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US Scented Candles Study

The following is an extract only of a Master of Science in Public Health thesis entitled "CHARACTERIZATION OF SCENTED CANDLE EMISSIONS AND ASSOCIATED PUBLIC HEALTH RISKS" by J. DAVID KRAUSE, Department of Environmental and Occupational Health, College of Public Health, University of South Florida, August 1999. Major Professor: Raymond D. Harbison, Ph.D. Copyright by J. David Krause 1999. All rights reserved. Extracts were chosen (and emphasis added) by The LEAD Group Inc.

ABSTRACT

The recent increased popularity of scented candles has prompted concerns by consumers and public health officials about their emission products. **According to the National Candle Association, candle sales are approaching $2 billion annually.** The combustion of scented candles in residences, which typically have low ventilation rates, may raise indoor concentrations of combustion products. A recently described phenomenon of residential black soot deposition, sometimes associated with scented candle usage, prompted concerns that occupant exposures to soot and other candle emissions may constitute a health risk. The lack of data on candle emissions prompted this research into the volatile, semi-volatile and particulate emissions from scented candles and their potential health risks.

This study characterized the products of emission by individually burning 91 candles inside a stainless steel combustion chamber and determining specific emission rates of soot, benzene and lead. Candle soot was typically less than 1 µm, contained up to 66% elemental carbon and carried numerous adsorbed organic compounds including dibutyl phthalate, diethyl phthalate, toluene and styrene. Volatile organic compound emissions included benzene, styrene, toluene, ethyl benzene, naphthalene, acetylaldehyde, benzaldehyde, benzene, ethanol, and 2-butanone (methyl ethyl ketone). Analysis for lead revealed some candles emitted significant quantities of aerosolized lead during combustion.

A risk assessment of occupant exposures to soot, benzene and lead resulted in the highest attributable risk being from soot, ranging from 9.7×10^{-5} to 4.7×10^{-2}. Lead exposures were modelled for children and suggest the potential to raise blood lead levels of children above 10 µg/dL when typical background exposures are also present. **The possible impacts on public health from consumer use of scented candles may include increased risk of cancer, neurological and behavioral deficits and acute aggravation of existing respiratory diseases such as asthma.**

Chapter 3 - Results

Scented candle emissions were determined to consist of vaporphase and particle-phase components. Low levels of benzene emissions were also detected from a non-burning candle.

Soot

Particulate emissions exhibited the physical and chemical characteristics of soot. SEM analysis revealed particle sizes ranging from 0.045 µm to 0.2 µm diameter.

Elemental carbon content ranged from 6% to 66%, with a median value of 32%. All soot samples tested for semivolatile organic compounds revealed high quantities of paraffins but varied in amounts of other adsorbed compounds. Dibutyl phthalate was identified in 33 of 53 samples, diethyl phthalate (8/53), bis (2-ethylhexyl) phthalate (7/53), didecyl phthalate (4/53), toluene (7/53) and styrene (3/53).

Analysis of soot did not reveal measurable amounts of benzo[a]pyrene or other PAHs typically identified in combustion products. This finding was inconsistent with previously reported studies and could not be readily explained. A recent study of candle soot from non-scented candles by Fine and Cass also did not reveal measurable amounts of PAHs.

Soot emissions from scented candles were significantly higher than those from non-scented candles. Forty five percent of non-scented (n=11) candles produced detectable amounts of soot, while 63% of scented candles (n=80) produced detectable amounts of soot. Soot production from non-scented candles, that produced soot, ranged from 20-175 µg/min/wick (mean 83 µg/min/wick). Soot production from scented candles, that produced soot, ranged from 20-3100 µg/min/wick (mode 1 = 180, mode 2 = 1650 µg/min/wick). The fine particulate matter collected from candle emissions was similar to that of diesel engine exhaust in particle size, morphology, elemental carbon content, and adsorbed chemical constituents, although lacking detectable quantities of PAHs.

