Effects of Saharan dust events on ambient PM oxidative potential

E. J. S. Souza, K.W. Fomba, N. Deabji, and H. Herrmann

Atmospheric Chemistry Department (ACD), Leibniz Institute for Tropospheric Research (TROPOS), Permoserstraße 15,04318, Leipzig, Germany

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Presenting author email: souza@tropos.de

The oxidative potential (OP) of ambient particulate matter (PM) has received increasing attention in recent years. Despite reports on OP values in different regions and assays, little research has been conducted on the effects of Saharan dust events on ambient PM and the potential drivers of mineral dust (MD) OP. Herein, this study examined MD's effects on $PM_{2.5}$ and PM_{10} OP, as well as its redox-active PM species.

A total of 60 PM samples (30 coarse and 30 fine) were collected continuously between 10 January and 16 February 2022 in Mindelo, Cape Verde. Aerosol particles were sampled using high-volume samplers in quartz filters during dust and non-dust events, with sampling intervals of 6, 8, or 24 hours. After sampling, each filter was placed immediately at -20 °C in a freezer until analysis. To ensure the quality of the samples, blank field filters were collected periodically. Phosphate buffer solution (PBS) was used to extract PM samples, and aliquots of the extracts were used to analyse both water-soluble elements (WS) and OPs. Experiments on the OP of PM extracts loaded with MD, chemical controls, and blank filters were performed using dithiothreitol (DTT) assay (OP^{DTT}). The decay kinetics of DTT concentration incubated with PM extracts were normalized by sampled air volume (DTT_V) and collected aerosol mass (DTT_M), which are representative of personal exposure and source-specific characteristics, respectively.

There were significant differences in DTTv and DTT_M activities on dusty and non-dusty days. On non-dust events, DTT_V activity ranged between 0.08 and 0.22 nmol min^{-1} m^{-3}, whereas DTT_M activity ranged between 23.4 and 51.1 nmol min^{-1} μg^{-1}. During dusty days, however, DTT_V varied between 0.07 and 2.76 nmol min^{-1} m^{-3}, and DTT_M varied between 1.37 and 32.7 nmol min^{-1} μg^{-1}. It is interesting to observe that non-dust events had higher DTT_M activity based on OP normalized by mass, with an average $OP^{DTT}{}_M$ value of 41.8 nmol min^{-1} μg^{-1}, which demonstrates that anthropogenic sources might produce more toxic PM components than MD. As a result, MD provides similar or even lower concentrations of redox-active PM species that increase OP. However, $OP^{DTT}{}_V$ values are greater during dusty days than those $OP^{DTT}{}_V$ values during non-dusty days, thereby indicating an increase in the exposure amounts to OP generated by PM samples loaded with MD.

In both $PM_{2.5}$ and PM_{10}, the average $OP^{DTT}{}_V$ was 0.60 and 0.84 nmol min^{-1} m^{-3}, respectively. This show that a significantly increased DTT_V response was found for $PM_{2.5\text{-}10}$ compared to the fine fraction $PM_{2.5}$. As dust events are dominated by coarse particles, these results demonstrate that PM containing MD increases personal exposure to redox-active PM species that induce higher levels of OP. People are more likely to experience oxidative stress during dust episodes due to the large volume of dust transported which increase levels of redox-active PM species.

DTT_V activity of fine particles is highly correlated with bulk PM mass both during dust (0.71) and non-dust events (0.80), which suggests that the DTT_V activity increases for higher $PM_{2.5}$ concentrations. DTT_V activity, on the other hand, is weakly correlated with PM_{10} bulk mass (0.34). As previously reported, the OP of fine particles correlates more with bulk mass than coarse particles[1].

In dusty conditions, Fe, Ti, OC, and EC are well correlated with fine particle oxidative potential, while Cu, Ti, and Mn correlate with the OP of coarse particles. During non-dust events, however, OP is highly associated with OC and Mn. We have also observed a significant correlation between OP values and the pH of the particles during non-dust events (0.64). In summary, on days without dust episodes, organic compounds, such as quinones and polycyclic aromatic hydrocarbons, as well as Mn have a strong impact on OP values of fine particles. On the other hand, transition metals are more closely associated with the OP of PM_{10} samples. Both fine and coarse particles correlate significantly less with OC during dust episodes.

Conclusion: DTT_M activity was similar or even lower during dust events than on non-dusty days. As a result, MD might transport equal, or on some days even lower, concentrations of redox-active PM species by mass that increase OP. In spite of this, PM loaded with MD significantly increases the oxidative potential of redox-active PM species since $OP^{DTT}{}_V$ values are much higher during dusty days facilitating more redox reactions.

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References

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