Report

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Report on the literature study of chimney sweepers exposure to harmful inhalable particles.

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Introduction:

This report is a part of Scindeep project (Safety Challenges for Industries: Dermal Exposure to nanosized Particles). It has been created with a goal of briefly summarizing relevant information concerning different harmful inhalable particles that chimney sweepers are exposed to on a regular basis. Information was found as part of a literature search conducted by research assistant Daniil Petrov. It should be noted that while the subject of chimney sweepers' health is not a new topic (originally visited by Sir Percival Scott) it is, however, not a very well explored one. The majority of the scientific documents on the subject of chimney sweepers' health date back 30 or more years ago, which is of course not ideal. Therefore, a different approach was used. Taking the most commonly used types of fuel into account the literature search focused on carcinogenic of post combustion particles. With all this in mind the following is a brief summary of the most relevant findings.

Most common health hazard: Airborne PAH

Before conducting this literature search a list of relevant particles and gases was received to start off the work. Among them PAH or polycyclic aromatic hydrocarbons have shown themselves to be by far one of the most common and most cancer inducing particles that chimney sweepers encounter.

PAH's are a class of chemicals that are comprised of multiple aromatic rings. They naturally occur during combustion of various burnable substances such as but not limited to: coal, oil, gasoline and wood. It is also worth noting that PAH's are quite capable of binding themselves to many different types of substances, therefore it is important to understand that the exposure to PAH's does not occur via only one source but rather multitude of different sources. Traces of PAH can often be found in food, soil and water (3). And while they may not be the main contributor to potential negative health effects they should still be considered.

PAH’s generally bear a low degree of danger, however prolonged exposure to them over a long period of time can lead to a number of health issues. Among them the most devastating ones are different kinds of cancer that PAH may induce in the human body. The type of cancer is often dependent on how one was exposed to either a large dosage of PAH in a short period of time or to a small dosage over a long period of time. In our case that would be inhalation during chimney sweeping, something that quite often leads to lung cancer (1).

PAH carriers: soot and carbon black

Both carbon black and soot are products of incomplete combustion (4) of several fuel types coal, coal tar, vegetable matter (such as wood), different petroleum products and so on. Incomplete combustion occurs due to a variety of factors however, the main cause is the lack of oxygen. It can be safely assumed that least partial incomplete combustion takes place in most houses that use firewood or coal as main heating sources (this assumption can also be made due to how difficult it is to facilitate fully complete combustion). Therefore, the combustion will naturally produce soot and carbon black.

Carbon black by itself is considered possibly carcinogenic (7). Several research papers studying this topic contradict each other. This potentially suggests that while carbon black bears an overall low degree of danger, it can in combination with other cancer inducing factors be dangerous. It is also worth noting that carbon black contains a certain amount of PAH, however the amount of PAH content is often negligible (7).

Soot on the other hand is considered directly carcinogenic (3). Soot by itself is quite toxic and induces oxidative stress. The severity of oxidative stress and potential lung diseases is largely determined by particle size (PM10, PM2.5, PM1) which is in terms determined by variety of factors during combustion process. Soot is also a carrier to a considerable amount of PAH making it a contributor towards a PAH induced cancer.

Airborne particulate matter

During combustion many different airborne masses other than PAH, soot and carbon black also naturally occur as a byproduct of combustion. This airborne particulate matter or PM10 also often ends up existing alongside the direct products of combustion. Research on the topic reveals that PM_{10} induces several proinflammatory, cytotoxic and genotoxic effects as well as cell invasion of lung’s epithelial cells (4). In addition, it is also capable of bonding PAH, metals, ions and other various biological components making it a potential carrier for a variety of harmful substances. Though it is important to note that even all this only nearly scratches the surface of various effects that particulate matter has on one's health. But while research is still being conducted one thing is clear: vast majority of particulate matter that occurs as byproduct of combustion is very toxic to human bodies (3,4,5,6).

Quantification:

First and foremost, it is vital to mention that quantification of all of these hazards are highly dependent on procedure of sample collection or sampling as it is commonly referred to. PAH is notoriously hard to detect due to the great number molecular combinations that fall under the category of PAH that differ in their respective properties. Therefore, in order to detect PAH we substitute the direct PAH count with an indicator certain substances that PAH binds itself to and that are easier to measure (usually either due to these substances being easier to detect, easier to gather etc.). With regards to soot and carbon black are the main carriers. During the cleaning process large amounts of soot and carbon black are cleaned out of the chimney (1), which naturally leads to them mingling with the air. Therefore, the main carriers that are used for most PAH quantification are these 2 materials. Though it should be noted that various experiments may use different materials to quantify specific types of PAH.

With regards to the specific types and properties PAH detected after combustion by far the most important factor is the fuel type (4). Quantification research on the subject typically uses emission factors to describe the amount of matter produced per unit of fuel burned. These factors are usually described as mg/kg fuel (mg of PAH produced for each kg of fuel) and/or a ng/kg fuel (same logic however here ng is used rather than mg) but can also come in the form of for example µg/MJ fuel (µg of PAH per MJ of energy produced by the fuel type). The specifics of emission factors usually depend on how much of specific matter was detected and sampling conditions.

