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Further Improvement of Air Quality in China Needs Clear Ammonia Mitigation Target

Zhaohai Bai,[†] Wilfried Winiwarter,[‡,§] Zbigniew Klimont,[‡] Gerard Velthof,[∥] Tom Misselbrook,[⊥] Zhanqing Zhao,[#] Xinpeng Jin,[†] Oene Oenema,[∥] Chunsheng Hu,[*,†] and Lin Ma[*,†]

[†]Key Laboratory of Agricultural Water Resources, Hebei Key Laboratory of Soil Ecology, Center for Agricultural Resources Research, Institute of Genetic and Developmental Biology, The Chinese Academy of Sciences, 286 Huaizhong Road, Shijiazhuang 050021, Hebei, China

[‡]International Institute for Applied Systems Analysis (IIASA), Laxenburg A-2361, Austria

[§]The Institute of Environmental Engineering, University of Zielona Góra, Zielona Góra 65-417, Poland

[∥]Wageningen Environmental Research, Wageningen University and Research, P.O. Box 47, 6700 AA, Wageningen, The Netherlands

[⊥]Sustainable Agricultural Sciences, Rothamsted Research, North Wyke, Okehampton EX20 2SB, U.K.

[#]School of Land Resources and Urban&Rural Planning, Hebei GEO University, Shijiazhuang 050031, China

Heavy air pollution has impacted strongly on the quality of life in China. The poor air quality has serious impacts on human health and reduces life expectancy. Focusing on the population group of 65 years and older, Li et al. (2018) estimated 1.77 million premature deaths in 2010 related to fine particle ($PM_{2.5}$) exposure.[1] There are significant regional differences in $PM_{2.5}$ concentrations, with the highest values in the Beijing-Tianjin-Hebei (BTH) and Yangtze-River-Delta (YRD).

While the causes of these high pollution episodes in China are not yet fully understood, many contributing factors have become clear. Highest $PM_{2.5}$ concentrations appear under stagnant weather conditions, with secondary inorganic aerosols playing a key role. The formation of $PM_{2.5}$ is limited by NH_3, as other important contributors such as SO_2 and NOx are available in excess. A modeling study concluded that ∼30% of the $PM_{2.5}$ mass during a severe haze event in 2015 was attributable to agricultural NH_3.[2]

China's government has implemented several strict policies to control air pollution, including the Blue Sky Protection Campaign in 2018. This policy has set targets for SO_2, NOx, and $PM_{2.5}$ emissions for 2020, requiring respective reductions of 15, 15, and 18%, compared with 2015, in the most heavily polluted regions (city clusters in BTH and YRD). This policy has triggered large changes, including improvements in energy efficiency and the relocation or closure of selected heavy industries. However, no emission reduction target was set for NH_3. With a large number of individual sources of relatively low magnitude, measures to reduce NH_3 emissions are particularly challenging, and easy fixes are rare. Even when focusing on industrial agriculture, system-scale approaches are needed that fully consider the internal flows of nitrogen compounds within the farm system to improve overall efficiency. With a strong trend in China toward large industrial-scale agricultural units, such a focus becomes realistic and emission abatement feasible.

To combat similar problems, the European Union established the National Emission Ceilings Directive as a legislative framework to limit national total emissions of five compounds - SO_2, NOx, volatile organic compounds (VOCs), NH_3, and $PM_{2.5}$ (http://ec.europa.eu/environment/air/reduction/index.htm). Based on country specific analyses of pollution impacts and of air pollution control costs while considering paths of future economic growth, country-specific reduction targets for 2020 and 2030 have been agreed upon. The program success depends critically on harmonized reporting and institutions that monitor air quality, validate emission reporting, and provide feedback on progress. The EU member countries benefit from a parallel initiative under the UNECE Convention on Long Range Transboundary Air Pollution (LRTAP). Reis et al. (2012) summarized the benefits of the multipollutant-multieffect agenda of the LRTAP.[3] Introduction of stringent end-of-pipe measures allowed for reduction of some of the pollutants by over 50%, while reduction of NH_3 resulted from massive changes of the

