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Impact of Trash Burning on Air Quality in Mexico City

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Supporting Information

ABSTRACT: Air pollution experienced by expanding urban areas is responsible for serious health effects and death for millions of people every year. Trash burning is a common disposal method in poor areas, yet it is uncontrolled in many countries, and its contribution to air pollution is unclear due to uncertainties in its emissions. Here we develop a new trash burning emission inventory for Mexico City based on inverse socioeconomic levels and recently measured emission factors, and apply a chemistry-transport model to analyze the effects on pollutant concentrations. Trash burning is estimated to emit 25 tons of primary organic aerosols (POA) per day, which is comparable to fossil fuel POA emissions in Mexico City, and causes an increase in average organic aerosol concentrations of ~0.3 μg m^{-3} downtown and up to 2 μg m^{-3} in highly populated suburbs near the sources of emission. An evaluation using submicrometer antimony suggests that our emission estimates are reasonable. Mitigation of trash burning could reduce the levels of organic aerosols by 2−40% and those of $PM_{2.5}$ by 1−15% over the metropolitan area. The trash burning contributions to carbon monoxide, nitrogen oxides, and volatile organic compounds were found to be very small (<3%), and consequently the contributions to secondary nitrate, sulfate, and secondary organic aerosols are also very small.

1. INTRODUCTION

Air pollution experienced by expanding urban areas is responsible for serious health effects and premature death for millions of people every year.[1] Burning of trash is an important source in many densely populated areas in developing countries, which can lead to substantial emissions of atmospheric pollutants including carbon monoxide (CO), nitrogen oxides (NO_x), aerosol particles, and volatile organic compounds (VOC). According to Christian et al.[2] about 2000 Tg of garbage are generated per year worldwide and about half of that may be burned, making these emissions a potentially major health concern. By using the emission factors reported by ref 2 we can estimate the global trash burning emissions of primary organic aerosols (POA) as more than 6 Tg per year which represents about 15% of POA global emissions from all biomass burning sources, and is comparable to the emissions from biofuel use.[3] The atmospheric fate of these emissions is largely undocumented, which makes it difficult to assess their effects on air quality and human health. This assessment is particularly needed in developing countries where trash burning is often uncontrolled and is a potential source of toxic pollutants such as metals and dioxins[4] within and near densely populated areas.

The characterization of the contribution of different sources to air quality was one of the objectives of recent field studies that took place in Mexico City. Air pollution causes serious health effects for Mexico City inhabitants.[5] According to ref 6 Mexico City inhabitants have seven times higher concentrations of particles in their lungs than people from less polluted cities. The 2006 MILAGRO field project (Megacity Initiative: Local and Global Research Observations,[7]) provided detailed chemical characterization of the pollution and sources in Mexico City and its outflow region, including a study of the emissions from cooking and trash burning.[2] Reference 2 reported source-specific emission factors for a number of gaseous and particulate species. Fine particle antimony (Sb) was put forward as a possible tracer of garbage burning, due to the high emission factor from this source. By assuming that all of the Sb present in Mexico City arises from this source, it was estimated[2] that trash burning contributes up to 28% of the fine particulate matter ($PM_{2.5}$). Trash burning emissions are currently not included in the Mexico City anthropogenic emission inventory,[8] and their impact has been ignored in the Mexico City regional modeling studies.

In this study, we provide for the first time an estimate of the impact of trash burning on air quality in a developing world megacity. An emission inventory is developed using the emissions factors measured as part of MILAGRO and the gridded demographic and socioeconomic population distribu-

