Short-lived Climate Pollutant Research Digest

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Short-Lived Climate Pollutants (SLCPs)

Description: This is a cross-cutting section which includes articles which specifically focus on SLCPs as a category of emissions and/or measures

Potential to reduce the concentrations of short-lived climate pollutants in traffic environments: A case study in a medium-sized city in Brazil

Understanding the spatio-temporal variation of short lived climate pollutants (SLCP) over cities is critical to protect public health and mitigate climate change. There is a lack of knowledge about the distribution of SLCP in South America, mainly in medium-sized cities (<1 million inhabitants). This work reports on results of a campaign conducted at several sites (street canyon, urban background, and suburban) in Londrina, Brazil. The pollution datasets (black carbon BC, nitrogen oxides NOx, ozone O3, fine particles PM2.5, and particle number PN) were analyzed by using descriptive statistics, diurnal cycles, time-space correlations, and establishing linkages with traffic rates and with wind conditions. Hourly mean (±standard deviation) BC concentrations ranged from 0.58 (±0.54) in the suburban area to 3.43 (±2.69) μg m−3 at the street canyon site (10,150 vehicles d−1 on weekdays), showing a high spatio-temporal variability even at short scales. PN (mean of 17,469 cm−3) and NOx (mean of 51.58 μg m−3) concentrations tracked BC levels and traffic rates, particularly the number of diesel buses at the canyon site. PM2.5 and O3 levels presented a lower spatial variability, with poor correlation with traffic rates in the canyon and were more tied to regional sources. NOx, BC, and PN showed the highest reduction potentials connected to the abatement of traffic emissions in the city center, particularly by targeting heavy-duty diesel vehicles. The reduction of PM2.5 and O3 concentrations is more challenging due to a significant regional contribution that requires cutting down emissions at state, national or even transboundary scales.

Krecl, P., Targino, A. C., Ketzel, M., Cipoli, Y. A., & Charres, I. (2019). Potential to reduce the concentrations of short-lived climate pollutants in traffic environments: A case study in a medium-sized city in Brazil. Transportation Research Part D: Transport and Environment, 69, 51-65.

Multiple Benefits/Impacts & Crosscutting

Description: This section includes articles addressing the multiple benefits of action to address SLCPs and implement SLCP measures.

Support for Emissions Reductions Based on Immediate and Long-term Pollution Exposure in China

Reducing power sector emissions in China is a critical step toward mitigating climate change and lowering health damages from air pollution. We conduct a discrete choice survey (N = 1060) among urban residents from 10 Chinese cities, assessing how individuals compare electricity source, cost, and reduction of emissions related to climate change or air pollution. Using observed air quality data, we also evaluate how pollution levels affect respondents' support for different types of emissions reductions. We find that reductions targeting both climate change and human health benefits have stronger support than those which address only one of the two. Furthermore, respondents in cities with the highest annual concentrations of particulate matter are willing to pay 30% more to clean up the air when compared to individuals living in less polluted cities. The analysis suggests that the public values co-optimizing mitigation policy across climate and health objectives, and that making available information on long-term air quality may encourage sustained support for cleaner energy.

Sergi, B., Azevedo, I., Xia, T., Davis, A., & Xu, J. (2019). Support for Emissions Reductions Based on Immediate and Long-term Pollution Exposure in China. Ecological economics, 158, 26-33.

The impact of human health co-benefits on evaluations of global climate policy

The health co-benefits of CO2 mitigation can provide a strong incentive for climate policy through reductions in air pollutant emissions that occur when targeting shared sources. However, reducing air pollutant emissions may also have an important co-harm, as the aerosols they form produce net cooling overall. Nevertheless, aerosol

impacts have not been fully incorporated into cost-benefit modeling that estimates how much the world should optimally mitigate. Here we find that when both co-benefits and co-harms are taken fully into account, optimal climate policy results in immediate net benefits globally, overturning previous findings from cost-benefit models that omit these effects. The global health benefits from climate policy could reach trillions of dollars annually, but will importantly depend on the air quality policies that nations adopt independently of climate change. Depending on how society values better health, economically optimal levels of mitigation may be consistent with a target of 2 °C or lower.

Scovronick, N., Budolfson, M., Dennig, F., Errickson, F., Fleurbaey, M., Peng, W., ... & Wagner, F. (2019). The impact of human health co-benefits on evaluations of global climate policy. Nature communications, 10(1), 2095.

Cleaning the air, protecting the climate: Policy, legal and institutional nexus to reduce black carbon emissions in China

There are significant co-benefits to reducing black carbon emissions for air quality, human health and the climate; yet the pollutant has not yet received sufficient policy attention in China. Overall, realizing co-benefits is complicated by the fact that climate and air quality policy goals have been pursued separately from each other. In this article, we explore the current policy and legal status of black carbon emissions across the domains of air pollution prevention and control, and climate change with a view to identify synergies and opportunities for an integrated approach.

We suggest three ways to strengthen the policy, legal and institutional nexus of air pollution and climate change to reduce black carbon emissions in China: improving scientific knowledge and the science-policy interface, increasing policy and legal connections between air quality and climate portfolios, and enhancing institutional linkages. For instance, we argue that more interdisciplinary cooperation and improvements to the black carbon inventory as well as a closer science-policy relationship are necessary. From a legal and policy angle, we identify clear openings through which to integrate reduction of black carbon emissions into the air pollution prevention and control agenda. Institutionally, the recent government reform brings air quality and climate portfolios under the supervision of the same ministry but their integration is still to be ensured. In addition, vertical linkages between different levels of environmental governance – central, provincial and municipal – need to be addressed.

Yamineva, Y., & Liu, Z. (2019). Cleaning the air, protecting the climate: Policy, legal and institutional nexus to reduce black carbon emissions in China. Environmental Science & Policy, 95, 1-10.

Methane

Description: This section includes articles addressing methane source apportionment, emissions factors, impacts and emissions trends.

Prediction of CH4 emissions from potential natural wetlands on the Tibetan Plateau during the 21st century

The alpine wetlands on the Tibetan Plateau (TP) are ecosystems vulnerable to global climate change. It has been recognized that future climate change may have a significant impact on methane (CH4) emissions from the plateau, while less attention has been paid to predicting temporal and spatial variations in CH4 emissions from TP natural wetlands. In this study, we used an integrated model framework based on the CH4MODwetland, TOPMODEL and TEM models to predict CH4 emissions from potential natural wetlands on the TP under IPCC AR5 scenarios from 2006 to 2100. The model estimates suggest that the mean area-weighted CH4 fluxes will increase from 4.45 ± 0.42 g m−2 yr−1 in 2006 to 4.79 ± 0.72, 5.99 ± 0.85 and 11.53 ± 1.33 g m−2 yr−1 under 3 Representative Concentration Pathway scenarios (RCP 2.6, RCP 4.5 and RCP 8.5 scenarios), respectively, by 2100. The dominant drivers stimulating CH4 emissions are air temperature, precipitation and net primary productivity (NPP). Spatially, CH4 fluxes and emissions showed a decreasing trend from south to north and from east to west. In response to climate change, a total of 0.42 ± 0.06, 0.54 ± 0.09 and 1.01 ± 0.12 Tg yr−1 of CH4 emissions will

be emitted from the TP's potential natural wetlands by the end of this century under the RCP 2.6, RCP 4.5 and RCP 8.5 scenarios, respectively.

Li, T., Li, H., Zhang, Q., Ma, Z., Yu, L., Lu, Y., ... & Liu, J. (2019). Prediction of CH4 emissions from potential natural wetlands on the Tibetan Plateau during the 21st century. Science of The Total Environment, 657, 498-508.