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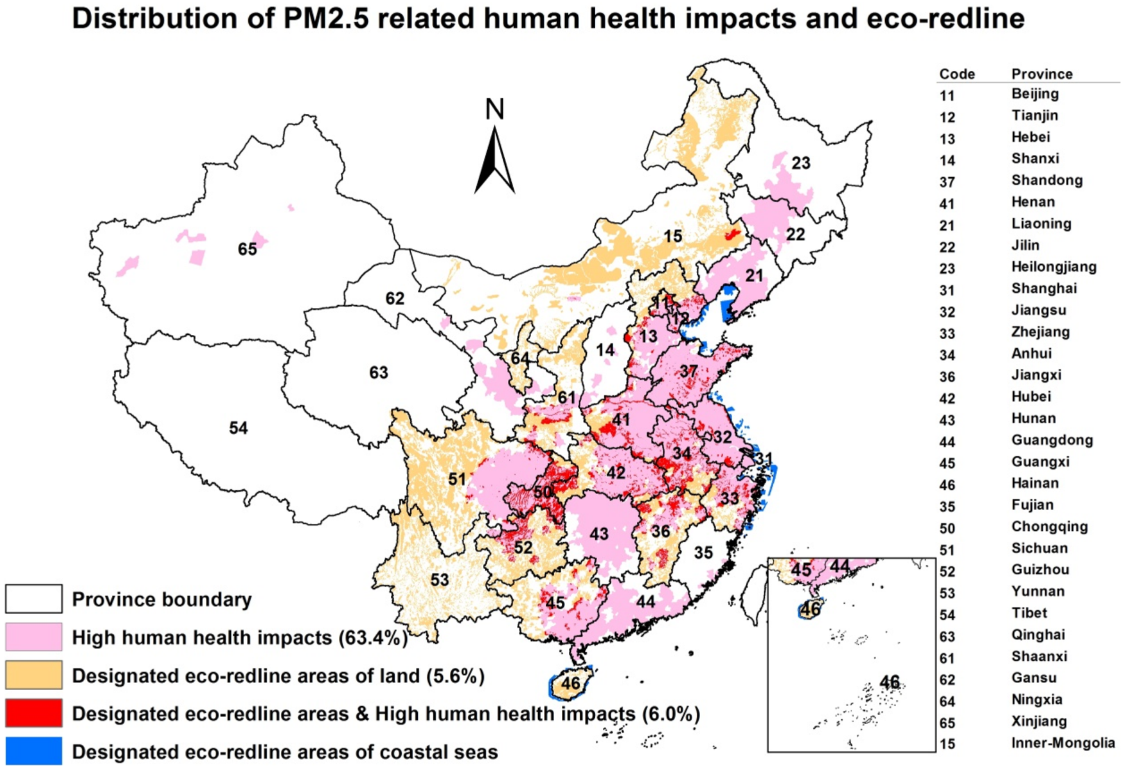

Figure 1. Air pollution related risks for human health and ecosystems in China. Health impacts refer to areas where Li et al. (2018) estimated more than 1000 premature deaths per 100 km^2 as a consequence of $PM_{2.5}$. Numbers in brackets represent the proportion of the total human population.

economic structures of some countries only, with more ambitious targets remaining for the current program.

In China, ambient $PM_{2.5}$ and SO_2 concentrations declined by 42% and 68% in 74 cities between 2013 and 2018 (https://go.nature.com/2xaWNEI). However, the current policy of pushing for primary $PM_{2.5}$, SO_2, and NOx has its limitations and possibly soon becomes very cost-ineffective as marginal costs of further control for some of the pollutants are very high. We argue that multipollutant mitigation targets are needed for China, most urgently to deliver NH_3 emission reductions. Here we develop the scope and the pathway toward establishing such mitigation targets.

Human health impacts due to atmospheric $PM_{2.5}$ must lie at the core of such mitigation targets. Prioritizing NH_3 reductions in such a strategy allows several ecosystem goals to be addressed simultaneously. The sensitivity of ecosystems to nitrogen loads is well-known, and the threats of acidification, eutrophication, and consequential loss of biodiversity played a key role in the development of European policy. Ecologically sensitive regions of natural forest, grassland, and wetlands, including the coastal seas, should be protected in addition to those where the protection of human health is most urgent, including the BTH, YRD, the Pearl-River-Delta, the Chengdu-Plain, and Hunan province (see Figure 1). Further studies are needed to evaluate the sensitivities of these regions to N deposition and soil acidification. This could be linked to the Ecological Red-Line designation.[4]

Avoiding pollution swapping between regions must be considered, recognizing potential conflicts in simultaneously trying to achieve goals of protecting soil, water, and the atmosphere. There may be interactions between measures specifically addressing losses to air or water. Thus, strategies designed to achieve the regional NH_3 emission ceilings need also to consider the risk of water pollution, particularly with reference to any proposed Nitrate–Vulnerable-Zones in China.[5]

Setting ammonia mitigation targets requires a clear understanding of the relationship between emissions and impacts, with the aim of reducing impacts at minimal cost. The level of socially acceptable impact, or of the economically acceptable cost, then determines the target chosen. This can be done using cost-effectiveness and cost-benefit analysis, although recognizing that health-related costs (beyond the costs of health treatment as such) are extremely difficult to quantify. Alternatively, guidance can be taken from costs that have already been considered as acceptable. Costs of the current air pollution control policies in China are estimated to be in the order of billions of Chinese Yuan; attributing an adequate share of these costs to the reduction of agricultural ammonia emissions would enable the realization of the improvements.[2]

The above provides an agenda of research priorities and highlights the need to develop proper institutions. Based on a harmonized ammonia emission inventory, measures specific to Chinese conditions can be identified, their effects quantified, and their implementation costs and limitations assessed. The clear relationship between emissions, atmospheric processes (PM concentration, nitrogen deposition), and impacts on human health and terrestrial and aquatic biodiversity needs to be established across the range of regionally differing conditions. Further research can address the effects of other atmospheric constituents on NH_3 and $PM_{2.5}$ concentrations. We believe the opportunities to develop such a multieffect strategy exist, not least because of the political recognition of the seriousness of air pollution in China, as also reflected in the formulation of the Green-Agricultural-Development program. The European experience, although far from complete,

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demonstrates the potential of this approach and the scientific tools and technologies that are available for emission abatement.

The Ecological Redline Design report delineates sensitive ecosystems but is not available yet for all provinces (Tibet, Xinjiang, Qinghai, Gansu, Shaanxi, Hunan, Liaoning, Jilin, Heilongjiang, Guangdong, and Fujian are missing.).

■ AUTHOR INFORMATION

Corresponding Authors

*E-mail: cshu@sjziam.ac.cn (C.H.).

*E-mail: malin1979@sjziam.ac.cn (L.M.).

ORCID

Lin Ma: 0000-0003-1761-0158

Notes

The authors declare no competing financial interest.

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