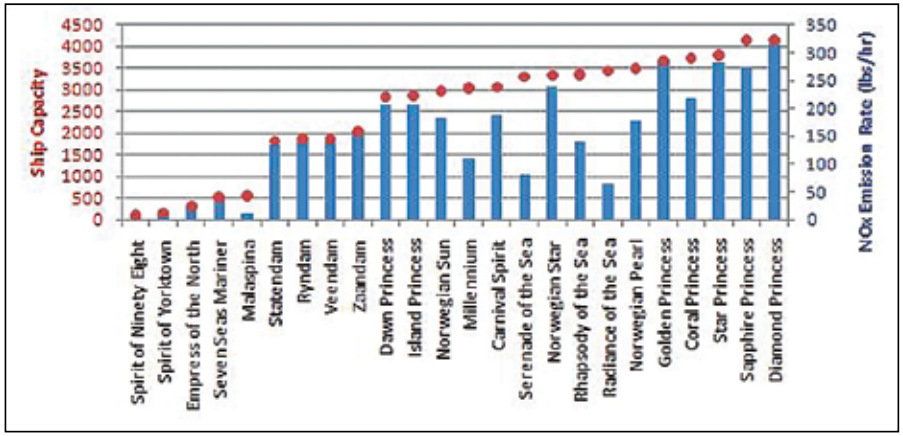

Figure 4. Emissions rates of NO_x from cruise ships and an Alaska Marine Highway ferry (*Malaspina*).

Photograph by Rick Graw

Figure 5. Inversion above Skagway.

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