Methane emissions from anaerobic sludge digesters in Mexico: On-site determination vs. IPCC Tier 1 method

Wastewater treatment is an important source of methane (CH4) emissions. In most large-size aerobic treatment plants, the excess sludge is digested in anaerobic reactors (AD), with the concomitant CH4 emissions. The guidelines of the Intergovernmental Panel on Climate Change (IPCC) have been adopted worldwide for quantifying the national emission inventories, which include wastewater treatment plants (WWTP) as a key category. The IPCC recommends using default emission factors (Tier 1) for countries with limited available data (such as Mexico and most developing countries). However, these estimates have a high degree of uncertainty, owing to the lack of reliable information about the operation process and local environmental conditions. In order to reduce uncertainty in the estimation of CH4 emission from WWTP in Mexico, a country-specific emission factor was determined for AD associated with activated sludge process. This was accomplished with on-site data obtained from the AD of six activated sludge WWTP. In addition, the measured CH4 emissions were compared to those resulting from the application of the IPCC Tier 1 method, using the recommended default methane correction factor (MCF: 0.8) as well as alternate values (0.32 and 0.26) recently proposed by the authors. Results show that the IPCC Tier 1 method, using the recommended MCF, highly overestimate CH4 emissions compared with the values obtained on-site. In contrast, the alternate MCF achieved better estimations than the IPCC-recommended MCF, much closer to the observed emission values. The CH4 emission factor proposed as country (Mexico) specific value is 0.49 kg CH4/kg BODrem, which would allow the application of IPCC Tier 2 method. By doing so, the uncertainty associated with CH4 emission from aerobic treatment plants with AD would be reduced. This, in turn, would provide important information for implementing appropriate CH4 mitigation strategies for the water sector.

Paredes, M. G., Güereca, L. P., Molina, L. T., & Noyola, A. (2019). Methane emissions from anaerobic sludge digesters in Mexico: On-site determination vs. IPCC Tier 1 method. Science of The Total Environment, 656, 468-474.

Long-Term Measurements Show Little Evidence for Large Increases in Total U.S. Methane Emissions Over the Past Decade

Recent studies show conflicting estimates of trends in methane (CH4) emissions from oil and natural gas (ONG) operations in the United States. We analyze atmospheric CH4 measurements from 20 North American sites in the National Oceanic and Atmospheric Administration Global Greenhouse Gas Reference Network and determined trends for 2006–2015. Using CH4 vertical gradients as an indicator of regional surface emissions, we find no significant increase in emissions at most sites and modest increases at three sites heavily influenced by ONG activities. Our estimated increases in North American ONG CH4 emissions (on average approximately 3.4 ± 1.4 %/year for 2006–2015, ±σ) are much smaller than estimates from some previous studies and below our detection threshold for total emissions increases at the east coast sites that are sensitive to U.S. outflows. We also find an increasing trend in ethane/methane emission ratios, which has resulted in major overestimation of oil and gas emissions trends in some previous studies.

Lan, X., Tans, P., Sweeney, C., Andrews, A., Dlugokencky, E., Schwietzke, S., ... & Montzka, S. (2019). Long-Term Measurements Show Little Evidence for Large Increases in Total US Methane Emissions Over the Past Decade. Geophysical Research Letters, 46(9), 4991-4999.

Estimating Methane Emissions From Underground Coal and Natural Gas Production in Southwestern Pennsylvania

Production of coal and natural gas is responsible for one third of anthropogenic methane (CH4) emissions in the

United States. Here we examine CH4 emissions from coal and natural gas production in southwestern Pennsylvania. Using a top-down methodology combining measurements of CH4 and ethane, we conclude that while Environmental Protection Agency inventories appear to report emissions from coal accurately, emissions from unconventional natural gas are underreported in the region by a factor of 5 (±3). However, production-scaled CH4 emissions from unconventional gas production in the Marcellus remain small compared to other basins due to its large production per well. After normalizing emissions by energy produced, total greenhouse gas emissions from Pennsylvania unconventional natural gas production produce half the carbon footprint compared to regionally produced coal, with carbon dioxide emissions from combustion being the dominant source of greenhouse gas emissions for both sources.

Barkley, Z. R., Lauvaux, T., Davis, K. J., Deng, A., Fried, A., Weibring, P., ... & Ren, X. (2019). Estimating Methane Emissions From Underground Coal and Natural Gas Production in Southwestern Pennsylvania. Geophysical Research Letters, 46(8), 4531-4540.

Asserting the climate benefits of the coal-to-gas shift across temporal and spatial scales

Reducing CO2 emissions through a shift from coal to natural gas power plants is a key strategy to support pathways for climate stabilization. However, methane leakage in the natural gas supply chain and emissions of a variety of climate forcers call the net benefits of this transition into question. Here, we integrated a life cycle inventory model with multiple global and regional emission metrics and investigated the impacts of representative coal and gas power plants in China, Germany, India and the United States. We found that the coal-to-gas shift is consistent with climate stabilization objectives for the next 50–100 years. Our finding is robust under a range of leakage rates and uncertainties in emissions data and metrics. It becomes conditional to the leakage rate in some locations only if we employ a set of metrics that essentially focus on short-term effects. Our case for the coal-to-gas shift is stronger than previously found, reinforcing the support for coal phase-out.

Tanaka, K., Cavalett, O., Collins, W. J., & Cherubini, F. (2019). Asserting the climate benefits of the coal-to-gas shift across temporal and spatial scales. Nature Climate Change, 1.

Black Carbon

Description: This section includes articles addressing black carbon source apportionment, emissions factors, impacts and emissions trends.

Factors controlling the long-term (2009–2015) trend of PM2.5 and black carbon aerosols at eastern Himalaya, India

A first-ever long-term (2009–2015) study on the fine particulate matter (PM2.5) and black carbon (BC) aerosol were conducted over Himalaya in order to investigate the characteristics, temporal variations and the important factors regulating the long-term trend. The study was conducted over a high altitude station, Darjeeling (27°01′ N, 88°15′E, 2200 m asl) representing a typical high altitude urban atmosphere at eastern Himalaya in India. The average concentrations of PM2.5 and BC over a period of seven years were 25.2 ± 5.6 μg m−3 (ranging between 2.2 and 220.4 μg m−3) and 3.4 ± 0.7 μg m−3 (0.4 to 15.6 μg m−3) respectively. We observed decreasing trends in both PM2.5 (49% at a rate of 170 ng m−3 month−1) and BC (34% at the rate of 20 ng m−3 month−1) mass concentration over this region from 2009 to 2015. We extensively studied the impact of micrometeorological parameters on the long-term trend in PM2.5 and BC through the correlation analysis. The significant changes in boundary layer dynamics over this region played a major role in the decreasing trend of aerosols. The concentration weighted trajectory analysis revealed that the important contributory long-distant source regions for PM2.5 and BC over eastern Himalaya were Indo Gangetic Plane and Nepal. The contributions from these regions were found to be decreased significantly from 2009 to 2015. Investigations on the fire counts associated with the forest fire, and open burning activities through the satellite observations revealed that the decreasing trend in PM2.5 and BC over eastern Himalaya is well correlated to the decreasing trend in the fire counts over IGP and Nepal. We also explored that the changes and up gradation of the domestic fuel at the Indo Gangetic

Plane regions in recent years not only improved the regional air quality but also affected the atmospheric environment over the eastern part of Himalaya.

Sarkar, C., Roy, A., Chatterjee, A., Ghosh, S. K., & Raha, S. (2019). Factors controlling the long-term (2009–2015) trend of PM2. 5 and black carbon aerosols at eastern Himalaya, India. Science of The Total Environment, 656, 280-296.