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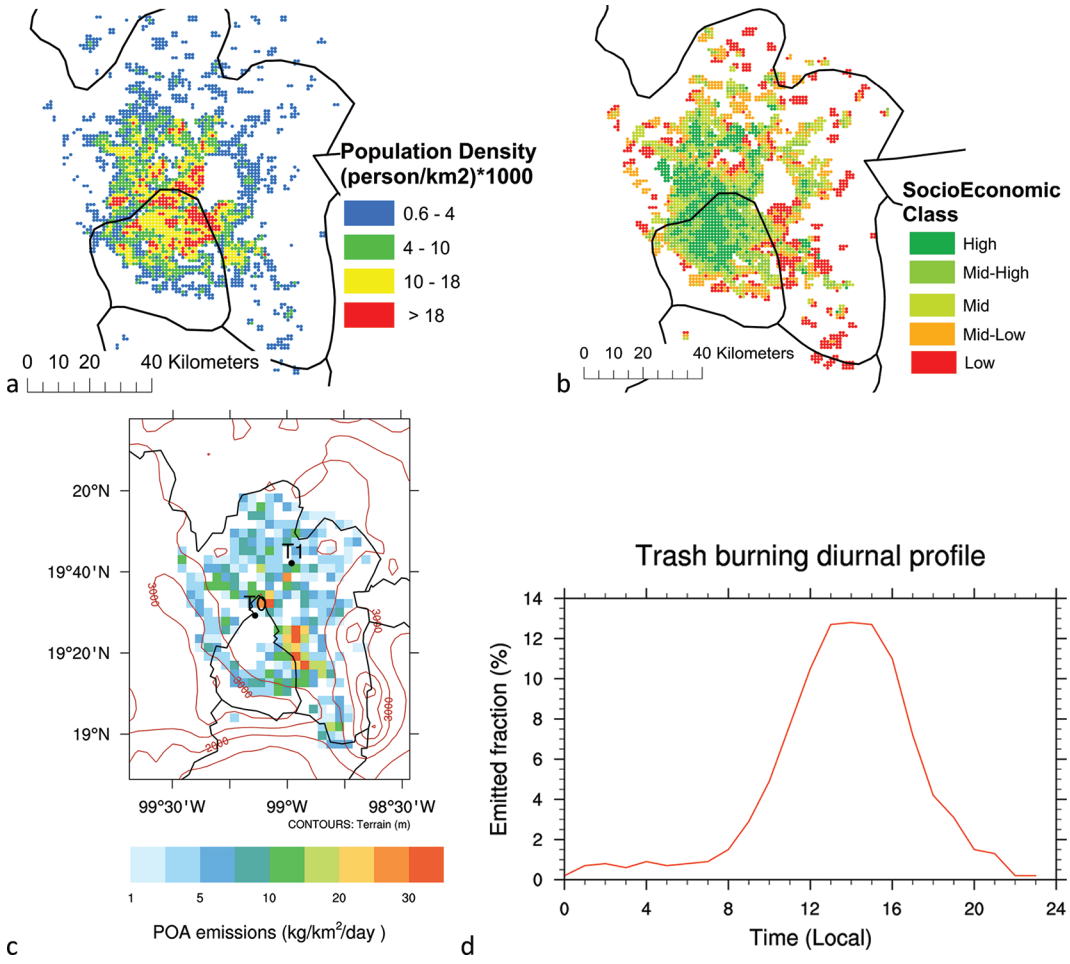

Figure 1. Spatial distribution of (a) population density, (b) socioeconomic classes according to Manuel Suárez (personal communication) and (c) gridded trash burning organic aerosol emissions (kg km^{-2} day^{-1}) in the Mexico City Metropolitan Area. (a) and (b) show Mexican state boundaries while (c) shows both the state boundaries and altitude contours. The assumed diurnal profile for trash burning emissions is also shown (d).

tions. The emissions are then used in a 3D chemistry-transport model, which has been previously validated for this region, with the goal of quantifying the contribution of this source to pollutant levels in Mexico City and estimate the likely benefits of mitigating trash burning in this region. Our analysis has wider implications, given the frequent occurrence of trash burning in developing countries.

2. DATA AND METHODS

2.1. Creating the Mexico City Trash Burning Inventory. Emissions from trash burning are not reported in the Mexico City or the national emissions inventory.[8,9] These fires are also very small and cannot be detected from satellites, and therefore are not included in typical biomass burning emission inventories (e.g., ref 10). For the purposes of this study, the Mexico City trash burning emissions were estimated by combining information on population density and socioeconomic levels with measured emission factors for trash fires. The inventory was built for the Mexico City Metropolitan Area (MCMA) including the Distrito Federal and the State of Mexico ranging from 18.95 to 19.99N, and from 99.48 to 99.63W with a spatial resolution of 1 km^2. Emissions are calculated as the product of the amount of trash produced, the fraction burned, and the amount of a compound emitted per unit mass of trash burned. The impact on MCMA air quality of trash burning in populated areas outside the MCMA is expected to be small, based on low contribution of CO from those sources to the MCMA valley.[11]

The spatial distribution of population and socioeconomic classifications for Mexico City are shown in Figure 1. For each socioeconomic classification, daily per capita trash production and the percentage of trash that is burned were assigned according to Table 1. The per capita trash production was taken from ref 12 for Low, Mid, and High socioeconomic classes. For the Mid-Low and Mid-High classes, the average per capita trash productions of the Mid and Low, and the Mid and High classes, respectively, were averaged. There are no

Table 1. Assigned Per Capita Trash Production Based on Ojeda-Benitez et al. (2008), and Assumed Fractions of Trash Burned (See Text)

ID	socioeconomic class	kg trash produced/person/day	percentage burned
1	Low	0.89	60
2	Mid-Low	0.96	60
3	Mid	1.04	30
4	Mid-High	1.05	20[a]
5	High	1.06	20[a]

[a]This trash is assumed to be transported and burned in the Low and Mid-Low socioeconomic areas.

