Abstract

Background

Approximately 90% of the world's population resides in areas where ambient air quality standards are exceeded. Particulate matter with an aerodynamic size of less than 2.5 µm ($PM_{2.5}$) has been identified as the leading contributor to indoor and outdoor air pollution. $PM_{2.5}$ can be released from natural and anthropogenic sources, however, anthropogenic sources such as ferromanganese smelters are among the major sources. Ferromanganese smelters tend to release Mn-bearing $PM_{2.5}$. Owing to their size, Mn-bearing $PM_{2.5}$ can remain suspended for longer periods and travel a greater distance from the emitting source and penetrate indoor environments. It is suggested that most people, especially vulnerable groups spend approximately 80%–90% of their time indoors. Chronic exposure to Mn-bearing $PM_{2.5}$ is associated with neurological disorders. Most of the evidence on the causal relationship between Mn exposure and neurological disorder was drawn from epidemiological studies that lacked exposure assessments.

Purpose

To systematically characterise the similarities between indoor and outdoor $PM_{2.5}$ airborne particles in residential areas within the vicinity of the smelter in Meyerton.

Methods

Indoor and outdoor airborne $PM_{2.5}$ were collected concurrently from selected households using two identical active samplers. A gravimetric sampling technique was used to sample $PM_{2.5}$ continuously over seven days from the 30 selected households. GilAir plus pumps were used to draw in air containing $PM_{2.5}$ into the sampling media at a flow rate of 2.75 L/min. The sampling media comprised of a 37 mm cassette, which was housed in a 37 mm polycarbonate filter. A 1.5 m long Teflon tubing was used to connect the sampling media outlet to the inlet of the pump. A total of 60 samples were collected over three months (August–November 2019) and comprised 30 indoor and 30 outdoor samples. $PM_{2.5}$ mass concentrations were obtained gravimetrically using a microbalance scale. The physicochemical properties were analysed using scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDX). Inductively coupled plasma-mass spectrometry (ICP-MS) was used to analyse the elemental composition of indoor and outdoor $PM_{2.5}$. The difference between indoor and

outdoor $PM_{2.5}$ mass concentration was determined by calculating the indoor-outdoor ratio, where a ratio greater than 1 indicated that indoor $PM_{2.5}$ is less than the outdoor. Furthermore, statistical analysis for indoor and outdoor $PM_{2.5}$ was performed using an F-Test and a Student t-test. A P-value of <0.05 indicated a statistically significant difference between indoor and outdoor $PM_{2.5}$.

Results

Indoor $PM_{2.5}$ mass concentration ranged between 2.88 and 19.19 µg/m^3 with an average of 10.99 ± 5.10 µg/m^3 while outdoor concentration ranged between 11.68 and 40.44 µg/m^3 with an average of 24.97 ± 6.77 µg/m^3. Outdoor $PM_{2.5}$ mass concentration in Meyerton was 2.7 fold greater than the indoor. The I/O ratio of $PM_{2.5}$ was 0.44 indicating that indoor $PM_{2.5}$ was lower than the outdoor. The I/O ratio of less than 1 further indicated and that indoor $PM_{2.5}$ was influenced by PM from the outdoor environment. A statistically significant difference was found (P=5.8×10^{-13}) between indoor and outdoor $PM_{2.5}$ mass concentrations. SEM images showed that indoor $PM_{2.5}$ consisted of irregular and agglomerated particles ranging from 0.1 to 0.7 µm in diameter while $PM_{2.5}$ outdoor also consisted of irregular but single spherical particles ranging from 0.1 to 1.3 µm in diameter. SEM images showed similarities between indoor and outdoor particles suggesting that they are from the same or similar source. ICP-MS results indicated an abundance of elements in decreasing order of Si > Fe > Zn > Mn both on indoor and outdoor $PM_{2.5}$. However, outdoor $PM_{2.5}$ had the highest concentration of Mn, Zn, Si, and Fe relative to indoor $PM_{2.5}$. The average indoor and outdoor Mn concentration was 1.30 µg/m^3 and 5.36 µg/m^3, respectively.

Conclusion

This study investigated the similarities between the physicochemical properties of indoor and outdoor $PM_{2.5}$ sampled in residential areas near a ferromanganese smelter and found that most indoor $PM_{2.5}$ originated from an outdoor source. Moreover, indoor and outdoor $PM_{2.5}$ were enriched with Mn and other elements, which can lead to chronic health outcomes amongst vulnerable groups. Since Mn and the other elements found in this study are mainly released from ferromanganese smelters, the nearby smelter might be a major source of indoor and outdoor Mn-bearing $PM_{2.5}$ in Meyerton. However, further studies using advanced source apportionment techniques are recommended to verify the findings. Lessons drawn from this study suggest the need for integrated town planning and development where ferromanganese smelter are not supposed to be built near residential areas. Measures such as tree plantation may be introduced in such residential areas to reduce or trap airborne PM.