Source apportionment of black carbon (BC) from fossil fuel and biomass burning in metropolitan Milan, Italy

In this study, the temporal variations of sources of black carbon (BC) concentrations were evaluated in the metropolitan area of Milan, Italy, during three distinct seasons over 2017–2018. We measured BC concentrations using Aethalometers at two sampling sites, one in the city center of Milan, and one in the less densely populated suburb of Bareggio, approximately 14 km to the west of Milan's urban center. PM samples were also collected for elemental carbon (EC) and 14C analyses. The Aethalometer model was used to apportion BC concentrations to the fossil fuel combustion (BCff) and biomass burning (BCbb) originated BC. Additionally, radiocarbon 14C analysis was performed on the PM samples, allowing us to refine our estimates of the contributions of both BCff and BCbb to total BC concentrations and assess the dependence of the mass absorption cross section (MAC) of BC on its source. Overall, our results indicated that the annually averaged BC concentrations were higher at the Bareggio site (2763 ± 1050 ng m−3) than at the Milan site (1921 ± 876 ng m−3). The Aethalometer model results demonstrated that in all of the sampling seasons, fossil-fuel-originated BC (BCff) concentrations were slightly higher in Milan (e.g., a summertime average of 1045 ± 150 ng/m3) than in Bareggio (e.g., a summertime average of 940 ± 89 ng/m3); however, black carbon (BCbb) concentrations from biomass burning were considerably higher at Bareggio (e.g., a wintertime average of 3284 ± 713 ng/m3) than in Milan (e.g., a wintertime average of 1154 ± 103 ng/m3). Diurnal variation plots indicated that both in Milan and Bareggio, BCff peaked during the morning and, to a lesser extent, afternoon traffic rush hours, while BCbb peaked during nighttime when residential wood burning for heating purposes is prominent. Our results also highlight the significant impact of residential wood burning on ambient BC concentrations in the Milan metropolitan area.

Mousavi, A., Sowlat, M. H., Lovett, C., Rauber, M., Szidat, S., Boffi, R., ... & Sioutas, C. (2019). Source apportionment of black carbon (BC) from fossil fuel and biomass burning in metropolitan Milan, Italy. Atmospheric environment, 203, 252-261.

Black carbon aerosol in India: A comprehensive review of current status and future prospects

India is currently the second-largest emitter of black carbon (BC) in the world, with emissions projected to rise steadily in the coming decades. In view of the large variations associated with BC emission inventories in this region, model outputs of BC mass and radiative forcing (RF) need to be validated against long-term regionally-representative atmospheric measurements. Such measurements are highly scattered spatially as well as temporally in India, and a systematic evaluation of BC data is non-existent so far. To address this issue, we present here a comprehensive review of BC measurements in India from a survey of >140 studies spanning 2002–2018. In addition to summarizing baseline BC levels in urban, semi-urban, rural and remote locations, we report impacts of anomalous environmental and/or emission conditions, e.g., truck/general strikes, firework events, fog/haze episodes, large-scale biomass burning events, etc. We also present a discussion on major BC sources and climate impacts (in terms of direct RF) in major land-use categories, mitigation strategies currently employed on a national scale, and recent advances in measuring brown carbon (BrC) in India. We identify key areas for improvement, such as – i) the need for long-term BC monitoring networks, especially in regions where estimated emissions are high but measurement coverage is low; ii) the general lack of understanding, despite some recent reports, of BC aerosol mixing states, aging and direct climate effects in the Indian context; iii) the need to shift from qualitative approaches of BC source apportionment to robust quantitative measures; and iv) the prospects for coupled chemical-optical characterization of BrC for a better understanding of its sources and climate effects. We list potential research directions for the scientific community to address these knowledge gaps. We also believe that this review will be beneficial to policymakers for prioritizing BC mitigation efforts.

Rana, A., Jia, S., & Sarkar, S. (2018). Black carbon aerosol in India: A comprehensive review of current status and

future prospects. Atmospheric research.

Socio-Economic impacts

Description: This section includes articles addressing the socio-economic impacts due to air pollutions and SLCP related climate changes

Health loss attributed to PM2.5 pollution in China's cities: Economic impact, annual change and reduction potential

Ambient fine particulate matter (PM2.5) has long been the primary air pollutant with alarming public health risk in China. PM2.5 pollution control in China still mainly concerned concentration declining. The qualification and identification of PM2.5-attributable health loss is crucial for China's air quality improvement and pollution prevention. This study assessed the annual health loss and economic impact attributed to PM2.5 exposure at a city level in China from 2015 to 2017. The health benefits from achieving specific PM2.5 concentration control targets were estimated for 2020. The economic value of health loss in China was 3205.05, 3223.51, and 3344.80 billion Yuan in 2015, 2016, and 2017, representing 4.34%, 4.07%, and 3.85% of the gross domestic product of China. The health loss value in Beijing–Tianjin–Hebei (BTH) and surrounding areas and the Yangtze River Delta (YRD) urban agglomeration in 2017 was 731.93 and 520.27 billion Yuan, accounting for 21.88% and 15.56%, respectively, of the total economic value of all assessed cities. The economic value of health loss in provincial cities was high. From 2015 to 2017, high health loss in BTH and surrounding areas showed a diffusion trend toward cities in Henan, Shanxi, and Shaanxi Provinces. High health loss in the YRD urban agglomeration transferred to cities located in the middle and upper reaches of the Yangtze River. If PM2.5 concentration control targets can be achieved by 2020, premature mortality attributed to PM2.5 exposure will fall by 91,860 cases, representing 11.20% of which in 2017. This study, for the first time, highlighted the spatial distribution and temporal variation characteristics of health loss in Chinese cities based on ground-monitoring PM2.5 concentration data and annual real-time population data. Distributional feature and time-trend analysis would provide a measurable assessment of health loss in Chinese cities to policymakers for effective allocating their efforts on air quality improvement.

Guan, Y., Kang, L., Wang, Y., Zhang, N. N., & Ju, M. T. (2019). Health loss attributed to PM2. 5 pollution in China's cities: Economic impact, annual change and reduction potential. Journal of cleaner production, 217, 284-294.

Tropospheric Ozone

Description: This section includes articles addressing tropospheric ozone source apportionment, emissions factors, impacts and emissions trends.

Estimates of reactive trace gases (NMVOCs, CO and NOx) and their ozone forming potentials during forest fire over Southern Himalayan region

In the present study, emission of trace gases [non-methane volatile organic compounds (NMVOCs), carbon monoxide (CO) and oxides of nitrogen (NOx)], their ozone forming potentials and ozone sensitivities have been investigated during the forest fire period (2003–2016) over the Southern Himalayan region. Reanalysis data of Global Fire Assimilation System model is used to retrieve the various parameters such as fire radiative power and emission rates of various trace gases. April 2016 is noticed to be anomalous in terms of fire events in the last fourteen years (2003–2016) over the lower Southern Himalayan region. Our estimation shows major contribution of oxygenated compounds (55.2%) amidst all NMVOCs. Mean CO and NOx emission rates are 533.81 and 13.66 mg/m2/day, respectively during the forest fire of April months for fourteen years. The emissions of NMVOCs, CO and NOx increased by 90.4, 110.6 and 132.5% and reaches up to 121.1, 958.3 and 25.3 mg/m2/day in April 2016 with respect to non-burning period (April 2015). Ozone forming potentials (OFP) of NMVOCs are also examined using the maximum incremental reactivity (MIR) method, which shows ~2 times higher OFP for total NMVOCs during 2016 as compared to 2015. Based on the MIR scale, the contribution of top 10 species to OFP are in the decreasing order of formaldehyde, acetaldehyde, ethane, propene, toluene, butane, isoprene, methanol, pentene and hexane. The ratio of NMVOCs/NOx is <8, which indicates that the

photochemical production of O3 is mainly controlled by the levels of NMVOCs. The surface observations of ozone and CO from a Himalayan station Nainital also showed substantial increase in concentration during the forest fire of April 2016. Our results are valuable for the better understanding of chemical composition of trace gases, their role in O3 formation and effective control strategies of O3 pollution during the forest fire events over the lower Himalayan region.

Kumar, A., Bali, K., Singh, S., Naja, M., & Mishra, A. K. (2019). Estimates of reactive trace gases (NMVOCs, CO and NOx) and their ozone forming potentials during forest fire over Southern Himalayan region. Atmospheric Research, 227, 41-51.

