Responses to Reviewer 1's Comments

We thank Reviewer 1's positive comments and constructive suggestions for improving the manuscript. Please see our response in blue font below.

General Comments

1. *The authors are encouraged to provide additional details and clarifications on the methodology, particularly regarding the selection of waste materials for combustion and the conditions under which the experiments were conducted.*
   Response: Additional information on the methodology, especially on waste materials and test conditions, is added and described in the responses to the reviewer's comments below.

2. *Regarding the collection of food discards and vegetation samples in Nevada to avoid potential degradation during transportation (Line 84), I am curious as to whether these samples accurately represent the conditions in South Africa.*
   Response: We tried our best to match the food discards and vegetation samples collected in Nevada with the materials in South Africa. The following text is added in Section 2.1:

   "Due to customs restriction and potential deterioration during shipping, the compositions of food discards and vegetation collected by the WCI were characterized and similar mixtures were collected in Nevada for testing. Food discards included bread, potato and banana peels, lettuce, cucumbers, and tomatoes (Cronjé et al., 2018) and vegetation included basin wild rye, Sandberg bluegrass, crested wheat grass, red willows, and creeping wild rye, representing African bunch grasses, African sumac, and crab grass."

3. *Could you please provide more details on the method used to determine moisture content (Line 89)?*
   Response: The following text about the moisture content determination method is added:

   > "The moisture contents for paper, leather/rubber, textile, and plastics were determined by a laboratory in South Africa by measuring the mass loss gravimetrically after heating a small fraction of samples at 103 °C for 30 minutes. The moisture contents for food and vegetation were determined at DRI by baking the samples at 90 °C for 24 hours."

4. *In the section describing the preparation of waste materials for testing, it is not entirely clear why each specific step (drying, rehydrating, and re-equilibrating) is necessary. Could you please elaborate on the purpose of these procedures (Lines 89-91)?*
   Response: The material moisture content will likely change during transport and storage. Therefore, we measured the natural moisture content immediately after material collection from the field. To return the materials back to this natural moisture condition before testing, we needed to first dry the materials, calculate the water that needs to be added to the dry material to achieve the needed moisture content, and equilibrate for ≥24 hours so that the moisture could assimilate into the materials. A similar procedure has been used in past

studies on the effects of moisture content in source emissions (e.g., Chen et al., 2010; Smith et al., 2013; Watson et al., 2019). The text was modified as below:

"Because material moisture content will likely change during transport and storage, to represent field conditions, the waste materials (except food discards) were oven dried at 90 °C for 24 hours, rehydrated to their natural moisture levels with distilled deionized water (DDW), and re-equilibrated for at least 24 hours before testing."

5. *I noticed that there is a considerable range in the fuel mass used in the experiments, varying from 0.5 to 20 g (Line 97). I am concerned that this variability could potentially influence the emission factors, particularly if the surface area or geometry of the samples plays a significant role in combustion. Could you please address this issue?*
   Response: We initially planned to use 10 grams of materials for each test. During trial tests, we found that some materials generated very high particulate emissions (e.g., plastic bottles) that clogged the sampling system while some materials generated low gas emissions (e.g., food discards). The weights of materials burned were adjusted to generate emissions that are within the instrument ranges.

   We agree that surface area and geometry of the sample affect emissions. The companion paper (Wang et al., 2023) recognizes this limitation and cautions that the lab results might need be adjusted for real-world emissions:

   "Real-world open burning emissions vary with waste material composition, pile size, packing structure, moisture content, ambient temperature, and wind speed. Such variations are reflected in the wide range of EFs reported in the literature. Although this and past studies agree within reported extremes, laboratory tests are an approximation of real-world variations. The EFs derived from laboratory experiments represent the values obtained under the specific conditions in laboratory tests; adjustment might be needed when real-world burning conditions are very different from laboratory test conditions."

   We added the following bullet point to the Conclusion and Discussion section:

   "(5) Results were obtained from laboratory tests simulating real-world conditions. The EFs might need to be adjusted when real-world burning conditions (e.g., moisture content, temperature, and wind) differ significantly from the test conditions used in this study."

6. *It would be helpful if you could provide the burn duration in minutes (Line 97), as this unit of measurement may be more intuitive for readers.*
   Response: Changed as suggested:

   "Each burn typically took 30 min, varying from 15 to 65 min."

7. *I am interested in understanding whether the temperature of 450 °C used in the experiments (Line 97) is indicative of smoldering combustion; does your setup allow control over combustion efficiency, which seems to depend on fuel type? Was the modified combustion efficiency calculated based on measurements from gas analyzers, and were these*

measurements consistent across different materials, especially those that were subjected to repeated testing (Lines 103-104)? How do emission factors and PM abundances depend on ignition temperature?

Response: The 450 °C heating temperature was selected to simulate the heating of the sample by surrounding materials in an open burning pile. This temperate is somewhat subjective, but it was based on an earlier study showing a transition from low to high mass loss between 450 and 500 °C for a range of materials including textiles and Teflon (Mulholland et al., 2015). Other than maintaining the crucible at 450 °C, the combustion efficiency was not controlled. The modified combustion efficiencies were calculated based on real-time carbon dioxide (CO_2) and carbon monoxide (CO) measurements for all tests and the data were reported in Table 2 of the companion paper (Wang et al., 2023). The relative standard deviations of repeated tests were <10% for all materials, indicating consistent test conditions. For flammable waste materials (i.e., paper, textile, plastic bags, dry and natural moist vegetations, and combined wastes), the combustion was ignited by an electric heat gun or a butane lighter. We did not vary the ignition temperature or the crucible heating temperature, so the dependences of PM abundance and emission factor on temperature is not known.

