Concerns Regarding Silver Iodide Cloud Seeding

In May 2013, the Environmental Epidemiology Program (EEP), Utah Department of Health, received a request from a private citizen for technical assistance regarding the potential health effects from cloud seeding with silver iodide.

Background

The vast majority of modern attempts at modifying weather involve cloud seeding, which is the intentional treatment of individual clouds or cloud systems to achieve a desired effect (WMA, 1996). As the second driest state in the U.S., the goal of cloud seeding programs in Utah has been winter snowpack augmentation in mountainous regions to increase spring and summer runoff for agricultural and municipal water supplies (Griffith et al., 2009; Stauffer, 2001).

Cloud seeding has been ongoing in Utah since 1973 (DWR, 2014). The Utah Division of Water Resources (DWR) has estimated that cloud seeding increased runoff by 181,700 acre-feet, or 59.2 billion gallons, during the 2009-2010 season; this corresponds to an approximately 10% increase in April 1st snow water content (a predictor of annual runoff) (DWR, 2012). For water year 2014, there are four large-scale projects in the state, all of which use ground-based silver iodide generators (**Map 1**) (DWR, 2012; DWR, 2014). The generators use silver iodide-containing pyrotechnic flares which produce trillions of extremely small silver iodide particles. These particles increase the probability of ice crystal formation in a cloud, which then increase in size at the expense of surrounding cloud moisture and eventually fall to the ground as snow (Griffith et al., 2009; WMA, 2014).

Health Effects

Most people are exposed to very low levels of silver through food and drinking water. Silver in these sources is at least partially due to naturally occurring deposits in water and soil (ATSDR, 1990). Exposure to silver can also come from the use of silver in medicines and anti-bacterial compounds (e.g., in many water filters), jewelry making, soldering, and developing photographic film. Background levels of silver from naturally occurring sources in the U.S. range from 0.2 – 2.0 parts per billion (ppb) in surface waters and 200 – 300 ppb in soil; between 10 and 30% of drinking water supplies contain greater than 30 ppb silver (ATSDR, 1990).

Exposure to high levels of silver over a long period of time can result a gray or blue-gray discoloration of the skin and other tissues known as argyria. While this condition is permanent, it is thought to only be a cosmetic problem that is not otherwise harmful to health (ATSDR, 1990; ATSDR, 1999). Most doctors and scientists believe that argyria is the most serious human health effect of silver exposure (ATSDR, 1990). No studies are available on whether silver exposure may cause cancer in people, and the U.S. Environmental Protection Agency (EPA) has determined that silver is not classifiable as to human carcinogenicity (ATSDR, 1999).

The EPA has not established a primary (i.e., enforceable) standard for silver in drinking water. However, as exposure to high levels can cause cosmetic skin discoloration, EPA has set a secondary (i.e., non-mandatory) drinking water standard at 100 ppb (EPA, 2013). Secondary drinking water standards are also known as secondary maximum contaminant levels (SMCLs), and contaminants are not considered to present a health risk at these levels.

Silver Levels in Precipitation Post-Cloud Seeding
There have been a number of studies investigating the concentration of silver in snow and groundwater following cloud seeding activities. While most found levels of silver that were higher than the local background level (taken as evidence of the program's success), few if any identified silver concentrations in excess of EPA's SMCL of 100 ppb. Warburton et al. evaluated snow in two cloud seeding areas in the central Sierra Nevada Mountains and found silver concentrations ranging from 0.002 – 0.4 ppb, compared with background levels of 0.002 ppb (Warburton et al., 1995). In another study, silver concentrations in snow resulting from cloud seeding with silver iodide were 0.01 – 4.5 ppb, compared with concentrations of 0 – 0.02 ppb in snow from unseeded storms (Cooper and Jolly, 1970). A three year study of a cloud seeding project in a large area of the San Juan Mountains discovered no significant increase in silver levels in different media (Teller et al., 1976). Wisnieski and Sax assessed silver concentrations in Florida rainwater and found that sample from seeded clouds yielded precipitation with an average silver concentration of 0.13 ppb versus 0.07 for unseeded clouds (Wisnieski and Sax, 1979). An exposure and risk assessment for silver was conducted by EPA, who determined that silver released in precipitation as a result of cloud seeding is not expected to contribute significant amounts to water (EPA, 1981). More recently, Stromsoe et al. investigated sources of metal accumulation in an alpine tarn in a cloud seeding area in the Snowy Mountains of Australia and determined that the contribution of cloud seeding to silver levels in lake sediment was negligible (Stromsoe et al., 2013).

