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Cookstoves, Candles, and Phthalates – Real Time Physicochemical Characterization and Human Exposure to Indoor Aerosols

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2021

Document Version:
Other version

Link to publication

Citation for published version (APA):
Andersen, C. (2021). *Cookstoves, Candles, and Phthalates – Real Time Physicochemical Characterization and Human Exposure to Indoor Aerosols*. Division of Ergonomics and Aerosol Technology, Department of Design Sciences Lund University.

Total number of authors:
1

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Popular Science Summary

The air we breathe contains small amounts of liquid and solid particles suspended in gas, altogether called aerosols. The sources of aerosol particles are both natural and human made, and they are essential for our climate. They affect cloud formation, the incoming solar light (radiation), and the radiation reflected back to space, thereby influencing Earth's radiative balance. Aerosol particles also impact human health negatively. Upon inhalation, some particles deposit in our lungs and can even be distributed to other organs. Nine out of ten of the world's population breathe air that does not live up to the air pollution guidelines set by the World Health Organization (WHO). Developing countries are experiencing the highest burden of increased air pollution levels.

The aim of the research presented in this thesis was to gain increased knowledge of characteristics of the emissions from common indoor aerosol sources, including cookstoves and candles, with a focus on emissions relevant to health and climate. An additional aim was to investigate the uptake of phthalates (hormone disrupting compounds) on different particle types, and to study how airborne phthalates are taken up in our bodies by conducting a human exposure study.

One of the main sources of household air pollution in developing countries is the use of simple biomass stoves for cooking and heating. A large variety of cookstoves are on the market, ranging from the traditional and most widely used 3-stone fire, which is an open fire between three stones, to improved and advanced stoves, where the insulation and more controlled air supply have been incorporated into the stove design. In this thesis research, the pollutant emissions from four different cookstoves were characterized chemically by using real time measurements. The traditional 3-stone fire showed the highest total aerosol mass concentration per kilo burned fuel. Concentrations decreased with the increasing advancement in stove design. However, even at decreased total particle concentrations, emissions of compounds that can be harmful for human health can still be high. Examples of such compounds are soot particles and polycyclic aromatic compounds (PAHs), compounds that may cause cancer.

Another frequently used source of combustion aerosols in indoor air is candle burning. Candles should preferably burn with a steady flame. However, in real indoor environments, air movements in the surrounding air caused by human movements and drafts from doors and windows are difficult to avoid and will cause flickering of the flame. Flickering candle flames are known to emit soot particles. This phenomenon can even be observed with the naked eye as a black puff of smoke coming from the candle flame when it flickers. However, the effect of the wax and wick material on emissions of soot and other pollutants is largely unknown. Emissions from the flickering burn of five candle types of similar shape but different wax and wick material were measured to study the influence of candle materials on the pollutant emissions. The results showed strong variations in the soot emissions between candle types. The candles with the lowest soot emissions also showed high emissions of ultrafine particles, which has a high probability of depositing in our lungs upon inhalation. Contrary to soot emissions, the levels of the gaseous pollutants NO_x, formaldehyde, and gas-phase PAHs, which are of concern for human health, varied much less among the tested candles. While reduction in soot emissions can be obtained by an optimized wax and wick combination, NO_x, formaldehyde, and the emission of gas-phase PAHs proved harder to prevent from candle burning.

Concerns have been raised about the widespread use of chemicals in consumer products. Many of these chemicals enter the market without sufficient testing and with little knowledge about their safety. Because of their frequent use, they find their way into our homes via building materials and consumer products. Phthalates are a group of such chemicals that has gained increasing attention over the past decades because some phthalates disrupt the human hormone system. Phthalates are, for instance, ingredients in personal care products (for example, diethyl phthalate [DEP]) and are used as plasticizers to increase the flexibility of plastic materials (for example, di-(2-ethylhexyl phthalate) [DEHP]). Because phthalates are not chemically bound in the material, they can evaporate into the surrounding air. In the thesis research, the uptake of DEHP, emitted from polyvinyl chloride (PVC) flooring, onto different particle types was measured. The results showed increased emissions of DEHP from the PVC flooring in the presence of particles. The results also showed a higher uptake of DEHP in indoor particles with a higher content of organic compounds compared to salt particles produced in the laboratory.

Besides exposure via inhalation, our skin is also exposed to surrounding air pollutants. To evaluate the human uptake of phthalates via skin and inhalation, a human exposure study was conducted. Sixteen voluntary participants were exposed for three hours to either a gas-phase phthalate (DEP) or to a particle phase phthalate (DEHP). They were exposed via both skin and inhalation in a combined exposure, and via skin only, with the participants breathing clean air through a hood. The gas-phase DEP uptake was observed via both inhalation and skin, with the inhalation uptake being approximately ten times higher compared to skin uptake. The participants wore clean clothing and showered after exposure, which may have rendered partial protection against uptake via the skin. No uptake via the skin was measured from particle phase DEHP exposure. The inhalation uptake of DEHP was four times lower compared to DEP, which may reflect the differences in the lung deposition of gases and particles.

These results emphasize the importance of chemical characterization and quantification of indoor particle emissions, and the need to consider the properties of aerosols and chemicals in risk assessments. The content of organic compounds in particles is often high in indoor environments, which may increase the uptake of DEHP on particles, which can end up in the human lung upon inhalation. To keep chemical exposure levels at a minimum, both harmful chemicals in consumer products and particle concentrations should be reduced.