Semi-Volatile Organic Compounds in Snowmobile Exhaust and in the Snowpack

Mark McDaniel, M.S.1,2 and Barbara Zielinska, Ph.D.2
1 Atmospheric Science Program, University of Nevada, Reno
2 Organic Analytical Laboratory, Desert Research Institute, Reno, NV

ABSTRACT

Two-stroke snowmobiles emit high levels of PM, over 90% of which is classified as organic carbon. Analysis for semi-volatile organic compounds (SVOCs) identifies 80 species of polycyclic aromatic hydrocarbons (PAHs) and 36 species of naphthalene and steranes in snowmobile exhaust and in snow taken from the snowmobile trail. Evolution of SVOCs deposited to the snowpack is documented for four days following snowmobile activity. Environmental parameters such as ultraviolet radiation, snowpack and ambient air temperature, and the accumulation of new snow over the snowmobile trail were monitored. Species of SVOC found to be the most stable include the naphthalenes, steranes, and some species of PAHs with 5 or 6 aromatic rings. These found to be the least stable are typically species with 2 or 3 aromatic rings, and are suspected of loss by volatilization. Additionally, photo-reactive compounds such as aromatics, phenanthrene, or fluorene may be readily photolyzed when exposed to UV radiation. Acumulation of fresh snow on the snowmobile trail isolates compounds from UV radiation incident on the snow surface and from gas exchange with boundary layer air, effectively reducing the degradation by photolysis and losses by volatilization.

OBJECTIVES

1. Characterize SVOCs in snowmobile exhaust and snow collected from snowmobile trails. Determine most stable species and most labile species.
2. Monitor environmental parameters to influence stability of SVOCs in snowpack and correlate with SVOC stability.

FUTURE RESEARCH

Develop chemical profiles for 2-stroke and 4-stroke snowmobile engines, and the transport of snowmobile emissions to the snowpack. Study transport and fate of snowmobile emissions in the snowpack.

METHODS

SVOCs were collected from snowmobile exhaust in a Tencon impregnated glass fiber filter followed by solid phase extraction cartridges (polyethylene foam + XAD resin) with a battery-powered personal sampler. During sampling, snow-mobiles were operated at various speeds and load conditions ranging from idle to 100% throttle. Samples were spiked with a surrogate mixture of deuterated PAHs and extracted by Microwave Assisted Extraction (MASE) with dichloromethane and fluoride in a PUF (polyurethane foam). Extracts were exchanged to 1 mL for analysis.

Samples of snow from the snowmobile trail were collected using a stainless steel tray and transported in a stainless steel container. Once collected, SVOCs in snow water were extracted with C12 solid phase extraction disks (C12 Nuplex, 100 mm). Disks were eluted sequentially with acetone, dichloromethane, and hexane. Eluted fractions were dried with anhydrous sodium sulfate and exchanged to 1 mL of acetone for quantification.

An analysis was performed using a Varian 3800 gas chromatograph with a Saturn 2000 ion trap mass spectrometer.

CONCLUSIONS

- Semi-volatile organic compounds present in exhaust and snowmobiles can be deposited to the snow surface in the snowmobile trail.
- Some species of SVOCs are more likely to persist in the snowpack, depending on volatility and reactivity.
- Environmental conditions can affect the persistence of SVOCs in a polluted snowpack.
- Burial of polluted snow layer by fresh snow reduces UV-B radiance driving photochemical reactions and thereby reduces degradation rates of photo-sensitive compounds.
- Temperature gradients in the snowpack affect oxygen movement in the snowpack, thereby influencing the distribution of gas-phase molecules, potentially redistributing vapor-phase SVOCs by advection with air movement.
- Transformation of PAH to oxidized-PAH can occur in-situ following deposition to the snowpack.