

The expected impact of fireworks-related pollution on human health

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I. Introduction

The potential human health impact derived from the use of fireworks has received increased scrutiny in recent years due to the broadening understanding of the individual chemical components of the various types of ordinance utilized in large community fireworks displays. In response, the City of Madison Commission on the Environment requested that Public Health Madison and Dane County (PHMDC) evaluate the need to conduct surveillance of the potential human and environmental impact derived from exposure to perchlorate and other chemical constituents of fireworks. To appropriately evaluate this issue, PHMDC conducted a review of the available literature and existing data resources to assess the potential human health threat resulting from exposure to fireworks and possible need for additional surveillance.

II. Chemical components of fireworks

Fireworks shells contain oxidizers, propellants, and metallic salts that are deposited in fumes, fallout debris, and dust following launch and detonation (Moreno et al, 2007; WI DNR, 2009; Wilken, Fine, & Burnett, 2007). Among these components perchlorate salts and heavy metals including copper, barium, magnesium, and strontium are deposited into the environment to some degree; leading to potential exposure to these chemicals via inhalation of the ambient air during and following the fireworks display, dermal contact with fallout debris, and ingestion of contaminated drinking water supplies.

Perchlorate has received a great deal of recent attention due to its association with hypothyroidism and potential links to congenital hypothyroidism and reduced neurological development, learning disabilities, and IQ deficiencies due to competitive inhibition of iodide transport and subsequent reduction of thyroid hormone levels (De Groef, Decallonne, Van der Geyten, Darras, & Bouillon, 2006; Greer; Goodman, Pleus, & Greer, 2002; Lamn & Dnemland, 1999; US EPA, 2008). However, these associations were reported following evaluations of chronic exposure to higher dose levels [$\geq 4000 \mu\text{g}/\text{kg}/\text{day}$ (ppb)] via drinking water; in each of these cases, perchlorate contamination was derived from industrial sources (Greer et al, 2002; Lamn & Dnemland, 1999). Similarly, other potentially toxic components of fireworks such as barium and strontium also require sustained exposures to higher levels than concentrations consistently found in the environment.

III. Environmental deposition and human health from fireworks displays

Research in various communities, including the City of Madison, indicate a sharp increase in the environmental concentration of fireworks shell components following fireworks displays that move back toward baseline values over the course of several days (Moreno et al, 2007; PHMDC, 2005; Ravindra, Mor, & Kaushik, 2003; Wilken et al, 2007). The typical human exposure to these chemical constituents is very limited; normally over the course of a few hours. The peak levels reported in these investigations were highly variable, site specific, and dependent upon weather conditions prior, during, and following the fireworks display. In addition, the highest concentrations of these constituents reported in the literature derived from large scale displays are not adequate to lead to acute human toxicity. For example, Wilken et al. (2007) reported a peak value of 44.2 ppb of perchlorate in surface water at a single inspection site that occurred one day post-display and rapidly declined to less than 10 ppb by day two post-display with levels returning to baseline (approximately 0 ppb) by day 25; peak concentrations recorded at the other two inspection sites were approximately 2 and 11 ppb that also rapidly returned to baseline levels. Despite the reported spike of 44.2 ppb, this level is far below the level of perchlorate recognized to impact human thyroid function following chronic exposure; approximately 400 ppb and above (DeGroef et al, 2006; US EPA, 2008; Wilken et al, 2007). Similarly, the investigation conducted in Dane County, Wisconsin (excluding perchlorate) did not record peak levels of any of the study indicators that exceeded Wisconsin Administrative Code (chapters 102 and 105) standards following community fireworks displays (PHMDC, 2005).

Concerns about the degradation of drinking water quality in Dane County from fireworks are equally unsupported. The water cycle that allows the recharging of Dane County aquifers is a slow process that involves natural filtration of water supplies through soils and sand coupled with dilution, microbial degradation, sediment binding, and plant uptake. Perchlorate has not been reported in Dane County municipal water supplies and the levels of heavy metals routinely tested are within state and federal regulatory standards (US GAO, 2005; Madison Water Utility, 2010; PHMDC, 2010).