Surface and tropospheric ozone trends in the Southern Hemisphere since 1990: possible linkages to poleward expansion of the Hadley circulation

Increases in free tropospheric ozone over the past two decades are mainly in the Northern Hemisphere that have been widely documented, while ozone trends in the Southern Hemisphere (SH) remain largely unexplained. Here we first show that in-situ and satellite observations document increases of tropospheric ozone in the SH over 1990–2015. We then use a global chemical transport model to diagnose drivers of these trends. We find that increases of anthropogenic emissions (including methane) are not the most significant contributors. Instead, we explain the trend as due to changes in meteorology, and particularly in transport patterns. We propose a possible linkage of the ozone increases to meridional transport pattern shifts driven by poleward expansion of the SH Hadley circulation (SHHC). The SHHC poleward expansion allows more downward transport of ozone from the stratosphere to the troposphere at higher latitudes, and also enhances tropospheric ozone production through stronger lifting of tropical ozone precursors to the upper troposphere. These together may lead to increasing tropospheric ozone in the extratropical SH, particularly in the middle/upper troposphere and in austral autumn. Poleward expansion of the Hadley circulation is partly driven by greenhouse warming, and the associated increase in tropospheric ozone potentially provides a positive climate feedback amplifying the warming that merits further quantification.

Lu, X., Zhang, L., Zhao, Y., Jacob, D. J., Hu, Y., Hu, L., ... & Querel, R. (2019). Surface and tropospheric ozone trends in the Southern Hemisphere since 1990: possible linkages to poleward expansion of the Hadley Circulation. Science Bulletin, 64(6), 400-409.

Biomass Burning & Household Energy

Description: This section includes articles primarily addressing SLCP measures and innovations related to the household energy initiative, open burning of agricultural residue, and SLCP emissions in relevant sectors. Solid waste burning is covered in the waste section.

Regional air quality impact of northern South America biomass burning emissions

Biomass burning emissions have a substantial impact on regional air quality and climate. The region of Amazonia in South America has long been identified as one of the largest contributors to short lived pollutants globally. However, massive natural wildfires and agricultural burns also occur every year in the grassland plains of Northern South America during the dry season (November to April). The regional-scale air quality impact of these biomass burning emissions has not been studied in depth and is analyzed in this study. We used PM2.5 and PM10 concentrations from three large urban areas: Bogotá, Medellín, and Bucaramanga, for the period 2006–2016. Carbon monoxide data was only available for the city of Bogotá for the analysis period. These cities are located hundreds of kilometers westward of the emission areas. The spatio-temporal distribution of fires was obtained from MODIS Active Fire Data. The back-trajectories of air masses reaching the receptor sites were computed with two different meteorological datasets. Radiosonde data, available only for Bogotá, was used to account for local meteorological factors impacting pollution dispersion. A novel analysis algorithm was developed to combine active fire data with back-trajectory locations to select those active fires in the vicinity of the air masses arriving at each city. This analysis allows the selection of only those upwind fires that can be related to the air quality in the selected locations. We show that anomalously high PM and CO levels occurred when air masses originated from the Orinoco grasslands during the times when the largest number of fires in

the region were active. The correlation between number of fires and PM10 concentration was found to decrease with increasing distance from the sources, ranging from 0.6 to 0.25. Our results are insensitive to the meteorological dataset used to generate back-trajectories. For Bogotá it was found that mixing height variations can explain an important fraction of the observed seasonal variations in PM10, PM2.5, and CO concentration. The number of upwind fires can explain 11% ± 5% of the seasonal variability in CO concentrations. Estimates of the seasonal variability of PM10 and PM2.5 explained by fires are 45% ± 7% and 39% ± 8% respectively. However, covariance between occurrence of fires and non-combustion local sources of PM imply that the latter estimates are likely an overestimation of the actual contribution. Our findings support the possibility that fires in the Orinoco river basin deteriorate air quality in highly populated urban centers hundreds of kilometers away from the sources.

Mendez-Espinosa, J. F., Belalcazar, L. C., & Betancourt, R. M. (2019). Regional air quality impact of northern South America biomass burning emissions. Atmospheric environment, 203, 131-140.

Agriculture and Livestock

Description: This section includes articles primarily addressing SLCP measures and innovations related to the Agriculture initiative and SLCP emissions in relevant sectors

Northward shift of historical methane emission hotspots from the livestock sector in China and assessment of potential mitigation options

China contributes approximately 10% of the total global methane (CH4) emissions from its livestock sector. However, existing inventories of CH4 emissions from the livestock sector involve significant uncertainty, and the reduction potentials and spatially varying efficiencies of different technical options (adding lipid to diets, acidification, composting, anaerobic digestion, and the combination of composting and anaerobic digestion) have not been systematically assessed at the provincial level. Here, we used a bottom-up approach to compile an up-to-date high-resolution CH4 emission inventory for the livestock sector in China using provincial condition-specific emission factors by considering the gross energy intake and the ambient temperature at the provincial level. A 1-km × 1-km gridded map was produced for 2014, and the temporal trends of the CH4 emissions from 1978 to 2013 were re-visited. The effects of the technical mitigation options that could have been used on CH4 emissions were further evaluated in five different scenarios. Livestock sector CH4 emissions decreased by 1.2 Tg CH4 per year from the period of 1999–2006 to the period of 2007–2014, and this rate was approximately 17–28% lower than previous estimates. During the period of 1978–2014, spatial-temporal emission trends indicated a possible relationship between the Chinese government policies and emissions to some extent and a northward shift of emission hotspots induced by economic and policy incentives. Hotspots with high mitigation potential and efficiency (the achieved reduction under a specific mitigation scenario divided by the baseline emissions from the species affected by the respective technical option) were also identified. The combination of composting and anaerobic digestion is a recommended policy, which can simultaneously address slurry and solid manure and significantly mitigated of CH4 emissions. Overall, this study provides insights into the region-dependent implementation of technical options used to reduce CH4 emissions from the livestock sector in China.

Xu, P., Liao, Y., Zheng, Y., Zhao, C., Zhang, X., Zheng, Z., & Luan, S. (2019). Northward shift of historical methane emission hotspots from the livestock sector in China and assessment of potential mitigation options. Agricultural and Forest Meteorology, 272, 1-11.

Long-term changes in greenhouse gas emissions from French agriculture and livestock (1852–2014): From traditional agriculture to conventional intensive systems

France was a traditionally agricultural country until the first half of the 20th century. Today, it is the first European cereal producer, with cereal crops accounting for 40% of the agricultural surface area used, and is also a major country for livestock breeding with 25% of the European cattle livestock. This major socioecological transition, with rapid intensification and specialisation in an open global market, has been accompanied by deep

environmental changes. To explore the changes in agricultural GHG emissions over the long term (1852–2014), we analysed the emission factors of N2O from field experiments covering major land uses, in a gradient of fertilisation and within a range of temperature and rainfall, and used CH4 emission coefficients for livestock categories, in terms of enteric and manure management, considering the historical changes in animal excretion rates. We also estimated indirect CO2 emissions, rarely accounted for in agricultural emissions, using coefficients found in the literature for the dominant energy consumption items (fertiliser production, field work and machinery, and feed import). From GHG emissions of ~30,000 ktons CO2 Eq yr−1 in 1852, reaching 54,000 ktons CO2 Eq yr−1 in 1955, emissions more than doubled during the 'Glorious thirties' (1950–1980), and peaked around 120,000 ktons CO2 Eq yr−1 in the early 2000s. For the 2010–2014 period, French agriculture GHG emissions stabilised at ~114,000 ktons CO2 Eq yr−1, distributed into 49% methane (CH4), 22% carbon dioxide (CO2) and 29% nitrous oxide (N2O). A regional approach through 33 regions in France shows a diversity of agriculture reflecting the hydro-ecoregion distribution and the agricultural specialisation of local areas. Exploring contrasting scenarios at the 2040 horizon suggests that only deep changes in the structure of the agro-food system would double the reduction of GHG emissions by the agricultural sector.

Garnier, J., Le Noë, J., Marescaux, A., Sanz-Cobena, A., Lassaletta, L., Silvestre, M., ... & Billen, G. (2019). Long-term changes in greenhouse gas emissions from French agriculture and livestock (1852–2014): From traditional agriculture to conventional intensive systems. Science of the Total Environment, 660, 1486-1501.