Lead

All candles which had wire core wicks were tested for lead emissions. Of the 91 candles tested, 27 had wire core wicks in addition to one candle which was in a metal container. Four of the 27 candles with wire core wicks were determined to emit detectable quantities of lead, ranging from 0.40 µg/min to 120 µg/min. **The candle in the metal container, which did not have a wire core wick, was found to emit lead at a rate of 1.3 µg/min.** Only one of the candles determined to emit lead also emitted detectable amounts of soot. This observation suggests that a visually clean burning candle could still emit significant quantities of lead.

Chapter 4 - Risk Assessment

Public health risks associated with scented candle usage, were estimated by identifying chemical emissions and then determining occupant exposures. The emission characterization performed on candle emissions in Phase I revealed there was great variability in both the vapor phase and soluble organic fraction of particulate emissions, but that the particle size was consistently less than 1 µm. The first step in assessing risk is identifying the chemical hazards associated with candle emissions.

Hazard Evaluation

Soot

While unit risk values exist for many of the vapor phase emissions from candles, unit risk values for candle soot have not been developed. Due to the numerous similarities between candle soot and diesel soot, the unit risk value for diesel exhaust could be used for the purpose of assessing risk associated with candle soot…. **IARC has classified diesel exhaust as a probable human carcinogen 2A.**

Lead

Although lead was only detected in the emissions of 5 out of 91 candles, the implications of lead exposures from a previously uncharacterized source supports its inclusion in this risk assessment. Extensive data exist on exposures to lead in both occupational and residential settings. Tremendous resources have been expended to remove lead containing materials from homes and schools.

Exposure Modelling

Due to the lower air exchange rates in newer homes, the residence time of emissions were determined to continue for up to 10 hours after extinguishing a candle.

Risk Characterisation

Scented candles have become common-place in homes and in certain businesses such as boutiques, salons, and spas. However, the indoor environment where the most significant exposures are likely to take place, due to low ventilation rates and long duration of occupancy, are homes.

Chapter 5 - Discussion

Scented candle usage indoors may cause high levels of respirable soot, with risks to occupants for both acute and chronic health effects, including an increased risk of cancer. Similarities between candle and diesel soot, suggest the potential for similar toxicological effects on exposed occupants.

Comparison with Diesel Exhaust

Studies indicated that filtered diesel exhaust is not as toxic or carcinogenic as whole diesel exhaust. The marked difference between whole and filtered diesel exhaust was also evident from general toxicological indices such as decreased body weights, increased lung weights, pulmonary function measurements, and pulmonary histopathology in animals (ie. proliferation of Type II cells and changes in the respiratory bronchiolar epithelium, and fibrosis). Numerous studies have shown that animal exposure to diesel particles plus vapor-phase compounds produced biochemical and cytological changes in the lung that are much more prominent than those evoked by the vapor-phase chemicals alone. These studies point to the predominant effects that soot may have on occupant health. Comparison of the particle-phase products from diesel and candle emissions is essential to demonstrate similarities in potential toxicity.

Acute health endpoints due to soot exposure include reduction in alveolar macrophage activity and acute inflammatory response. For individuals with pre-existing asthma and allergies an increased risk of acute attacks are also potential health effects. The US EPA has determined a Reference Concentration (RfC) for diesel exhaust of 5 $\mu g/m^3$. The American Conference of Governmental Industrial Hygienists (ACGIH) has served notice of intent to change the Threshold Limit Value (TLV) for diesel exhaust particulate from 150 $\mu g/m^3$ to 50 $\mu g/m^3$ for 8 hour exposures. These are considered safe levels of exposure based upon a scientific consensus. The lowest observable adverse effects level (LOAEL) for DPM has been determined to be 300 $\mu g/m^3$ (HEC [human equivalent concentration]). The no observable adverse effects level (NOAEL) was determined to be 155 $\mu g/m^3$ (HEC). The concentrations of candle soot an occupant may be exposed to due to candle combustion may be significantly higher.

Ambient Particulate Matter

Concerns of population risks associated with exposure to submicron dust particulate and its impact on acute respiratory and cardiopulmonary disease has resulted in regulation of ambient particulate levels. Changes in NAAQS to include regulation of particulate matter 2.5 µm and smaller (PM2.5) are intended to address microscopic soot, which is believed to contribute greatly to the urban illnesses associated with air pollution. The contribution of candle soot during indoor exposures can be orders of magnitude higher than outdoor exposures and may be significant sources of total soot exposure.