As for the fuel types themselves there is obviously great variation however the one that is most central for us is the standard household fireplace fuel. The materials used for heating vary from household to household however the materials that are most widely available and are most commonly used for household heating by Norwegian populace are: household coal, birch, oak, spruce and pine. Each of these materials has a different emission factor that will be demonstrated in the table below. These tree types and coal are readily available in most hardware stores (stores such as Biltema, Obs Bygg, Clas Ohlson, etc. were taken as refence for this report) at a reasonable price. The table below is a simplified version of various tables that can be found in documentation detailing combustion experiments that were conducted to measure PAH release:

Table 1: PAH value of different fuels

Material:	Amount detected:	Emission factor:
Household coal	25[5]	mg/kg fuel
Birch	14.8[2]	µg/MJ fuel
Oak	3.97-3.83[6]	mg/kg fuel
Spruce	82.8[2]	µg/MJ fuel
Pine	15.6[2]	µg/MJ fuel

Since the results for this table have been collected from separate documents their emissions factors and sampling methods vary. There are however some common sampling factors such as that the sampling has been conducted from the very start of combustion process to the very finish including the refuel stages where extra fuel was added to maintain steady combustion. This did however result in different sample times for different material due to the natural differences in length of combustion.

For birch, pine and spruce various particulate matter was sampled in the flue gas channel approximately 2.5 mm from the top of the stove (2). A porous glass tube diluter was user to collect material for further analysis on a 90 mm glass fibre filters. Household coal flue gas sampling relied on iso-kinetic withdrawal of a portion of the total flue gasses throughout second and third burning cycles (5). Sampling was maintained during de-ashing and refueling due to these operations contributing greatly to the number of various pollutants. Gas was collected in a cyclone separator that lead to which led to the polypropylene stabbing and flange assembly which in turn lead to the Whatman GF/C grade 90 mm glass circle filters. Samples were later retrieved for analysis. As for the oak gas sampling, the samples were collected through a dilution tunnel system (6). The fireplace construction used in test allows the products of combustion to cool and mix with the indoor air in the dilution tunnel system allowing for collection of samples in their ambient atmosphere form on a 47 mm filter. At the time of measuring the flowrate was measured to be 1.1 L/min in the dilution tunnel system.

It is important to note that this table is simplified and contains the average values of the most harmful PHA’s detected after combustion. The values in this table also do not include PAH that are largely regarded as harmless but over dramatize the end result of research. An example of this is levoglucosan which as of the time of writing this report has not been proven to have any sort of relation to the inflammatory gene expression. As such it is highly recommended that the values in the table should be taken as a preliminary estimate. For all further information about these values, you can consult documentation listed as sources.

Another important aspect worthy of consideration is the difference in emission due to the regional nature of the fuel. Even if much of the wood and household coal is imported to the country, there is still a large percentage of wood that is acquired locally in Norway. Emission data from other countries where tests were conducted may not be fully representative of those that one could get here, were they conduct the same experiment with but with local wood. One should not discount the possibility of different climate and soil leading to different results.

As for the airborne particulate matter that also occurs due to combustion it has been difficult to find any research that would directly give us any concrete emission factor. Therefore, a different approach was used. Instead of studying just the emission factor an attempt was made to also search for PM_{10} concentration in the air after the combustion. This attempt would soon bore fruit and lead us to study conducted in Greece on the matter of biomass fuel type and combustion conditions. The research itself used a variety of wood pellets rather than simple logs and does not include values for household coal (due to it not being tested). Overall, 5 types of pellets were used during this experiment: mix of pine-beech-oak, mix of spruce-pine-oak, 100% spruce pellets, olive pellets and pellets from the olive core (4). Following are the values that were obtained as part of this experiment:

Table 2: Average total mass of PM10 emissions in the filters after combustion

Type of combustion:	PM_{10} concentration (mg/m^3):
Lab scale 20% O_2	154.12[(4)]
Lab Scale 13% O_2	97.35[(4)]
Pellet Stove 10 kW	62.46[(4)]
Pellet Stove 8.5 kW	50.49[(4)]
Fireplace	150[(4)]

The PM_{10} was collected using a Thermo 6186 FRM exhaust dual filter holder system with a Whatman PM_{10} quartz filter with a diameter of 4.7 cm attached underneath in order to retain all of the particles with diameter from <10 µm to 0.31µm (4). In addition, a dual stage Oerlikon Leybold Vacuum pump with the flowrate of 5.4 m^3/h was attached to the filter holder in order to boost particle retention for isokinetic sampling. Lastly 2 moisture traps were used to ensure the safety of the pump and to ensure that samples would not lose or gain any additional moisture.

Sources:

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