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published data on the percentage of trash which is burned for each socioeconomic class, but anecdotal evidence and conversations with Mexican researchers indicate that this fraction may exceed 50% in the poorest areas and is negligible in the areas of high socioeconomic level. In the latter areas we assumed that a fraction of the trash collected was transported to landfills located in lower socioeconomic areas and burned there. Therefore, we have distributed any assumed emissions from trash produced in Mid-High and High socioeconomic areas to the Mid-Low and Low areas in equal proportions. The uncertainties associated with these estimates in Table 1 are large, and the consistency of this data set with ambient data will be discussed later in the paper.

The emission factors (mass of a compound emitted per mass of trash burned) for trash burning are taken from refs 2,13, and 14 and are summarized in Supporting Information SI-Table 1. Especially relevant emissions factors for this study include those for primary organic aerosols (6.9 g kg^{-1} of trash burned, calculated from the reported OC emission factors assuming an OM/OC = 1.3), CO (45 g kg^{-1} of trash burned), NO_x (3 g kg^{-1} of trash burned) and antimony (0.011 g kg^{-1} of $PM_{2.5}$ emitted by trash). As there is no available information concerning the temporal variations of trash burning, we assume here that daily emissions are the same every day and that the burning is most intense during the afternoon hours as is common for biomass burning activities, due to the higher ambient temperatures and lower humidities (Figure 1d).

2.2. Submicrometer Particulate Antimony (Sb) Measurements. Antimony has been identified as a potential tracer of trash burning emissions in Mexico City[2] and other locations.[15] To evaluate the trash burning emission estimates calculated in this study, we use submicrometer antimony concentrations from the Aerodyne high resolution aerosol mass spectrometer (AMS) measurements performed in Mexico City at the T0 site. The instrument was located in a mixed residential/industrial neighborhood, and was located about 200 m from a major roadway. The AMS has been used before to quantitatively detect lead (Pb) in submicrometer particles in Mexico City.[16] Peaks corresponding to both Sb isotopes (^{121}Sb and ^{123}Sb) in the AMS high resolution spectra were identified using their exact mass, and their identity was confirmed by their isotopic ratio. Sb was quantified using a vaporization model similar to that for Pb,[16] a collection efficiency of 0.5 that was found to be accurate for other species measured by the AMS including Pb, and an ionization efficiency relative to nitrate (RIE_{Sb}) of 0.75. RIE_{Sb} was derived from the ionization cross-section of Sb by 70 eV electrons (7.4 A^2).[17,18] Measurement uncertainties are estimated as ±50%. Sb and its chloride and oxide have similar or lower melting and boiling temperatures than Pb,[19] and thus are expected to evaporate and be detected similarly to Pb in the AMS. The submicrometer Sb data from the AMS might be biased low if some of the ambient Sb was in the form of species with much lower vapor pressures than the metal, chloride, or oxide, and did not evaporate in a time scale of several hours at 600 °C under high vacuum. Antimony has a high material density (6.7 g cm^{-3} for the pure element), but may only represent a small fraction of the mass of the particles in which it is present. If an Sb-containing particle was mostly composed of other metals of similarly high densities, the size cut of the AMS in physical diameter may be significantly below 1 μm.[20] On the other hand, if the rest of the particle is mostly composed of OA (as expected for trash burning particles), the usual AMS size cut around 1 μm (vacuum aerodynamic diameter) will apply. The model concentrations are summed up to 600 nm in physical diameter for comparison with the measurements.