8. *When you mention that some materials exhibited both flaming and smoldering phases (Line 99), does this mean that the average fire condition was a mix of both? Were these phases visually confirmed or inferred from MCE calculations?*

   Response: For flaming materials (i.e., paper, textile, soft plastic bags, vegetations with dry and natural moisture contents, and combined waste), they all had both flaming and smoldering phases. The splits between the flaming and smoldering phases were determined by visual observation from the burning videos as well as from the MCE time series. For gases and particles that are measured by real-time instruments, emission factors for flaming and smoldering phases were reported separately in Table 2 of the companion paper (Wang et al., 2023). As the chemical data were collected from integrated samples, only emission factors of the entire burns were reported.

9. *Lines 132-134: "The multiwavelength measurement allowed separation of light absorption by black carbon (BC) from brown carbon (BrC), which has unique wavelength dependence based on fuel and combustion conditions (Chow et al., 2015b; 2018; 2021)". Does this statement contribute to the manuscript, or can it be omitted?*

   Response: Large variations of filter colors were observed for filters collected from burning of each material, indicating differences in chemical composition and optical properties. This was presented in Figure 6 of the companion paper. The black and brown carbon will be presented in a future paper on particle optical properties from waste burning. Therefore, we prefer to leave the method description here.

10. *Line 153: please provide the abundances of OC and EC from the referenced studies, and then draw comparisons with the data from your own research.*

    Response: The OC and EC abundances from referenced studies are added:

    "High OC and EC abundances were also found for $PM_{2.5}$ from waste burning in other studies. For example, Jayarathne et al. (2018) found average OC and EC abundances of 77% (ranging

59–114%) and 2.6% (ranging 0–12%), respectively, for mixed waste in Nepal. Wu et al. (2021) found carbonaceous components were 80.5–91.4% of $PM_{2.5}$ for flaming burning of various plastics in China, with OC and EC ranging 45–63% and 7–53%, respectively, which are similar to the flaming emissions in this study."

11. *Line 156: it would enhance the clarity of the figure caption if a direct reference were made to Fig. S1b and the related content in the SI, specifically Text S1, lines S 23-34.*
Response: A direct reference to S1 is added in the Figure 2 caption:
"See detailed description of the major composition categories in Supplemental Materials S1."

12. *Line 156: please cite a study to support the choice of "(organic matter= OC × 1.4)" and justify its use (is it because you study primary organic emissions?).*
Response: The organic mass (OM) to organic carbon (OC) ratio varies with the composition of OM, ranging from 1.2 for fresh vehicle engine emissions (Kleeman et al., 2000) and fresh urban aerosols (Chow et al., 2002) to 2.6 for aged aerosols (Turpin and Lim, 2001). A value of 1.4 has been most commonly used for urban aerosols, and a value of 1.8 is used for more aged non-urban aerosols (Chow et al., 2015). Reid et al. (2005) found the ratio to be ~1.5 for fresh biomass burning smoke, cautioning that this value is highly uncertain. We calculated the OM/OC ratio assuming 100% mass closure for each test condition, and took the average value of 1.4 as the final multiplier. This factor accounts for unmeasured organic elements (e.g., hydrogen, oxygen, and nitrogen) and resulted in reasonable mass closure as shown in Figures 2 and S1b. The following explanation is added to Supplemental S1:

"The multiplier ($f_{OM/OC}$) for converting OC to OM varies with the composition of OM, ranging from 1.2 for fresh vehicle engine emissions (Kleeman et al., 2000) and fresh urban aerosols (Chow et al., 2002) to 2.6 for aged aerosols (Turpin and Lim, 2001). A value of 1.4 has been most commonly used for urban aerosols, and a value of 1.8 is used for more aged non-urban aerosols (Chow et al., 2015). Reid et al. (2005) found the $f_{OM/OC}$ to be ~1.5 for fresh biomass burning smoke. Assuming that all species are measured and analytical uncertainties are negligible, $f_{OM/OC}$ values for different materials are estimated from mass closure as (Pani et al., 2019):

$$f_{OM/OC} = \frac{PM_{2.5} - EC - Ions - Minerals - Others}{OC} \quad \text{(S1)}$$

Table S1 shows that $f_{OM/OC}$ varies from 1.22 for dry vegetation to 1.87 for food discards, with smoldering materials (except rubber) having higher values than flaming fuels, indicating more oxygens in organic aerosols from smoldering combustions. The overall average $f_{OM/OC}$ value for all test conditions is 1.4, which is used to convert OC to OM in mass reconstruction.

Table S1: Measured organic matter (OM) to organic carbon (OC) ratio $f_{OM/OC}$.

Material	OM/OC
Paper	1.66 ± 0.16
Rubber	1.27 ± 0.07
Textile	1.36 ± 0.28
Plastic (Bottles)	1.42 ± 0.02
Plastic (Bags)	1.66 ± 0.60
Vegetation (0%)	1.22 ± 0.11
Vegetation (20%)	1.38 ± 0.15
Vegetation (50%)	1.63 ± 0.12
Food Discards	1.87 ± 0.09
Combined	1.40 ± 0.21

"

13. *Line 158: refer the readers to the SI text (Text S1) to support the equation: "minerals = 2.2×Al + 2.49×Si + 1.63×Ca + 2.42×Fe + 1.94×Ti)".*
    Response: Revised as suggested.

14. *Line 255: please correct the unit (g kg^{-1}).*
    Response: Revised as suggested.

References

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