Water management to mitigate the global warming potential of rice systems: A global meta-analysis

Rice is a main staple food for roughly half of the world's population, but rice agriculture is also a main source of anthropogenic greenhouse gas (GHG) emissions. Many studies have reported that water management (e.g. alternate wetting and drying, intermittent irrigation, mid-season drain, aerobic rice) affects rice yields and methane (CH4) and nitrous oxide (N2O) emissions from rice paddies. However, these studies span a variety of practices and vary in experimental design and results, making it difficult to determine their global response from individual experiments. Here we conducted a meta-analysis using 201 paired observations from 52 studies to assess the effects of water management practices on GHG emissions and rice yield. Overall, compared to continuous flooding, non-continuous flooding practices reduced CH4 emissions by 53%, increased N2O emissions by 105%, and decreased yield by 3.6%. Importantly, N2O emissions were low, contributing, on average, 12% to the combined global warming potential (GWP; CH4 + N2O). As a result, non-continuous flooding reduced GWP (-44%) and yield-scaled GWP (-42%). However, non-continuous flooding practices stimulated N2O emissions to a greater degree in soils with high organic carbon or with manure additions. The reduction in CH4 emissions increased with the number of drying events, soil drying severity, and the number of unflooded days. Currently, Intergovernmental Panel on Climate Change (IPCC) scaling factors for single and multiple ($\geqslant$ 2) drying events are 0.6 and 0.52. Based on this analysis using actual side-by- side field studies, we suggest changing these to 0.67 for a single event and 0.36 for multiple events.

Jiang, Y., Carrijo, D., Huang, S., Chen, J., Balaine, N., Zhang, W., ... & Linquist, B. (2019). Water management to mitigate the global warming potential of rice systems: A global meta-analysis. Field Crops Research, 234, 47-54.

The potential impacts of dietary plant natural products on the sustainable mitigation of methane emission from livestock farming

Livestock production is one of the major contributors of greenhouse gases such as methane (CH4) and carbon dioxide (CO2). These gases contribute greatly to global warming, environmental degradation and pollution. Livestock production is responsible for 18% CH4 and 9% CO2 productions of all greenhouse gases emissions. Methane has a greater global warming effect (about 23 times) more than CO2. Currently, livestock production faces a great challenge of increasing production to meet global demand for agricultural products and at the same time reduces environmental impact. Many researchers have reported the effects of substituting phytoconstituents such as tannins, saponins and essential oil as chemical feed additives to modify rumen fermentation. These modifications are aimed at reducing loss of feed energy, improving animal productivity and mitigating CH4 and CO2 emitted during livestock production. This present review is aimed at providing information on the influence of plant natural products or secondary metabolites (PNP) such as tannins, saponins and essential oils on ruminal microflora and their potentials to mitigate biogases during livestock production.

This work will also review purported anti-microbial activities of plant secondary metabolites and its ability to improve animal health and enhance productivity. From the findings of this review, PNP have the potential to improve rumen fermentation, reduce loss of feed energy, improve animal health and productivity, increase animal lifetime performance, and reduce greenhouse gases production- CH4 and CO2 during animal production. This review also revealed that supplementation of saponin, tannins or essential oils at low to moderate doses have more potentials and are the promising natural feed additives suitable to manipulate microbial ecosystems, inhibit pathogenic bacteria proliferation in gastrointestinal tract, improve rumen fermentations, mitigate rumen CH4 production and reduce environmental impact of livestock production. However, further research is required to establish the effective daily doses of plant natural products to animals without any detrimental effect.

Ugbogu, E. A., Elghandour, M. M., Ikpeazu, V. O., Buendía, G. R., Molina, O. M., Arunsi, U. O., ... & Salem, A. Z. (2019). The potential impacts of dietary plant natural products on the sustainable mitigation of methane emission from livestock farming. Journal of cleaner production, 213, 915-925.

Transportation

Description: This section includes articles primarily addressing SLCP measures and innovations related to the Diesel initiative and SLCP emissions in relevant sectors

Aviation's emissions and contribution to the air quality in China

With a rapid increase in air traffic, aviation has become an increasingly important contributor to anthropogenic air pollutants (particularly nitrogen oxides (NOX)) over China. This study provides the first overall estimation of the aviation emissions from all civil airports in mainland China as well as the associated contribution to ambient air quality. First, aircraft emissions (NOx, sulfur dioxide (SO2), carbon monoxide (CO), hydro-carbons (HC), particulate matter (PM2.5 and PM10), volatile organic carbons (VOCs) and black carbon (BC)) during landing and take-off cycles (below 3 km) are estimated for both recent (2000–2016) and future (2020) scenarios. Second, the corresponding environmental impacts are measured by the Comprehensive Air Quality Model with extensions (CAMx). The results have insightful policy implications for China's aviation planning. (1) Generally, China's aviation emissions and their effect on air quality have been and will continue to increase. (2) Among species, NOx dominated China's aircraft emissions in terms of both emission amount and environmental impact, while PM2.5 generated an extensive influence. (3) With respect to spatial distribution, the air quality effect was highly concentrated at emission-intense airports that served economic zones and/or tourist spots.

Bo, X., Xue, X., Xu, J., Du, X., Zhou, B., & Tang, L. (2019). Aviation's emissions and contribution to the air quality in China. Atmospheric environment, 201, 121-131.

Impact of next-generation vehicles on tropospheric ozone estimated by chemical transport model in the Kanto region of Japan

The plans to introduce next-generation hybrid and zero-emission vehicles in the market are now enacted by governments in many countries to manage both global warming and air pollution problems. There are only a few studies evaluating the effects of the next-generation vehicles on the changes in concentrations of ozone generated by the photochemical reactions between volatile organic compounds and nitrogen oxides (NOx). To evaluate these changes, we performed chemical transport modeling in the Kanto region, Japan in the summer of 2013. The results show that if the vehicles are substituted by hybrid vehicles, average ozone concentrations increase in urban areas and decrease in suburban areas due to NOx titration. Substitution with zero-emission passenger vehicles decreases the concentrations in both urban and suburban areas. Substitution with both hybrid and zero-emission passenger and heavy-duty vehicles highly increases the concentrations in urban areas. Using the model results, we also discuss the effect of ozone concentration changes on premature mortality of humans in summer. The results suggest that, in some cases the introduction of next-generation vehicles might exasperate ozone concentrations, even leading to 5 to 10 times higher premature mortality during the summer compared to that of influenza and heat stroke in Japan.

Hata, H., & Tonokura, K. (2019). Impact of next-generation vehicles on tropospheric ozone estimated by chemical

transport model in the Kanto region of Japan. Scientific reports, 9.

Waste and Waste Management

Description: This section includes articles primarily addressing SLCP measures and innovations related to the solid waste initiative and SLCP emissions in relevant sectors

Regulating landfills using measured methane emissions: An English perspective

Methane emissions from landfills are an important source of greenhouse gases in the UK and worldwide. This paper considers how measurements of methane emissions could be used to regulate landfills in England in order to reduce the contribution of landfilling to climate change. The paper presents the results of a number of UK studies undertaken to quantify methane emissions from landfills. The methods used have included the DIAL (Differential Absorption Lidar) technique and a tracer gas dispersion method. A method based on aerial measurements has been developed. Methane emission rates were measured at 15 biodegradable waste landfills. All of the landfills where measurements took place had an active landfill gas extraction system. A methane collection index (MCI) is calculated for each landfill using the ratio of the methane collection rate to the sum of the collection and emission rates. The values of the index in the campaigns reported here ranged from 0.28 to 0.90. The modern operational landfills surveyed achieved MCI values with a much narrower range of between 0.64 and 0.90 with an average of 0.76. This has demonstrated that it is possible for these landfills to collect a high proportion of the landfill gas. A proposed approach is presented for regulating landfills using the measured MCI. This would involve an annual measurement campaign to quantify the methane emissions and the use of the data provided by these surveys to develop an achievable but challenging MCI limit. A limit value of 0.75 for the MCI is used to illustrate the approach. An MCI that falls below the limit would trigger actions to reduce the methane emissions from the landfill.