2.3. WRF/Chem Simulations. The effects of trash burning emissions on air quality in and around Mexico City are investigated using the Weather Research and Forecasting model coupled with chemistry (WRF/Chem[21]). The WRF/Chem model is a community tool that provides several packages for gas-phase and aerosol transport and chemistry. In this study the chemistry is simulated using the SAPRC99 gas-phase chemical mechanism,[22] and the MOSAIC aerosol module.[23] The aerosol module solves the chemistry and dynamics of internally mixed inorganic and organic aerosol constituents for four size bins ranging from 40 nm to 10 μm. Details on the model aerosol treatment and application over Mexico City can be found in previous model applications for this region;[24,25] however, this particular study differs from those cited in the treatment of organic aerosol species. POA is considered physically and chemically inert, similar to ref 24. Secondary organic aerosol (SOA) formation from anthropogenic, biomass burning and trash burning sources is parametrized based on observed ratios of organic aerosols to CO as described in ref 11. Due to lack of information on SOA formation from trash burning emissions, an emission factor of 0.025 g of surrogate SOA precursor per g of CO was used (and converted to SOA upon atmospheric oxidation), based on recent biomass burning field studies summarized by ref 26. An alternative method to calculate SOA would be based on the known SOA precursors in the emissions, benzene, and toluene. Assuming an SOA yield of 10% for these species, we obtain a ratio of 0.0031 g SOA/g CO. Accounting for SOA formation from nontraditional precursors (e.g., ref 27) will increase SOA formation several-fold, resulting in predicted SOA levels similar to those predicted from the ref 26 approach.

The simulations were carried out from March 18 to 29, 2006. Two-way nesting was applied between a coarse-scale simulation at 36 km horizontal resolution covering all of Mexico and the North of Central America, and a fine-scale simulation with a 4 km horizontal grid covering the Mexico City valley. The updated MCMA 2006 anthropogenic emissions inventory based on ref 9 is used. The primary aerosol organic emissions for anthropogenic sources have been increased by a factor of 2 as suggested by ref 25. The biomass burning emissions are derived from MODIS satellite retrievals and are similar to those used by ref 27. Shrivastava et al.[25] used an earlier estimate of the municipal trash burning emissions in their modeling study and lumped trash burning emissions together with other anthropogenic sources; however, a numerical error in the emission processing produced an estimate that was an order of magnitude too low. Trash burning emissions are derived from this work. The initial and boundary conditions for the meteorological variables are taken every 6 h from the National Center for Environmental Prediction Final Operational Global Analysis data (NCEP/FNL) and the model coarse-scale domain is nudged to the large-scale analyzed meteorology for the predicted wind, temperature, and specific humidity. The initial and boundary conditions for gas-phase and aerosol variables were obtained from the MOZART4 global chemistry-transport model.[28] The ability of state-of-the-art regional models including WRF/Chem to simulate the meteorology, boundary layer height, and the concentrations of the main gas-phase pollutants in the Mexico City region has been evaluated in detail in previous publications and found to be reasonable (e.g., refs 24 and 29).

Table 2. Anthropogenic Emissions Inventory and Estimated Trash Burning Emissions from This Study (Tons Day^{-1}) Integrated over the Mexico City Metropolitan Area (MCMA)

MCMA[a] (tons day^{-1})	CO	NO_x	NH_3	SO_2	volatile organic compounds[d]	primary organic aerosols (POA)
anthropogenic emissions 2006[b]	5574	332	58	1193[e]	1943	29[c]
trash burning	166	11	4	2	38	25

[a]Emissions are integrated from 19.1 to 19.86N, and 99.42 to 99.69W. [b]Includes mobile sources, area sources, and industrial source emissions based on ref 9. Biomass burning emissions are not included. [c]POA emissions reported in the MCMA 2006 inventory have been doubled according to ref 25. [d]Trash burning emitted VOC includes species reported in SI-Table 1 (propene, benzene, toluene, ethene, acetic acid, formaldehyde, methanol, formic acid, acetylene, acetaldehyde, acetone). [e]SO_2 anthropogenic emissions also include volcanic and industrial contributions.