Conclusions

Soot Exposure Risks

The characteristics observed in candle emissions match those of diesel emissions in the aspects considered to contribute to toxicity. Their size, less than 1 µm, allows deep penetration of the respiratory system and alveolar deposition. The insoluble, carbonaceous core structure with high surface area allows adsorption of extractable volatile, and semi-volatile organic compounds. Its origin is from the incomplete combustion of hydrocarbon containing fuel, allowing the formation of aromatic structures, which become adsorbed to the carbonaceous core. Studies of diesel particulate have indicated the above factors are those which contribute to its toxicity and carcinogenicity. Diesel soot and candle soot share the same physical and many of the same chemical properties which are believed to contribute to both toxicity and carcinogenicity. These similarities point to a similar potential for adverse health effects.

Comparison with the reference concentration (RfC = 5 $\mu g/m^3$) for diesel soot shows the emissions from candles can cause significantly higher exposures to occupants (3-520 $\mu g/m^3$). This exposure indicates that further examination of scented candle emissions is needed to determine its toxicity and carcinogenicity. Due to the current absence of information on scented candle emission toxicity, and its numerous similarities with diesel exhaust, it would be prudent to tentatively adopt the recognized toxicity values for diesel emissions until specific testing can be accomplished. When the unit cancer risk for diesel exhaust is applied to exposures to candle soot, **the estimated increased cancer risk for a lifetime exposure, would range** from 9.7×10^{-5} to 3.0×10^{-4} for the lowest emitting candle to 1.5×10^{-2} **to 4.7×10^{-2} for the highest emitting candle,** using the range of unit cancer risk of 2.9×10^{-5} to 9.0×10^{-5} per $\mu g/m^3$.

Benzene Exposure Risks

Candle emissions can contribute to increased exposure to benzene and other potentially carcinogenic volatile and semi-volatile organic compounds. Average daily inhalation exposures to benzene were found to range from 0.02 - 1.6 μg/m^3-day due to the use of 1 candle per day. The carcinogenic risk attributable to a lifetime exposure would range from 3.3 x 10^{-8} to 1.2 x 10^{-7} for the lowest emitting candle to 3.5 x 10^{-6} to 1.2 x 10^{-6} for the highest emitting candle using the Inhalation Unit Risk of 2.2 x 10^{-6} to 7.8 x 10^{-6} per μg/m^3. Further consideration of benzene as a significant risk in the use of scented candles should be made. Due to the use of multiple candles simultaneously, occupants may become exposed to levels of benzene constituting a cancer risk greater than 1 x 10^{-5}.

Lead Exposure Risks

Average daily doses of lead were shown to range from 0.4 to 120 μg/day. By comparison, the upper range of these values exceeds the equivalent dose caused by exposure to the NAAQS limit of atmospheric lead of 1.5 μg/m^3, equivalent to 30 μg/day. Using the IEUBK model, blood lead levels for children 2-3 years of age could exceed 10 μg/dL if exposed to daily emissions of certain candles which emit lead.

Summary

Use of scented candles may contribute significant quantities of pollutants to the indoor environment, especially soot, benzene and lead. Dozens of other compounds were identified in individual candles, but their contribution to occupant risks were not characterized in this limited scope risk characterization. Due to the variability in candles and their respective emission rates, great uncertainty would exist in a generalized risk assessment. The available data suggest that each candle type should be evaluated for its emissions and contribution to occupant exposure. There appear to be three distinct candle types with regards to soot emissions; low emitting candles, with no detectable emissions of soot; moderate emitting candles ranging from 20-600 μg/min; and high emitting candles ranging from 900 to 3000 μg/min. It has also been observed that visible soot emissions are not associated with significant lead emissions, thus do not offer any protective warnings for users. The absence of consumer warnings concerning candle emissions and their potential health effects may contribute to exposure of susceptible individuals to respiratory inflammatory agents, carcinogens and teratogens.