Studying the biological effects of combustion aerosols on air/liquid-interface exposed human and murine lung cells within the HICE-project: Composition and molecular biological effects of emissions from wood combustion, ship emissions and car engines

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Aerosol emissions from combustion processes are important for human health. It is known that the initial response of lung tissue-cells onto combustion aerosols include oxidative stress, inflammation and apoptosis, but only few molecular links to the chemical composition of the particulate and gaseous part of the combustion emissions have yet been established. The Virtual Helmholtz Institute-HICE studies physical and chemical properties of anthropogenic combustion emissions as well as their biological effects on lung cells. On the one hand the chemical composition and physical parameters (size, morphology etc.) of relevant emissions are thoroughly characterized, including the application of innovative on- and off-line analytical technologies (e.g. SMPS, ELPI, AMS, ultra high resolution chromatography: GCxGC-MS, ICP-MS, ultra high resolution mass spectrometry: FT-ICRMS, TEM-XRF, on-line photoionisation-MS). On the other hand, human lung cells are exposed to the diluted combustion exhaust fumes at the air-liquid interface (ALI). A special ALI-exposure technology has been developed, allowing a realistic lung-cell exposure by simulation the situation in the lung at-site of the combustion facility. After 4h exposure the biological response of the exposed lung cells are analysed by a comprehensive multi-omics molecular biological effect characterisation on the transcriptomic, proteomic and metabolomic level. Emissions of wood combustion, (ship-) diesel engines and (car-) gasoline engines are addressed in this study: Wood burning is made responsible for adverse health effects in many cities and rural regions while shipping emission have influence on human health in coastal regions worldwide. The new fuel injection gasoline engines (operated with ethanol or gasoline) are of concern albeit the gaseous emissions are heavily controlled by 3-way catalyst systems. For wood combustion experiments emissions from a masonry heater (log wood), a pellet burner (soft wood pellets) were used. Shipping emission were generated on a test-bed ship diesel engine, running either on common heavy fuel oil (HFO) or cleaner-burning diesel fuel (DF). Finally a modern car engine operated with gasoline (E10) and ethanol (E85) was investigated. Two special field deployable ALI-exposition systems and a mobile S2-biological laboratory were set up and applied for this study. Human alveolar basal epithelial cells (A549, BEAS2B and primary cells) were ALI-exposed to freshly diluted combustion aerosols. The cellular effects were then comprehensively characterized (viability, cytotoxicology, multi-omics molecular-biological effects monitoring) and put in context with the chemical and physical aerosol data. The HICE concept is summarized in the literature [1]. The overall cellular response of the combustion aerosols (i.e. the regulation strength on the different 'omics levels) is compared at a similar aerosol dilution (~ 1:40), which was selected to guarantee a particle and gas deposition dose. The dilution/dose was selected to be below a measurable direct cytotoxicity after the 4 h exposure, as we intend to acquire the sub-toxic reaction of the lung cells to the stressor. The following order of overall cellular response-strength was observed: A surprisingly weak cellular effect regulation was observed for the diluted wood combustion emissions. However, interestingly the biological effects-strength for the log-wood and pellet burner emissions are very similar, although the PM concentration, OC and EC content was much higher for the log-wood heater. A slightly higher biological effect-strength is observed for the gasoline car emissions (with ethanol fuel emission being slightly more reactive than gasoline). The ship diesel engine emissions, however, induced the most intense biological responses. The most surprising result in this context was that HFO emissions showed lower biological effect strengths than the supposedly cleaner DF, which was unexpected as the HFO-emission contained high concentrations of known toxic compounds (transition metals, organic toxicants). This result was recently confirmed by experiments with murine RAW macrophages. Detailed analyses of the activated cellular response pathways, such as pro-inflammatory responses, xenobiotic metabolism, phagocytosis and oxidative stress were performed. The obtained holistic molecular biological results show the complexity of PM-induced biological effects as the activation pattern and strength differed considerably for the aerosol sources, suggesting a large difference in relative toxicity of different combustion sources. In addition to organic PM-composition also the content of elemental carbon (EC) and the elemental composition play a role. Surprisingly strong effects were observed for the gaseous aerosol fraction as well.

[1] Oeder et al., PLoS one, 2015, DOI: 10.1371/journal.pone.0126536