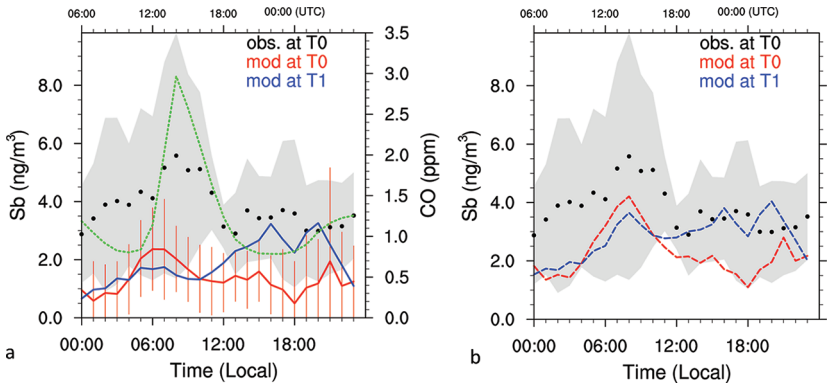

Figure 2. Nine-day average diurnal profiles comparing antimony (Sb, ng m^{-3}) submicrometer mass concentrations as measured by the aerosol mass spectrometer at T0 downtown site, and predicted by the WRF/Chem model at both downtown T0 and suburban T1 locations from 20 to 29 March 2006. Panel (a) shows the modeled Sb from trash burning source only, whereas panel b includes both trash burning and estimated traffic Sb contributions. The measured CO diurnal profile is also plotted (in green, panel a). The gray shading denotes the variability among observations (1 sigma) and the red bars indicate the variability in the model.

3. RESULTS AND DISCUSSION

3.1. Trash Burning Emission Estimates. The trash burning emission estimates over the MCMA as derived in this work are summarized and compared in Table 2 to the anthropogenic MCMA emissions inventory for 2006 for four major pollutant categories. The results suggest that trash burning contributes a very small fraction to the emissions of gas-phase pollutants such as CO (3%), NO_x (3%) or VOC (2%, species included are listed in SI-Table 1), in comparison to other anthropogenic sources. VOCs emitted by trash burning include aromatic compounds such as toluene and benzene that are known SOA precursors, but the increase in their emissions due to trash is very small, so that their impact on SOA is expected to be negligible.

More importantly, the trash burning contribution to POA emissions is estimated to be substantial. According to our estimates, the trash burning contribution to POA is of the same order as all other anthropogenic sources, that is, the trash burning is responsible for 25 tons day^{-1} of organic aerosol emissions vs 29 tons day^{-1} for other anthropogenic sources. Although the emitted POA amounts are comparable, the trash burning emissions are expected to be more harmful to local populations as they contain significant amounts of toxic materials.[30]

Figure 1c shows the spatial distribution of estimated trash burning emissions for POA. The emission flux ranges from zero in the downtown area to 30−40 kg km^{-2} day^{-1} at the edges of the city. Two potential emission hot spots emerge from our inventory. The largest one is located in the southeastern part of the city, whereas the second one is in the northeast close to the T0 measurement site. These areas are densely populated and are associated with low socioeconomic classes.

3.2. Evaluation of Trash Burning Emission Estimates. The uncertainties associated with these emission estimates are large, and here we examine two ways of evaluating them. First, a back-of-the-envelope calculation of the trash burning emissions in Mexico City was performed. If we consider that the Mexico City population is about 20 million inhabitants, and that each person produces about 1 kg of trash per day, the daily trash production can be estimated to 20 kTons. This number is close to another independent estimate by F. Menendez (*Management of Solid Waste Commission, personal communication, 2010*) where 22.1 kTons of trash production per day was estimated for the MCMA region. According to local authorities, the city has 17 000 sanitation workers and a fleet of more than 2000 trucks that can collect 11.8 kTons of trash per day. If we assume that the rest (8.2 kTons) is recycled and burned in equal proportions, the burned fraction exceeds 4 kTons of trash per day. After applying the emission factor for POA of 6.9 g/kg, we can estimate that about 28 Tons of POA are emitted due to trash burning every day in the vicinity of Mexico City, which is of the same order as the total emission estimates presented above and retrieved using the socio-demographic criteria.

Second, to verify our estimates we use particulate antimony (Sb) that was reported to be a potential tracer of trash burning emissions.[2] High levels of Sb in $PM_{2.5}$ and PM_{10} particles were observed in Mexico City and attributed mainly to brake wear emissions based on factor analysis[31] or on comparable ratios of $Sb/PM_{2.5}$ found in other urban areas where trash burning is very minor.[32] These authors reported the highest Sb concentrations of 15 ng m^{-3} in $PM_{2.5}$ at the urban site, with lower levels (8 ng m^{-3}) at the T1 site northeast of the city, where the trash burning might be playing a larger role according to our estimates. The higher concentrations at T0, closer to the areas of higher traffic emissions, are consistent