Additional concerns of environmental health have also questioned the impact of plant uptake and soil deposition of the chemical constituents of fireworks shells; several of these constituents, including perchlorate demonstrate this chemical behavioral to some degree. In fact, perchlorate has been reported to be taken up by aquatic and terrestrial plants including cucumber, lettuce, soybean, water lily, and a variety of trees where the contaminant was observed to accumulate in the leaves and not in the root systems (Tan, Anderson, Jones, Smith, & Jackson, 2004; Yu, Cañas, Cobb, Jackson, & Anderson, 2004). However, this uptake was governed by the species type, duration and concentration of exposure, and proximity to the contamination site. These investigations were conducted near industrial contamination sites over extended periods of time; therefore, the results do not reflect the expected environmental outcomes derived from fireworks displays due to the lower concentrations of contaminants, and lower frequency and duration of exposures.

Potential bioaccumulation in fish has also been suggested in the literature evaluating chronic exposure to perchlorate in surface waters adjacent to industrial contamination sites. In fact, fish collected from these sites were reported to contain elevated levels of perchlorate in the head area and the fillets. Impacts to thyroid structure and function have also been observed among fish at perchlorate contaminated industrial sites at concentrations as low as 100 ppb and exposure times of 30 days (Wilken et al, 2007). However, as previously stated, this may not be relevant to the expected impact of firework-related environmental contamination due to lower concentrations produced from the fireworks displays and the significantly smaller duration of exposure; the fish are exposed 24 hours/day for the reported time period while typical human exposures to elevated concentrations from fireworks extends only a few hours.

Despite the above commentary, there are legitimate human health concerns derived from exposure to fireworks displays. In addition to the direct exposure to chemical constituents contained in the fireworks shells themselves, the launching and detonation of the shells also produce sulfur dioxide (SO₂), carbon dioxide (CO₂), carbon monoxide (CO), and suspended particles that include fine particles (PM 10 and PM 2.5). Inhalation of the smoke and fine particulate matter has led to reported increases in respiratory illness reports such as asthma and bronchitis following fireworks displays; heart attacks and arrhythmias have also been associated with fireworks displays among individuals with cardiovascular diseases (Ravindra et al, 2003; WI DNR, 2009). Therefore, individuals with respiratory and/or cardiovascular diseases should take appropriate precautions when attending fireworks displays or view from a safe distance to reduce exposure to smoke and particulate matter.

IV. Summary

- The primary route of exposure to the chemical components and combustion products of fireworks displays is via inhalation of the dust, fallout, and smoke; exposure from dermal contact and ingestion also occur but are considered less significant than inhalation. The greatest risk to human health is the smoke and particulate matter (PM) that is created by launching and detonation of fireworks displays which temporarily reduces ambient air quality. Individuals with respiratory and/or cardiac diseases are particularly at risk and should take appropriate precautions to avoid potential health effects.
- Each of the chemical constituents of fireworks including perchlorate, strontium, copper, and barium are considered toxic to variable degrees; however, toxicity is not expected from fireworks displays due to the observed exposure levels and limited duration of environmental increases.
- No impact to municipal drinking water quality is expected from environmental pollutants derived from fireworks.

V. Conclusions

Following a thorough review of the available literature and existing data resources, PHMDC does not feel that additional surveillance is necessary at this time for perchlorate and other chemical pollutants derived from launching and detonation of fireworks at large community level displays. Due to the short duration of exposure to the chemical constituents of fireworks shells during the display itself and the rapid reduction of residue pollution levels in the environment following the display, no human health impact is expected from this source.

However, individuals with respiratory and/or cardiovascular diseases should take appropriate precautions due to an increased risk of disease-related complication and/or exacerbation associated with exposure to the smoke and particulate matter derived from fireworks displays.

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