Conclusions
While silver iodide cloud seeding programs do result in elevated silver levels in precipitation compared with background, these levels remain significantly below the EPA SMCL for silver in drinking water of 100 ppb. It is also important to note that the majority of precipitation in cloud seeding areas is still the result of natural processes and will not contain silver iodide. For example, Utah cloud seeding projects during the 2012 – 2013 season were estimated to have resulted in a 10.9% increase in precipitation during the active seeding period (DWR, 2014). Thus, silver iodide in the snowpack in cloud seeding areas will be considerably diluted during the spring melt. Given these facts, and the relatively low toxicity of silver in humans, the EEP concludes that silver from cloud seeding projects is not expected to harm people's health.

Additionally, iodine from silver iodide cloud seeding is not expected to be a human health or environmental hazard as it is ubiquitous in the environment, an essential micronutrient for most organisms, and concentrations of iodine in precipitation from seeded clouds is far below the concentration found in iodized table salt (Cooper and Jolly, 1970; NAWC, 2012).

Report Prepared by:
Nathan LaCross, Ph.D., MPH
Epidemiologist
Environmental Epidemiology Program
Bureau of Epidemiology
Utah Department of Health

References

ATSDR, 1990. Agency for Toxic Substances and Disease Registry. Toxicological profile for silver.

ATSDR, 1999. Agency for Toxic Substances and Disease Registry. ToxFAQs for silver. Available online at: http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=538&tid=97

Cooper and Jolly, 1970. Ecological effects of silver iodide and other weather modification agents. Water Resource Research. 6:88-98.

DWR, 2012. Utah Division of Water Resources. Utah cloud seeding program: increased runoff/cost analyses. Available online at: http://www.water.utah.gov/cloudseeding/CostRunoff/Cloudseeding2011Final.pdf

DWR, 2014. Utah Division of Water Resources. Cloud seeding. Accessed on 01-23-14. Available online at: http://www.water.utah.gov/cloudseeding/Default.html

EPA, 1981. U.S. Environmental Protection Agency. An exposure and risk assessment for silver.

EPA, 2013. U.S. Environmental Protection Agency. Secondary drinking water regulations: guidance for nuisance chemicals. Accessed on 01-27-14. Available online at: http://water.epa.gov/drink/contaminants/secondarystandards.cfm

Griffith et al., 2009. 30+ winter seasons of operational cloud seeding in Utah. Journal of Weather Modification. 41:23-37.

NAWC, 2012. North American Weather Consultants. Cloud seeding frequently asked questions. Accessed on 01-27-14. Available online at: http://www.nawcinc.com/wmfaq.html

Stauffer, 2001. Cloud seeding – the Utah experience. Journal of Weather Modification. 23:63-69.

Stromsoe et al., 2013. Attribution of sources to metal accumulation in an alpine tarn, the Snowy Mountains, Australia. Environmental Pollution. 181:133-43.

Teller et al., 1976. Disposition of silver iodide used as a seeding agent in ecological impacts of snowpack augmentation in the San Juan Mountains of Colorado. Final report of the San Juan Ecology Project. 105-139.

Warburton et al., 1995. How the transport and dispersion of AgI aerosols may affect the detectability and seeding effects by statistical methods. Journal of Applied Meteorology. 34:1929-1941.

Wisnieski and Sax, 1979. Silver concentrations in rainwater from seeded and nonseeded Florida cumuli: 1973-1975 results. Journal of Applied Meteorology. 18:1044-1055.

WMA, 1996. Weather Modification Association. Weather modification: some facts about cloud seeding. Available online at: http://www.water.utah.gov/cloudseeding/PDF/Facts96.pdf

WMA, 2014. Weather Modification Association. Frequently asked questions concerning cloud seeding activities. Accessed on 01-23-14. Available online at: http://www.weathermodification.org/faq.php

Map 1. Current Utah large-scale cloud seeding project areas (from DWR, 2012).