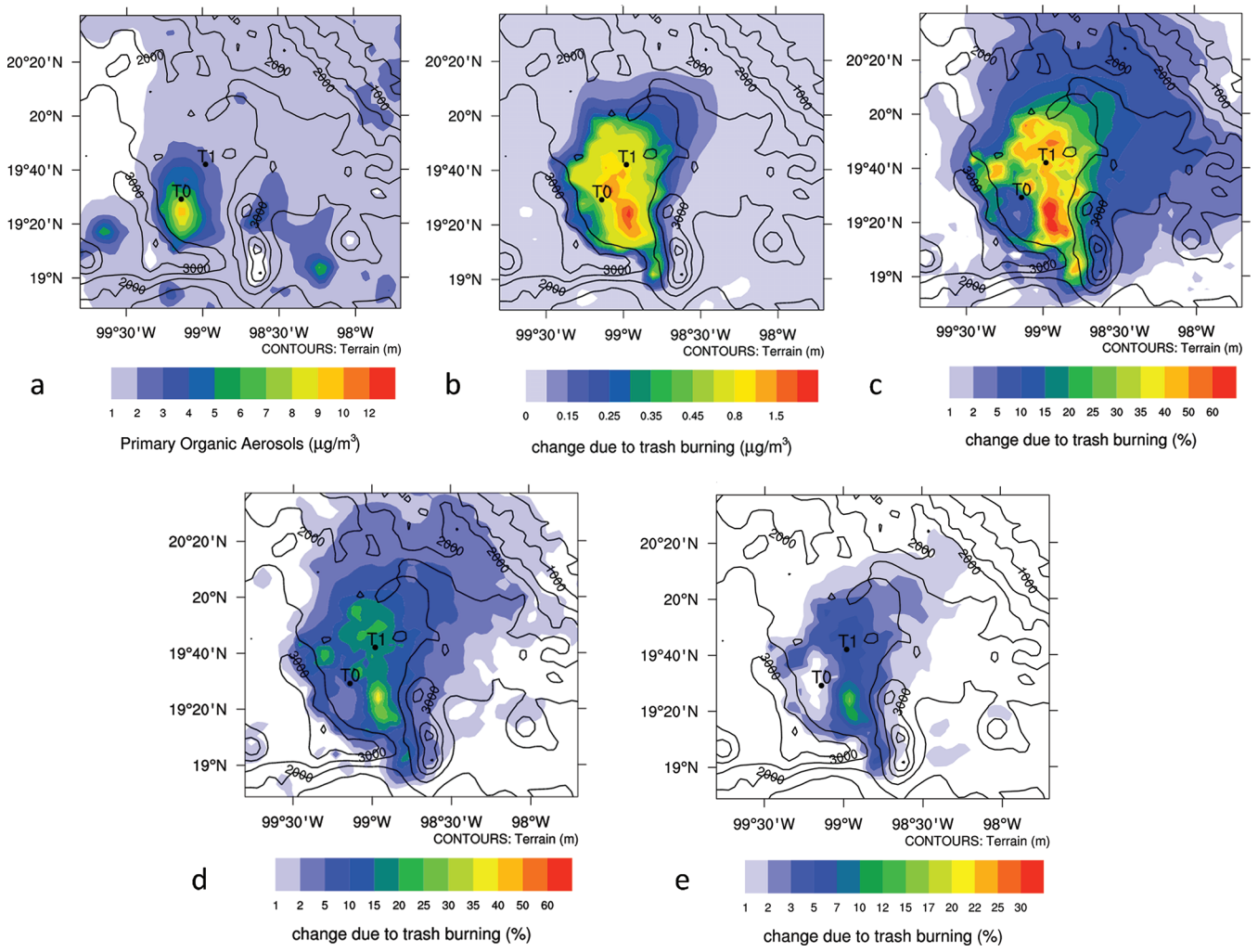

Figure 3. Predicted changes in POA, OA and $PM_{2.5}$ due to trash burning emissions. Spatial distribution of (a) surface mass concentrations of POA as initially predicted by the model in the vicinity of Mexico City between 20 and 29 March 2006. The absolute (b) and percentage (c) increase in POA due to the introduction of trash burning emissions is shown. The average percentage increase in total organic aerosol (d) and $PM_{2.5}$ (e) are also shown.

with the dominance of brake wear for $PM_{2.5}$ Sb. Most of the brake wear emissions occur in the supermicrometer range, with a ~10−20% ratio of $PM_1/PM_{2.5}$ for Sb.[33,34] This would suggest an impact of brake wear to submicrometer Sb of the order of 1−3 ng m^{-3}.