Bourn, M., Robinson, R., Innocenti, F., & Scheutz, C. (2019). Regulating landfills using measured methane emissions: An English perspective. Waste Management, 87, 860-869.

China's Urban Methane Emissions From Municipal Wastewater Treatment Plant

The increased number and capacity of municipal wastewater treatment plants (WWTPs) in China has driven the emission of methane (CH4). Few studies have focused on quantification of CH4 emissions from municipal WWTPs of different cities and analysis of socioeconomic factors influencing the quantity of emissions. Here we estimated CH4 emissions from WWTPs in China for 229 prefectural-level cities, based on data from 2,019 working municipal WWTPs. The results show the total CH4 emissions to be 1,169.8 thousand tons (29.2 MtCO2e) in 2014, which is over three times that of the municipal WWTPs in the United States in 2016. Large cities along the east coast regions had larger CH4 emissions in absolute and per capita terms. Correlation analysis shows that cities with higher gross domestic product, household food consumption expenditure, or household consumption expenditure produced more degradable organics in wastewater, thus more CH4 emissions. Measures to control the sources of degradable organics and regulate WWTP processes with less emission factor are key to mitigate CH4 emissions. In addition to aerobic or anaerobic wastewater treatment systems, factors such as wastewater temperature, length of sewer, and the addition of nitrate that influencing emission factor are suggested to be involved in CH4 emission modeling.

Zhao, X., Jin, X. K., Guo, W., Zhang, C., Shan, Y. L., Du, M. X., ... & Li, Y. P. (2019). China's urban methane emissions from municipal wastewater treatment plant. Earth's Future, 7(4), 480-490.

Air pollution & Health Impacts

Description: This section includes articles primarily addressing linkages between air pollution exposure and health impacts

Nonlinear relationships between air pollutant emissions and PM2.5-related health impacts in the Beijing-Tianjin-Hebei region

A direct and quantitative linkage of air pollution-related health effects to emissions from different sources is critically important for decision-making. While a number of studies have attributed the PM2.5-related health impacts to emission sources, they have seldom examined the complicated nonlinear relationships between them. Here we investigate the nonlinear relationships between PM2.5-related premature mortality in the Beijing-Tianjin-Hebei (BTH) region, one of the most polluted regions in the world, and emissions of different pollutants from multiple sectors and regions, through a combination of chemical transport model (CTM), extended response surface model (ERSM), and concentration-response functions (CRFs). The mortalities due to both long-term and short-term exposures to PM2.5 are most sensitive to the emission reductions of primary PM2.5, followed by NH3, nonmethane volatile organic compounds and intermediate volatility organic compounds (NMVOC+IVOC). The sensitivities of long-term mortality to emissions of primary organic aerosol (POA), NMVOC+IVOC and SO2 do not change much with reduction ratio, whereas the sensitivities to primary inorganic PM2.5 (defined as all chemical components of primary PM2.5 other than POA), NH3 and NOx increase significantly with the increase of reduction ratio. The emissions of primary PM2.5, especially those from the residential and commercial sectors, contribute a larger fraction of mortality in winter (57–70%) than in other seasons (28-42%). When emissions of multiple pollutants or those from both local and regional emissions are controlled simultaneously, the overall sensitivity of long-term mortality is much larger than the arithmetic sum of the sensitivities to emissions of individual pollutants or from individual regions. This implies that a multi-pollutant, multi-sector and regional joint control strategy should be implemented to maximize the marginal health benefits. For NOx emissions, we suggest a nationwide control strategy which significantly enhances the effectiveness for reducing mortality by avoiding possible side effects when only the emissions within the BTH region are reduced.

Zhao, B., Wang, S., Ding, D., Wu, W., Chang, X., Wang, J., ... & Zheng, M. (2019). Nonlinear relationships between air pollutant emissions and PM2. 5-related health impacts in the Beijing-Tianjin-Hebei region. Science of the Total Environment, 661, 375-385.

Estimating mortality burden attributable to short-term PM2.5 exposure: A national observational study in China

Studies worldwide have estimated the number of deaths attributable to long-term exposure to fine airborne particles (PM2.5), but limited information is available on short-term exposure, particularly in China. In addition, most existing studies have assumed that short-term PM2.5-mortality associations were linear. For this reason, the use of linear exposure-response functions for calculating disease burden of short-term exposure to PM2.5 in China may not be appropriate. There is an urgent need for a comprehensive, evidence-based assessment of the disease burden related to short-term PM2.5 exposure in China. Here, we explored the non-linear association between short-term PM2.5 exposure and all-cause mortality in 104 counties in China; estimated county-specific mortality burdens attributable to short-term PM2.5 exposure for all counties in the country and analyzed spatial characteristics of the mortality burden due to short-term PM2.5 exposure in China. The pooled PM2.5-mortality association was non-linear, with a reversed J-shape. We found an approximately linear increased risk of mortality from 0 to 62 μg/m3 and decreased risk from 62 to 250 μg/m3. We estimated a total of 169,862 additional deaths from short-term PM2.5 exposure throughout China in 2015. Models using linear exposure-response functions for the PM2.5-mortality association estimated 32,186 deaths attributable to PM2.5 exposure, which is 5.3 times lower than estimates from the non-linear effect model. Short-term PM2.5 exposure contributed greatly to the death burden in China, approximately one seventh of the estimates from the chronic effect. It is essential and crucial to incorporate short-term PM2.5-related mortality estimations when considering the disease burden attributable to PM2.5 in developing countries such as China. Traditional linear effect models likely underestimated the mortality burden due to short-term exposure to PM2.5.

Li, T., Guo, Y., Liu, Y., Wang, J., Wang, Q., Sun, Z., ... & Shi, X. (2019). Estimating mortality burden attributable to short-term PM2. 5 exposure: A national observational study in China. Environment international, 125, 245-251.

Blood pressure and pulmonary health effects of ozone and black carbon exposure in young adult runners

Physical activity has been shown to promote health and well-being, however, exercising in environments with high level of air pollution might increase the risk of cardio-respiratory impairments. In this crossover study, we constructed linear mixed models to investigate the impact of short-term exposure to black carbon (BC) and ozone on blood pressure and pulmonary functions among 30 healthy adult runners after 30-minute run on a clean and polluted route on separate days in August 2015 in Hong Kong. Runners were on average 20.6 years old, with mean body mass index of 20.3 kg/m2. Air pollution concentrations were higher in the polluted route than in the clean route, with the highest difference in BC (5.4 μg/m3 versus 1.3 μg/m3). In single-pollutant models, no significant association was found between air pollution and changes in blood pressures, forced vital capacity, forced expiratory volume in 1 s, peak expiratory flow and fractional exhaled nitric oxide, after adjusting for gender, type of route, temperature and relative humidity. When further adjusting for both BC and ozone simultaneously, increment in BC became statistically significantly associated with increase in systolic blood pressure (relative risk = 3.18; 95% CI: 0.24, 6.13) after running exercise. Stratified analysis further shows that the significant adverse association between systolic blood pressure and BC was only observed in the polluted route (e.g., relative risk = 4.51, 95% CI: 0.75, 8.27 in two-pollutant). Our finding of BC is consistent with existing literature, while further studies with greater sample size and longer exposure time are needed to investigate the effects of ozone to cardio-respiratory functions in runners. Given that exercise has clear health benefits, one should consider ways to minimize the air pollution exposure.

Pun, V. C., & Ho, K. F. (2019). Blood pressure and pulmonary health effects of ozone and black carbon exposure in young adult runners. Science of The Total Environment, 657, 1-6.

