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Tobacco smoke particles and indoor air quality (ToPIQ) - the protocol of a new study

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Abstract

Environmental tobacco smoke (ETS) is a major contributor to indoor air pollution. Since decades it is well documented that ETS can be harmful to human health and causes premature death and disease. In comparison to the huge research on toxicological substances of ETS, less attention was paid on the concentration of indoor ETS-dependent particulate matter (PM). Especially, investigation that focuses on different tobacco products and their concentration of deeply into the airways depositing PM-fractions (PM10, PM2.5 and PM1) must be stated. The tobacco smoke particles and indoor air quality study (ToPIQS) will approach this issue by device supported generation of indoor ETS and simultaneously measurements of PM concentration by laser aerosol spectrometry. Primarily, the ToPIQ study will conduct a field research with focus on PM concentration of different tobacco products and within various microenvironments. It is planned to extend the analysis to basic research on influencing factors of ETS-dependent PM concentration.

Introduction

The supply of clean air is regarded as one of the most important basic factors for the human health and well-being. In consequence, polluted air is able to threat human health and is considered as a major global health problem [1]. According to an estimation of the WHO (World Health Organization) approximately 2 million premature deaths worldwide per year are caused by air pollution [2]. Especially the quality of indoor air is of utmost importance for human health. Not only because people spend most of their time indoors (in industrialized countries, as the USA, up to almost 90 percent [3]) but also because the indoor concentration of pollutants is often much higher [4]. The wide range of indoor pollutants contains organic or inorganic chemicals, biological aerosols (bioaerosols) and particles. A major source of indoor air pollution is the environmental tobacco smoke (ETS, also called second hand smoke) [5-7], which is a mixture of exhaled mainstream smoke (MS) and sidestream smoke (SS) released from the smouldering tobacco product. Since decades it is well documented that ETS can be harmful to human health and causes premature death and disease to the non-smoking population [8]. Especially ETS exposed children have an increased risk for acute respiratory infections, sudden infant death syndrome, more severe asthma and ear problems [6,8]. In the adult population, exposure to ETS is associated with acute coronary heart disease [9-11] and lung cancer [12,13]. According to a 2004 published estimation by Öberg et al., almost half of the world's children (approx. 40%) are regularly exposed to ETS followed by nonsmoking women (35%) and men (33%) [14]. Although exposure to ETS appears to present smaller risks than active smoking, the large percentage of exposed people, coupled with evidences that ETS causes illness and premature death, demonstrates a substantial public health threat. Because of these adverse effects to human health, tobacco smoke has been intensely investigated. To date, about 5000 individual compounds have been quantitatively determined in cigarette smoke [15], including many toxic substances as well as 69 carcinogens, of which 11 are known human carcinogens and 7 are probably carcinogenic in humans [16]. Many of these toxic and carcinogenic substances can be found in ETS as well. Particulate matter (PM) is one of those harmful components that can be found in ETS and is responsible for ETS as a substantial contributor to the level of particulate indoor air pollution [17]. Because of their capability to deposit deeply in the respiratory tract, particles of the PM10- and PM2.5-

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fraction can cause serious health problems. For a long time, PM10 and PM2.5 have been proven to be associated with acute and chronic health effects. Epidemiological data suggesting that exposure to particle pollution (PM10 and PM25) is able to increase morbidity and mortality of cardiopulmonary diseases like pre-existing COPD [18-23], cardiovascular diseases [24-26], exacerbation of asthma [20,27,28] and other conditions [29]. In addition, exposure to PM and especially to PM2.5 has been linked to the development of cancer [30]. However, the exact mechanism of cancer induction due to PM is still not resolved. Regarding the impact of both ETS and PM on human health, only few data is published about the concentration of PM in ETS so far.

Aims

It is the aim of the ToPIQ study to assess the particle concentrations (PM10, PM2.5 and smaller particle fractions) that are produced by different tobacco products under a multitude of different conditions. Next to the determination of ETS-dependent PM concentrations within various microenvironments, like vehicle cabins, this study aims to examine the role of physical influencing factors on the PM concentration.

Methods

For the implementation of the ToPIQ study (ToPIQS), generation of ETS it will be necessary. To avoid health risks on human smokers a self-made ETS emitter (ETSE) will be used for the indoor ETS generation (Figure 1). Basically, the ETSE consists of a bag valve mask (BVM) plus tubing by which MS from the burning cigarette can be collected and afterwards vented out into the testing chamber. Throughout the experiment the burning tobacco product will be situated inside the testing chamber, producing the SS in between the time of MS collection. When the bag is inflating it collects the smoke inside. During the compression of the bag, the smoke will be released in the chamber. The compression and decompression of the bag will follow a predefined protocol under support of acoustic signals. The hand-operating ETSE will be attached outside of the chamber. There, the researcher can operate the device without the potential harm of an ETS exposure. Glove ports on the outside of the chamber will provide an isolated access to the chamber (Figure 1). In the future, the implementation of an automatic ETSE (AETSE) in the study is planned. With this device, simulations of ETS emitted by multiple smokers will be conducted.