High levels of Sb have also been observed in the emissions from garbage burning experiments, suggesting that road traffic is not the only source of Sb in $PM_{2.5}$. Antimony is used as a flame retardant for textiles and in lead alloys in batteries, and antimony trioxide is used as a catalyst in the production of polyethylene terephthalate, found in soft drink bottles and textile polyester fiber, all of which are very common garbage items.[2] Sb from combustion sources will be formed by an evaporation/condensation process and will be dominantly in the submicrometer mode.[34] It is also possible that other industrial sources of Sb exist in Mexico City as is the case for other metals,[35,16] but there is insufficient information to estimate their emissions. Their absence from the model may result in a low bias for the predicted Sb.

Figure 2 shows the comparisons between the model predicted levels of submicrometer Sb and the measurements at the T0 site north of downtown Mexico City. The predicted antimony was computed using the trash burning emission factors from ref 2 and the chemistry-transport model used here.

The brake wear contribution has been estimated by multiplying the diurnal cycle of ambient CO measurements (shown in Figure 2a, and after subtraction of a background CO concentration of 100 ppb) using an estimated emission ratio of Sb_{PM1}/CO of 0.85 × 10^{-6} g/g, based on the measurements of ref 33. The average measured diurnal cycle of Sb shows values ranging from 3 to 5 ng m^{-3} with an increase in concentrations of 1−2 ng m^{-3} during the morning traffic rush hours, consistent with road traffic being a source of submicrometer Sb. During the day, concentrations of particulate Sb stay steady in the growing and well-developed boundary layer showing a much flatter diurnal profile than that of CO. This suggests that Sb is being continuously produced by other sources in addition to road traffic with stronger emissions during the day, as assumed here for trash burning.

The predicted submicrometer Sb levels from trash burning only at T0 are ~53% of the averaged measured levels. During the morning rush hour the predicted Sb is 2−3 times lower, as expected in the absence of mobile emission sources. When the estimated emissions from brake wear are added, the modeled concentrations are within the uncertainties of the measure-

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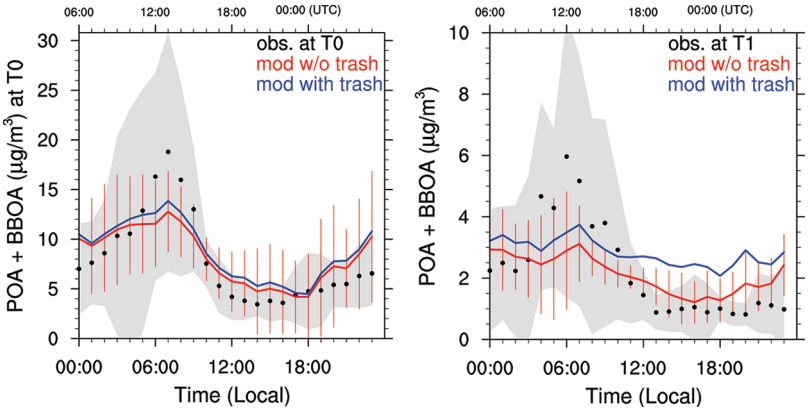

Figure 4. Average diurnal profiles comparing primary and biomass burning organic aerosols (POA and BBOA) submicrometer mass concentrations as observed by the aerosol mass spectrometer and predicted by WRF/Chem at T0 and T1 sites from 20 to 29 March 2006. The gray shading denotes the variability among observations (1 sigma).

ments, adding about 2 ng m^{-3} of PM_1 Sb during the rush hour peak. The highest predicted values of trash buring Sb (~3.5 ng m^{-3}) are found during the afternoon hours at the suburban site T1 that was located downwind of trash emissions. This comparison suggest that the trash emission estimates are of the right order, and that they can be used to evaluate the estimated impact of trash burning on air quality in Mexico City.

