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The influence of indoor air cleaners on the oxidative potential and sources of metals in indoor, outdoor, and personal exposure of school aged children to $PM_{2.5}$ in suburban Shanghai, China

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1 Introduction

Atmospheric metals play an important role in the toxicity of fine particulate matter air pollution ($PM_{2.5}$) to humans. *In-vitro*, metals can catalyse Fenton reduction-oxidation reactions that produce cellular reactive oxygen species (ROS). Cellular ROS may result in cellular oxidative stress, which has been associated with disease (Lushchak, 2014).

There is strong evidence that mechanical air cleaners with high-efficiency particulate air (HEPA) filters can reduce indoor concentrations of $PM_{2.5}$ (Kelly and Fussell, 2019). There is a less clear understanding of whether reduced household $PM_{2.5}$ concentrations translates to reduced personal exposure to $PM_{2.5}$ and improved health outcomes (Kelly and Fussell, 2019). The chemical composition of PM may influence the capacity of PM to produce cellular ROS (oxidative potential). Therefore, air cleaner intervention studies should be reproduced with detailed evaluation of the sources of the toxic components of PM (i.e. metals).

2 Materials/Methods

Forty-three children from suburban Shanghai, China were recruited to participate in an air cleaner intervention study. For the intervention, a portable air cleaner was placed in each child’s bedroom on two occasions with differing filtration conditions. The air cleaner was equipped with a pre-filter, HEPA filter, and an activated carbon filter for “true” filtration, and only the pre-filter for “sham” filtration. Time-integrated 48-h $PM_{2.5}$ measurements were collected on Teflon filters in the child’s bedroom (“indoor”), on a balcony or windowsill (“outdoor”), and using backpacks outfitted with personal exposure monitors that the participants carried with them during the study (“personal exposure”).

$PM_{2.5}$ measurements were analyzed for mass using a microbalance, trace elements by inductively coupled plasma mass spectrometry, and oxidative potential by a rat alveolar macrophage assay (Brehmer et al. 2020).

The sources of metals and their contributions to the samples in our study were determined using the US Environmental Protection Agency's Positive Matrix Factorization 5.0 model.

3 Results and Discussion

Source apportionment found six sources of metals that were identified as regional aerosol (RA), resuspended dust (RD), residual oil combustion (ROC), roadway emissions (RE), alloy steel abrasion (ASA), and La and Ce (La/Ce). As outdoor concentrations of all sources did not differ by filtration status, any observed changes between true and sham filtration may have resulted from the air cleaner. Indoor concentrations of the RA, ROC, and RE sources as well as personal exposure concentrations of the RA and RE sources were reduced under true filtration (Table 1).

Table 1. Median contribution to the sources of metals and metalloids in indoor and personal exposure $PM_{2.5}$ samples by filtration status.

Source	Sample type	True (μg m^{-3})	Sham (μg m^{-3})
RA	Indoor	**0.12**	**0.49**
	Personal	**0.49**	**0.64**
RD	Indoor	0.075	0.072
	Personal	1.4	0.99
ROC	Indoor	**0.045**	**0.18**
	Personal	0.15	0.18
RE	Indoor	**0.037**	**0.28**
	Personal	**0.16**	**0.31**
ASA	Indoor	**0.026**	**0.079**
	Personal	0.75	0.60
LA/CE	Indoor	3.4×10^{-4}	1.0×10^{-3}
	Personal	0.016	0.010

Bolded values: Wilcoxon-signed ranked p-value < 0.05 when comparing true and sham filtration.

The median (interquartile range) oxidative potential for indoor measurements was reduced from 138 (140) μg Zymosan m^{-3} under sham filtration to 38 (54) μg Zymosan m^{-3} during true filtration. Personal exposure oxidative potential measurements followed the same trend and was 106 (54) μg Zymosan m^{-3} for true and 157 (71) μg Zymosan m^{-3} for sham filtration. A univariate multiple regression model found that an IQR increase in the percentages (μg source ug^{-1} $PM_{2.5}$) of the ROC, RA, and RE sources were associated with 94% (95% CI: 70-130%), 58% (40-79%), and 56% (30-87%) increases in oxidative potential respectively. These sources were among those that were reduced in indoor and personal exposure measurements, which likely explains why the oxidative potential was lower under true filtration for both sample types.

4 Conclusions

Our study demonstrates that indoor air cleaners equipped with HEPA and activated carbon filters can reduce indoor concentrations of metal and metalloid sources. This improvement in indoor air quality may benefit those who spend a majority of time in indoor environments. Our results also show that evaluations of indoor air quality interventions should include personal exposure measurements. The indoor environment may not be the primary source of personal exposure to some sources (i.e. ROC, ASA), so reduced concentrations indoors may not translate to reduced personal exposure.

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6 References

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