Projected air quality and health benefits from future policy interventions in India

Air pollutants have been an urgent environmental problem in India due to adverse impacts on human health and social-economical lost. Different control strategies have been discussed to reduce air pollution, but possible outputs have not been identified. In this study, the Community Multi-scale Air Quality (CMAQ) model was applied to simulate potential benefits from future emission control with unchanged meteorology. Fourteen scenarios towards energy, residential, agriculture, industry, and open burning were simulated and the changes in ozone (O3) and PM2.5 as well as health outcomes were evaluated. PM2.5 concentrations decreased significantly by reducing uses of solid fuels (S4), uses of diesel generating sets (S13) and applying new standards to industry facilities (S11) with maximum reductions of ~50 μg/m3, ~30 μg/m3 and ~15 μg/m3 in north India, separately. Reducing uses of solid fuels caused significant O3 reduction by maximum >8 ppb (S4, December), significant effects also occurred when applying new standards to current power plants (S1) (~4 ppb, October.) and in S13 (~3 ppb, December). Combination of all possible strategies would reduce O3, primary PM components (PPM) and total PM2.5 in December by >20 ppb, >40 μg/m3 and >60 μg/m3 in north India, while O3 and secondary inorganic aerosol (SIA) would increase by 5 ppb and 2 μg/m3 in October in western and southern India. SIA also increased in part of northern regions in December by ~2 μg/m3. A total of up to 0.68 million premature mortality and 43% years of life lost (YLL) would be avoided by applying all controlling strategies.

Chen, K., Guo, H., Hu, J., Kota, S., Deng, W., Ying, Q., ... & Zhang, H. (2019). Projected air quality and health benefits from future policy interventions in India. Resources, Conservation and Recycling, 142, 232-244.

The health and social implications of household air pollution and respiratory diseases

Approximately three billion individuals are exposed to household air pollution (HAP) from the burning of biomass fuels worldwide. Household air pollution is responsible for 2.9 million annual deaths and causes significant health, economic and social consequences, particularly in low- and middle-income countries. Although there is biological plausibility to draw an association between HAP exposure and respiratory diseases, existing evidence is either lacking or conflicting. We abstracted systematic reviews and meta-analyses for summaries available for common respiratory diseases in any age group and performed a literature search to complement these reviews with newly published studies. Based on the literature summarized in this review, HAP exposure has been associated with acute respiratory infections, tuberculosis, asthma, chronic obstructive

pulmonary disease, pneumoconiosis, head and neck cancers, and lung cancer. No study, however, has established a causal link between HAP exposure and respiratory disease. Furthermore, few studies have controlled for tobacco smoke exposure and outdoor air pollution. More studies with consistent diagnostic criteria and exposure monitoring are needed to accurately document the association between household air pollution exposure and respiratory disease. Better environmental exposure monitoring is critical to better separate the contributions of household air pollution from that of other exposures, including ambient air pollution and tobacco smoking. Clinicians should be aware that patients with current or past HAP exposure are at increased risk for respiratory diseases or malignancies and may want to consider earlier screening in this population.

Simkovich, S. M., Goodman, D., Roa, C., Crocker, M. E., Gianella, G. E., Kirenga, B. J., ... & Checkley, W. (2019). The health and social implications of household air pollution and respiratory diseases. NPJ primary care respiratory medicine, 29(1), 12.

PM2.5 and Air Pollution

Description: This section includes articles addressing PM2.5 and air pollution source apportionment, impacts and emissions trends.

Impacts of holiday characteristics and number of vacation days on "holiday effect" in Taipei: Implications on ozone control strategies

This study investigated the influence of holiday characteristics and numbers of vacation days on the "holiday effect" of three crucial Chinese holidays in Taipei. Surface measurements of NOx, CO, NMHC, O3, SO2, and PM10 from 13 air quality-monitoring stations of the Taiwan Environmental Protection Administration (TEPA) in the Taipei metropolitan area during holiday and non-holiday periods of 1994–2012 were used.

All six pollutants were proven to exhibit holiday effects between Chinese New Year (CNY) and non-Chinese New Year (NCNY) periods. However, almost all pollutants exhibited holiday effects for the two other holidays; the exceptions were O3 between Tomb Sweeping Day (TSD) and non-Tomb Sweeping Day (NTSD) periods and CO and PM10 between Mid-Autumn Day (MAD) and non-Mid-Autumn Day (NMAD) periods. Air pollutants, including NOx, CO, NMHC, SO2, and PM10, that exhibited holiday effects had consistently lower concentrations in holiday periods than in non-holiday periods, whereas O3 concentrations were higher in holiday periods than in non-holiday periods. A widespread holiday effect with consistent signs indicates a high degree of urbanization in the study area. Compared with CNY–NCNY and MAD–NMAD periods, the TSD–NTSD period had a considerably lower difference of the titration effect, lower NOx resulting in less ozone destruction, in evening traffic hours and an inconsistent holiday effect in the daytime and nighttime, leading to the lack of O3 holiday effect. Because the MAD period had more nighttime activities than the other two holiday periods did, the MAD–NMAD period lacked CO and PM10 holiday effects. The prevalently higher ratios of CO, NMHC, SO2, and PM10 relative to NOx as a proxy of mobile sources and a lower PM2.5/PM10 ratio in the MAD period than in the CNY and TSD periods indicate different pollution sources oriented from holiday activities.

The air pollutants exhibited a weakening trend are all associated with a greater improvement in air quality during the non-holiday periods than the holiday periods, which implies successful air pollution control policies. Holiday effects of NOx, NMHC ($p < 0.05$), and CO ($p < 0.10$) are associated with mobile sources; the holiday effects for the three holidays tend to have a strong relation with the number of vacation days in a holiday, indicating that a large reduction of air pollution occurs when a holiday has a high number of vacation days, which probably encourages extensive behavioral changes. Moreover, the aforementioned conditions imply that air pollution control strategies are effective with time; pollution reduction for only 1–2 days may fail to improve ambient air quality. Holiday effects of pollutants emitted during long holiday periods have crucial implications in formulating ozone control strategies in Taiwan and in other countries with similar national or cultural holidays.

Chen, P. Y., Tan, P. H., Chou, C. C. K., Lin, Y. S., Chen, W. N., & Shiu, C. J. (2019). Impacts of holiday characteristics and number of vacation days on "holiday effect" in Taipei: Implications on ozone control strategies. Atmospheric

environment, 202, 357-369.

Impact of the implementation of Lisbon low emission zone on air quality

Air pollution is an increasing concern due to the negative impacts on human health, environment, and patrimony. The implementation of a Low Emission Zone (LEZ) is an important air quality policy action to reduce air pollutant emissions. This study aims to assess the air quality improvements in Lisbon with the LEZ implementation, analysing its impact on the air pollutant concentrations.

The analysis performed from 2009 to 2016 showed an improvement in air quality. In the Zone 1, the reduction of PM10 and NO2 annual average concentrations were 29% and 12%, respectively, while, in the Zone 2, the reduction of PM10 and NO2 annual average concentrations were 23% and 22%, respectively. The background pollution analysis showed the LEZ effect on the lowest levels of ambient air pollution to which the population is chronically exposed. The achieved reductions of PM10 and NO2 levels were 30.5% and 9.4% in Zone 1, and 22.5% and 12.9% in the Zone 2, respectively. Concluding, this study evidenced an air quality improvement mainly for PM10 and NO2; however, insignificant reductions were observed for NOx and PM2.5. Therefore, stricter restriction standards should be defined, combining with other air quality policy decisions to reduce the population exposure to air pollutants.

Santos, F. M., Gómez-Losada, Á., & Pires, J. C. (2019). Impact of the implementation of Lisbon low emission zone on air quality. Journal of hazardous materials, 365, 632-641.

Mitigation pathways of air pollution from residential emissions in the Beijing-Tianjin-Hebei region in China

Air pollution is one of the most harmful consequences of China's rapid economic development and urbanization. Particularly in the Beijing-Tianjin-Hebei (BTH) regions, particulate matter concentrations have consistently exceeded the national air quality standards. Over the last years, China implemented ambitious measures to reduce emissions from the power, industry and transportation sectors, with notable success during the 11th and 12th Five Year Plan (FYP) periods. However, such strategies appear to be insufficient to reduce the ambient PM2.5 concentration below the National Air Quality Standard of 35 μg m−3 across the BTH region within the next 15 years. We find that a comprehensive mitigation strategy for the residential sector in the BTH region would deliver substantial air quality benefits. Beyond the already planned expansion of district heating and natural gas distribution in urban centers and the foreseen curtailment of coal use for households, such a strategy would redirect some natural gas from power generation units towards the residential sector. Rural households would replace biomass for cooking by liquid petroleum gas (LPG) and electricity, and substitute coal for heating by briquettes. Jointly, these measures could reduce the primary PM2.5 and SO2 emissions by 28% and 11%, respectively, and the population-weighted PM2.5 concentrations by 13%, i.e., from 68 μg m−3 to 59 μg m−3. We estimate that such a strategy would reduce premature deaths attributable to ambient and indoor air pollution by almost one third.