3.3. Estimated Contribution of Trash Burning Emissions to Organic Aerosol Levels in Mexico City. As discussed above the contribution of trash burning emissions to concentrations of main gaseous pollutants was found to be relatively small (<3%) in this region, so we have focused our discussion below exclusively on the aerosol fraction. The largest increase due to trash burning was found for POA as expected from the estimated doubling of POA emissions due to trash burning, compared to the initial inventory. Figure 3 shows the predicted enhancement in 9-day average surface concentrations of POA resulting from the impact of trash burning in the Mexico City valley, while Figure 4 shows the diurnal profiles of POA for the urban (T0) and suburban (T1) sites. In comparison to POA concentrations generated by other anthropogenic sources (Figure 3a), the predicted POA levels from trash burning have a lower peak, but are also more widely spread over the Mexico City valley. Simulated POA concentrations increase with the inclusion of trash burning by 0.2−0.6 $\mu g\ m^{-3}$ in the downtown area, and up to 1.5−2 $\mu g\ m^{-3}$ in the southeast and east suburbs of the city. The locations of maximum increases are unsurprisingly the trash burning emission hotspots (Figure 1c), resulting in higher exposures for areas of high population density of low socioeconomic level. Some of the emitted material is advected downwind to the northern edges of the plateau (north of T1 site) under the influence of southerly and southwesterly winds. The model results indicate that the $\sim^2/_3$ of the MCMA located to the southeast and east parts of the valley that generally experience low levels of POA emissions see their average levels increase by 40−80% during trash burning.

The change in SOA concentrations was found to be negligible (<1%) when the trash burning emissions are included in the simulations. This result is expected since SOA formation is parametrized in our study based on CO emissions (based on the results summarized by ref 26 for biomass burning sources), and the increase in CO emissions due to trash burning is very limited (3%). As discussed above, if the modeling was based on the oxidation of VOC and condensation of their reaction products, the change in concentrations would have also been very small as the emissions of VOC precursors (aromatics) have not significantly increased due to trash burning. Given the fact that SOA contributes about half of the total organic mass in Mexico City,[36] the relative contribution of trash burning to the total organic aerosol is smaller as shown in Figure 3d. According to our model predictions, the complete mitigation of trash burning from the Mexico City valley could reduce the levels of organic aerosols by 2−5% downtown, and 15−40% in the most impacted areas. The highest reduction is expected to occur near densely populated areas of the city, and therefore the health benefits might be considerable.

Figure 3e shows the contribution of trash burning to the modeled total $PM_{2.5}$ concentrations in the vicinity of Mexico City. The model results suggest that trash burning represents less than 1% of the $PM_{2.5}$ mass in the city center where the $PM_{2.5}$ concentrations are the highest, from 2 to 7% in the prevailing outflow region north and northeast of the city, and about 15% in the strongest emission hotspot which experiences average $PM_{2.5}$ levels of 5−8 $\mu g\ m^{-3}$. The contribution of trash burning to secondary inorganic aerosol compounds ranged from 1% downtown to 7% in the emission hotspots (not shown here). Although NO_x, NH_3, and SO_2 are emitted from trash burning, the amounts emitted are relatively small compared to other sources in this region.

Our inventory and model-based estimates of the trash burning effect on aerosols are more than five times lower than the estimates by ref 2. These authors estimated a contribution of trash burning of ~28% of $PM_{2.5}$ in downtown Mexico City, or about 10 $\mu g\ m^{-3}$, based on attributing 100% of the measured Sb in $PM_{2.5}$ to this source. However as discussed above there are other important sources of Sb, especially in the PM_1 to $PM_{2.5}$ size range, and a lower predicted impact than the one reported by ref 2 is consistent with the fact that other sources also contribute to submicrometer Sb concentrations in the city. Finally, our results show a strong spatial variability in the role that trash burning plays on air quality in Mexico City. The model suggests that trash burning impacts are highest close to their source region, while the regional impact is more limited. Mitigation of trash burning could lead to reduced human health effects, especially in the poorer areas of Mexico City, while the

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regional climate impact of these emissions is expected to be limited in this case.

■ ASSOCIATED CONTENT

Supporting Information

SI-Table 1. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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Supplementary Information: "Impact of Trash Burning on Air Quality in Mexico City" by Hodzic et al.

SI-Table 1: Assigned emission factors (EF in g kg^{-1} of fuel) for trash burning

Species	EF (g kg^{-1} fuel)
Based on ref 2 and 13	
CO_2	1367
CO	45
CH_4	3.7
NH_3	1.12
Ethene	2.19
Acetic Acid	2.42
Formaldehyde	0.62
Methanol	0.94
Formic Acid	0.38
Acetylene	0.4
Propene	1.26
Organic Carbon	**5.3**
Organic Aerosol	**6.9**
Elemental Carbon	**0.6**
Ref 14	
$PM_{2.5}$	**8**
SO_2	0.5
NO	3
Toluene	0.37
Benzene	0.98
Acetaldehyde	0.43
Acetone	0.25