The experiments will be carried out in different microenvironments. For the basic research on ETS of different tobacco types, a 1.75 m^3 telephone cabin will be used as an ETS test chamber (Figure 2). To simulate natural conditions the test chamber will be placed on an outdoor

Figure 1 Picture taken from outside of the testing chamber (telephone cabin) showing the ETSE (1) and the glove ports (2).

area in urban surrounding. Inside the chamber, mobile sensing modules will be placed, which will continuously measure the concentration of particulate matter (PM10, PM2.5 and PM1) and physical parameters (temperature, humidity, wind velocity). Subsequently, the measured data will be saved on an ultra-mobile PC unit. The generation of indoor ETS will be performed by the ETSE. Monitoring will be carried out in different ventilation modes with open and closed windows. In a next step, basic studies on the effect of volume size will be conducted on self-constructed testing chambers with a sizes-range of some cubic centimeters to several cubic meters. To study the effect of physical parameters on ETS particle concentration, the environmental conditions in these chambers will be kept stable. In future setups it is planned to investigate microenvironments of various vehicle cabins. Similar to the procedure at the testing cabin, mobile sensing modules will be monitoring PM and physical parameters inside the vehicle during ETS generation by the ETSE. The measurements will take

Figure 2 Testing chamber (telephone cabin) with outside mounted ETSE (E).

place in stationary cars with focus on the effect of different window positions and different air vent or air-conditioning modes on the particle concentration of PM10, PM2.5 and PM1. To study the influence of different driving conditions on the particle concentration, they will be simulated in stationary cars with the help of ventilators. In each testing chamber, the mobile sensing module will be mounted inside the chamber at a location where children are potentially exposed to ETS. To create comparable settings, all conditions (ETS generation, test chamber, measurement) will be standardized. Prior to every sequence, a 20-minute background collection of the PM-concentration will be performed. Since a part of the sampling will be taken outdoors, it is important to prevent data bias due to environmental factors. Therefore, the measurements of the different tobacco products or cigarette brands will be measured alternately with a reference cigarette. To avoid bias due to daily variation of PM concentration, a data correction will be performed. For that reason, values of the prior collected average PM background concentration will be subtracted from the measured data during and after the ETS emission.

Initially, the received basic data from the measurements will be processed. Each average background concentration will then be subtracted from the concentration of the following ETS measurement to avoid bias from daily variation of PM concentration. The obtained data of the different sensors will be integrated. Subsequently, the data of every measurement will be divided in the two intervals "ETS emission" and "ETS elimination". The interval "ETS emission" will represent the phase of ETS generation and the interval "ETS emission" will outline the time where the ETS concentration will be reduced due to processes of ventilation and deposition. For both intervals and for every PM-fraction the arithmetic mean (C_{mean}-PM), the maximum concentration (C_{max}-PM), and the area under the curve (AUC-PM) will be calculated. Following data processing, an exploratory data analysis will be carried out. Data processing and analysis will be performed using specific calculating and statistical software.

Discussion

So far, large scale assessment of PM generation by tobacco products was not performed. Therefore, only little data is available in scientific databases such as PubMed, Medline or ISI-Web. Novel approaches including scientometric and visualizing techniques are not applicable [31-43] and the few existing studies can easily be summarized. Early researches of particulate matter concentration in ETS focused on respirable suspended particle mass (RSP) [44-47]. Distinction between different PM-fraction (PM10, PM2.5, and PM1) and cigarette brands, as planned in the ToPIQ study, however, were not made. Since two of these published articles were conducted or supported by cigarette companies [44,45] the impartiality of these results is at least debatable. In most of these studies the ETS generation was carried out by human smokers in special testing chambers with a capacity of 18 to 45 m^2 [44,45,47]. Although realistic ETS generation can be guaranteed by using human smokers, this approach is dangerous to human health and therefore unethical. That is why an ETSE or AETSE will be used in the ToPIQ study. Other studies undertaken in the last decade focused on the ETS-dependent emissions of PM10 or PM2.5 or both [48-53], but of these studies only three investigated specific cigarette brands as planned in the ToPIQ study [48,50,51]. Only two of these studies were performed without human smokers by using smouldering cigarettes [48,51]. However, the usage of smouldering cigarettes for the ETS generation is insufficient since smouldering cigarettes can only produce SS and no MS. That is why the emissions generated by this method are not comparable to ETS emissions. To simulate ETS for the research in the ToPIQ study, we will use ETSE or AETSE, which are capable of generating SS as well as MS and therefore the two major components of ETS.

Conclusion

The ToPIQ study will serve as a new platform to investigate ETS-dependent particulate matter of different tobacco products and within variable microenvironments. Using the knowledge of this platform, further studies may focus on mechanisms by which particulate matter harms the human body, i.e. with the use of modern techniques of toxicology [54,55], molecular biology [56-60] and biochemistry [61-64].

List of abbreviations

AETSE: automatic environmental tobacco smoke emitter; AUC-PM: area under the PM-concentration curve; BVM: bag valve mask; C_{max}-PM: maximum PM-concentration; C_{mean}-PM: arithmetic mean of the PM-concentration; ETS: environmental tobacco smoke; ETSE: environmental tobacco smoke emitter; MS: mainstream smoke; PM: particulate matter; RSP: respirable suspended particle mass; SS: sidestream smoke; ToPIQS: Tobacco smoke particles and indoor air quality study; WHO: World Health Organization.

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Authors' contributions

DM, SU, MB, DK, SB, MS, DAG have made substantial contributions to the conception and design of the review, acquisition of the review data and have been involved in drafting and revising the manuscript. All authors have read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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