Liu, J., Kiesewetter, G., Klimont, Z., Cofala, J., Heyes, C., Schöpp, W., ... & Guo, F. (2019). Mitigation pathways of air pollution from residential emissions in the Beijing-Tianjin-Hebei region in China. Environment international, 125, 236-244.

Source apportionment and health risk assessment of organic constituents in fine ambient aerosols (PM2.5): A complete year study over National Capital Region of India

Fine ambient aerosols (PM2.5) levels in the atmosphere are continuously worsening over Delhi and National Capital Region (NCR) of India. Complete source profiles are required to be assessed for implementation of proper mitigation measures over the NCR. In this study, emission sources of PM2.5 are reported for the NCR of India for samples collected during December 2016 to December 2017 at three sampling sites in Delhi, Uttar Pradesh and Haryana. Organic constituents (n-alkanes, isoprenoid hydrocarbons, polycyclic aromatic hydrocarbons, phthalates, levoglucosan and n-alkanoic acids) in PM2.5 were measured to apportion the sources over the study area. Source apportionment of PM2.5 was performed using organic constituents by Positive Matrix Factorization

(PMF) and Principal Component Analysis (PCA). Health risk associated with organic pollutants [PAHs and carcinogen BEHP bis(2-ethylhexyl) phthalate] demonstrated the threat of PM2.5 exposure via inhalation. Transport pathways of air masses were evaluated using 3-day backward trajectories and observed that some air masses originated from local sources along with long-range transport which influenced the PAHs concentration during most of the study period over the NCR. PMF and PCA resulted in the five major emission sources [vehicular emissions (32.2%), biomass burning (30%), cooking emissions (16.8%), plastic burning (13.4%), mixed sources (7.6%) including biogenic and industrial emissions] for PM2.5 over the sampling sites. The present study reveals that transport sector is a major source to be targeted to reduce the vehicular emissions and consequent health risks associated with organic pollutants especially PAHs.

Gadi, R., Sharma, S. K., & Mandal, T. K. (2019). Source apportionment and health risk assessment of organic constituents in fine ambient aerosols (PM2. 5): A complete year study over National Capital Region of India. Chemosphere, 221, 583-596.

Air pollution reduction in China: Recent success but great challenge for the future

China's rapid economic growth has caused severe air pollution, raising serious concerns about the growing evidence of its negative health, environmental, and economic impacts. Consequently, the Chinese government has implemented a number of policies and measures to reduce air pollution. Relying on published information over the last three decades in China, we analyzed trends in air pollutant emissions (SO2 and NOx) and concentrations of particulate matter (PM) and ozone (O3). During the past decade, SO2 and NOx emissions had declined throughout China and concentrations of PM2.5 and PM10 had considerably decreased in most cities, but average reported 90th MDA8 O3, M7, and AOT40 O3 for 31 capital cities showed an increasing trend between 2013 and 2017. Despite progress in air pollution reduction and an increasing number of “clear sky” days, PM concentrations throughout China remain higher than the World Health Organization guidelines, and urban smog and haze remain a major threat to human health and the environment. Thus far, significant emission reductions have occurred largely through robust administrative power, especially when emission reductions were tied to the performance evaluations and promotion of government officials. Similar to most already-industrialized nations, China is now shifting away from SO2-dominated to NOx- and O3-dominated air pollution. Existing technologies and improved operations of existing control equipment appear unlikely to achieve sufficient reductions in NOx and O3 pollution. Considering the complex relationship between O3, NOx, VOCs, weather, and socio-economic changes in China, it is necessary to increase research on impacts of increasing ozone on plants and to adopt novel technologies and implemented to further reduce air pollution to levels that will protect human health and the environment.

Zeng, Y., Cao, Y., Qiao, X., Seyler, B. C., & Tang, Y. (2019). Air pollution reduction in China: Recent success but great challenge for the future. Science of The Total Environment, 663, 329-337.

SLCPs & Vulnerable Regions

Description: This section includes articles addressing SLCP impacts on vulnerable regions or studies discussing the specific vulnerabilities of regions to SLCPs.

Radiative Forcing by Dust and Black Carbon on the Juneau Icefield, Alaska

Here we present the first known data set on black carbon (BC) and mineral dust concentrations in snow from the Juneau Icefield (JIF) in southeastern Alaska, where glacier melt rates are among the highest on Earth. In May 2016, concentrations of BC (0.4–3.1 μg/L) and dust (0.2–34 mg/L) were relatively low and decreased toward the interior of the JIF. The associated radiative forcing (RF) averaged 4 W/m2. In July, after 10 weeks of exposure, the aged snow surface had substantially higher concentrations of BC (2.1–14.8 μg/L) and dust (11–72 mg/L) that were not spatially distributed by elevation or distance from the coast. RF by dust and BC ranged from 70 to 130 W/m2 (87 W/m2 average) across the JIF in July, and RF was dominated by dust. The associated median snow water equivalent reduction in the July samples is estimated at 10–18 mm/day, potentially advancing melt on the scale of days to weeks. Aging of the snow surface in summer likely resulted in a positive feedback of melt consolidation, enhanced solar absorption and melting, and further concentration of surface particles. Regional

projections of warming temperatures and increased rain at the expense of snow make it likely that summer season darkening will become a more important contributor to the high melt rates on the JIF. Further studies are needed to elucidate the spatiotemporal occurrence of various light-absorbing particles on the JIF, and models of ice field wastage should incorporate their associated RF.

Nagorski, S. A., Kaspari, S. D., Hood, E., Fellman, J. B., & Skiles, S. M. (2019). Radiative Forcing by Dust and Black Carbon on the Juneau Icefield, Alaska. Journal of Geophysical Research: Atmospheres, 124(7), 3943-3959.

Black carbon and other light-absorbing impurities in snow in the Chilean Andes

Vertical profiles of black carbon (BC) and other light-absorbing impurities were measured in seasonal snow and permanent snowfields in the Chilean Andes during Austral winters 2015 and 2016, at 22 sites between latitudes 18°S and 41°S. The samples were analyzed for spectrally-resolved visible light absorption. For surface snow, the average mass mixing ratio of BC was 15 ng/g in northern Chile (18–33°S), 28 ng/g near Santiago (a major city near latitude 33°S, where urban pollution plays a significant role), and 13 ng/g in southern Chile (33–41°S). The regional average vertically-integrated loading of BC was 207 µg/m2 in the north, 780 µg/m2 near Santiago, and 2500 µg/m2 in the south, where the snow season was longer and the snow was deeper. For samples collected at locations where there had been no new snowfall for a week or more, the BC concentration in surface snow was high (~10–100 ng/g) and the sub-surface snow was comparatively clean, indicating the dominance of dry deposition of BC. Mean albedo reductions due to light-absorbing impurities were 0.0150, 0.0160, and 0.0077 for snow grain radii of 100 µm for northern Chile, the region near Santiago, and southern Chile; respective mean radiative forcings for the winter months were 2.8, 1.4, and 0.6 W/m2. In northern Chile, our measurements indicate that light-absorption by impurities in snow was dominated by dust rather than BC.

Rowe, P. M., Cordero, R. R., Warren, S. G., Stewart, E., Doherty, S. J., Pankow, A., ... & MacDonell, S. (2019). Black carbon and other light-absorbing impurities in snow in the Chilean Andes. Scientific reports, 9(1), 4008.