Toxicological effects of particulate matter from residential coal combustion

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Keywords: Residential coal combustion, particulate matter, cell viability, cell cycle, oxidative stress, apoptosis
Associated conference topics: 4.5, 4.6
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Residential coal combustion is a significant source of airborne particulate matter (PM) pollution (Zhou et al., 2020). Coal remains a widely used household heating source driven not only by economic and availability considerations but also by cultural practices (Kerimray et al., 2017). PM emissions from coal combustion have been linked to cytotoxicity, oxidative stress, genotoxicity, and inflammation in different cell lines (Huang et al., 2023; Ihantola et al., 2022). This study aimed to evaluate the toxicity of indoor PM samples lower than 10 µm (PM_{10}) from residential coal combustion in a European household using coal for heating purposes in human alveolar epithelial cells (A549).

PM_{10} samples were collected from a detached house, testing different conditions: indoors, with and without (background) the operation of a coal-fueled stove, and outdoors on the front porch of the residence. The cytotoxicity of the PM_{10} total organic extracts was evaluated on the A549 cell line using the MTT assay, while reactive oxygen species (ROS) production was analyzed using the Fluorometric Intracellular ROS Assay Kit. Flow cytometry assessed the interference in cell cycle dynamics and apoptosis.

PM_{10} organic extracts significantly affected the metabolic activity of A549 cells ($p < 0.05$). The biggest significant cell viability decreases were observed in indoor PM_{10} samples during coal burning when compared to the background and the outdoor PM_{10} sample, at the maximum concentration (150 µg/mL).

For the ROS assay test, cells were exposed to PM_{10} at the concentration of the IC_{10} and IC_{20}, while for cell cycle and apoptosis analysis only the IC_{20} concentration was used. Indoor PM_{10} samples during coal burning on days 1 and 4 significantly increased ROS levels at both IC_{10} and IC_{20} concentrations. In contrast, for indoor PM_{10} samples on day 3, background and outdoor samples, a significant ROS increase was only observed at the IC_{20} concentration. No effects on ROS levels were observed for the indoor PM_{10} sample during coal burning on day 2.

Cell cycle results show deregulation in cell cycle dynamics with a significant increase in G1 and S phases in all tested samples compared with the control, except for the indoor PM_{10} sample on day 2, where the cell cycle distribution was similar to those in the control group. Regarding the effects on cell apoptosis, an abrupt decline in viable cells occurred in the indoor PM_{10} sample on day 3, with a significant increase in necrose and late apoptosis. A significant increase in necrotic cells was also verified for PM_{10} samples on days 1, 3, and 4 with stove operation, as well as in the background sample.

These results demonstrate the significant impact of PM_{10} on A549 cells, emphasizing its relevance for environmental studies, public health guidelines, and initiatives to reduce air pollution.

This work was done within the projects i) APAM, supported by national funds (OE), through FCT/MCTES (DOI: 10.54499/2022.04240.PTDC) and ii) TED2021-132292B-I00, supported by "NextGenerationEU"/PRTR and MCIN/AEI/10.13039/501100011033. The financial support to CESAM by FCT/MCTES (UIDP/50017/2020 + UIDB/50017/2020 + LA/P/0094/2020), through national funds, is acknowledged. D. Figueiredo thanks the grant 2020.06414.BD from FCT, which is also acknowledged for the research contracts under Scientific Employment Stimulus to H. Oliveira (DOI 10.54499/CEECIND/04050/2017/CP1459/CT0023) and E. Vicente (DOI: 10.54499/2022.00399.CEECIND/CP1720/CT0012).

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