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Editorial

Atmospheric Pollution of Agriculture-Dominated Cities

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1. Introduction

With rapid development of modern agriculture, a multitude and a large amount of air pollutants were generated by agricultural activities, which are becoming more and more serious issues with regards to air pollution [1,2]. Atmospheric aerosols and gaseous pollutants emitted by agricultural activities can reach densely populated cities, and harm the health of human and animals [3–6], and the greenhouse gases can affect reginal climate change [7,8]. The atmospheric emissions of urban and rural areas may be inhomogeneous because of the emission sources, meteorological conditions, topography, and inefficient allocation of regulatory resources [9,10]. With the increase of demand in food by growing world population, it is necessary to carry out more studies on agricultural pollution and develop better mitigation measures.

This Special Issue, comprising nine original papers and one review, reports recent findings in the atmospheric pollution of agricultural-dominated regions. Most of these papers focused on the characterization and mitigation of air pollutants in the rural areas, and few of them considered the air pollutants from urban area. Various air pollutants were pointed out in this Special Issue, including particulate matter (PM) [11–15], ammonia (NH_3) [15,16], hydrogen sulfide (H_2S) [15], odor [15,17], greenhouse gases [GHG: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O)] [11,15,18,19], NOx [13,14], carbon monoxide (CO) [11,14], volatile organic compounds (VOCs) [13,15], sulfur dioxide (SO_2) [13,14], as well as bacteria, fungi and viruses [15,20]. Six of the nine original papers used the experimental data in the field [12,15–17,19,20] or in a laboratory [14], and others used modeling system [12,13] or database and other online sources [11].

The articles in the Special Issue span a variety of subjects, primarily aimed to accomplish the following: (1) to investigate the trends and factors of air emissions from animal farms and facilities; (2) to analyze the spatial-temporal variations of agricultural burning; (3) to evaluate the potential hazards of bio-aerosols to human health; and (4) to develop and assess different strategies on the air emission control for rural areas.

2. Trends and Factors of Air Emissions from Animal Farms and Facilities

The most concerned agricultural activity leading to the atmospheric pollution in rural areas and even cities was the animal feeding operations in this Special Issue. Due to the intensification and concentration of animals, an abundant mixture of pollutants, mostly consisting of NH_3, CO_2, CH_4, N_2O, H_2S, VOCs, PM, odors and bio-aerosols, were emitted to the atmosphere simultaneously from animal housing, yards, manure storage, and land spreading [12,13,15–17]. In the original papers of this Special Issue, NH_3 [13,16], PM [12], and odor [17] were the major objectives of those studies. Odor and PM can be easily sensed or perceived by the residents around the farms, who complained and protested against the unpleasant odors and dusty environment. Meanwhile, the NH_3 play a critical role in formulating the secondary inorganic aerosols, arising distinct odor, and causing various

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sick symptoms of animal or human under different thresholds. Complaint and protests, as well as environmental issues, have spurred new legislation and all of these pollutant's emissions are regulated to achieve emission reductions in animal farming [15].

The concentrations of all of pollutants differed with location and season, and differed for individual animal species and housing system [15–17]. It is impossible to generalize the concentration or emission factor, since they are influenced by many factors, such as building construction, ventilation system, feed type and management, manure management, weather conditions and so on [12,15,17]. Based on the study of Oh et al. [16], the ammonia concentration at site of a pig farm presented a peak in June, which was significantly higher than that in the urban and remote areas. However, the rural area influenced the ammonia levels in the adjacent urban area. Rzeznik and Mielcarek-Bochenska [17] found that fattening pig house showed the highest odor burden compared with that in hen house and dairy cow barn. The emission factor of odor for poultry was higher than that for dairy cows, while the mean concentration of odor in hen house was lower than that in the dairy cow barn. In the study of Zhang et al. [12], the data showed that concentration of ultrafine and fine particles for a layer house were positively and negatively correlated with temperature and relative humidity as well as wind speed, respectively. The concentration of PM in the atmosphere at nighttime was lower than daytime. The particle size was proportional to the diffusion distance and diffusion height.

3. Spatial-Temporal Variations of Biomass Burning

Biomass burning, including agricultural residual burning, and residential biofuel burning, are significant sources of atmospheric aerosol particles and gas-phase pollutants impacting regional and even global air quality, the chemical composition of PM, earth's radiation budget, climate change, and human health [11,21]. The open burning of agricultural residues is one of the main forms of biomass burning and most concerned cause of air pollutant emissions, which comprise CO2, CH4, CO, NOX, SO2, and PM, and have a complex chemical composition dominated by primary organic matter (POM), elemental carbon (EC), and inorganic material [11,22]. The plumes of biomass burning may impact on the air quality for sites located several thousand kilometers away from the burning sources [21].

In this Special Issue, Zhao et al. [11] analyzed the spatial-temporal variations of biomass burning in he Beijing-Tianjin-Hebei region of China using the fire counts and carbon emissions data of the Global Fire Emissions Database. They found that the number of fire counts fluctuated from 2003 to 2020 with a generally rising trend and peak in 2013. Most fire counts were concentrated in March, June–July, and October, leading to high carbon emission. Agriculture accounted for 58.1% vegetation types of fires, which was the highest followed by grassland, forest, and peat. Taking the year of 2020 as an example, they found that the North China Plain, with flat terrain where the study region located, could be easily investigated for fire count aggregation. Fire events can cause high transient air pollutant concentrations [23]. The field burning of agricultural residues normally occurs after a harvest season, which can be identified and attended to quickly by the government to reduce air pollution [4].

4. Potential Hazards of Bioaerosols to Human Health

Recently, much attention has been drawn to the exposure to bioaerosols, which exist extensively in human living and natural environments, due to adverse effects on human health [24]. Bioaerosols, predominantly including bacteria, fungi, archaea, viruses, pollen, and endotoxins, play an important role in atmospheric chemistry and climate change as a component of atmospheric PM [20,25]. Sources of bioaerosols are the microbial decomposition of organic material in all naturally occurring processes and/or the atmospheric dispersion of bioaerosols [25]. Exposure to these agents, particularly pathogenic bacteria, may cause a series of diseases, such as respiratory, digestive system, and cardiovascular diseases [20,24].

In this Special Issue, Yan, et al. [20] studied the concentrations and size distribution characteristics of culturable airborne total bacteria and four antibiotic-resistant bacteria in Xinxiang, central China. Their results showed that the concentrations of all studied agents in winter and night were higher than that during other seasons and diurnal periods. Under moderate pollution or heavy pollution, the maximum concentrations of these agents were detected from the air. They were mainly distributed in stage of 1.1–2.2 μm. *Bacillus*, *Staphylococcus* and *Macrococcus* were the dominant genus of ampicillin-resistant bacteria (75.97%), tetracycline-resistant bacteria (46.05%) and erythromycin-resistant bacteria (47.67%), respectively. The opportunistic pathogens of *Micrococcus*, *Sphingomonas*, *Entero*coccus, *Rhodococcus*, and *Stenotrophomonas* were also identified. They concluded that inhalation was the major exposure pathway for the intake of bioaerosols, and the health threats from bioaerosols in the atmosphere should be paid more attention especially when the Air Quality Index (AQI) is higher than 100.

The Special Issue did not cover studies on bioaerosol generated from any specific occupational activities. Previous studies had found specific occupational facilities have specific compositions of bioaerosols, and the concentration levels varied from source to source with many times higher than natural background levels [26]. A multitude of processes associated with human activities lead to elevated bioaerosol emissions [25]. In rural areas, crop and livestock production, waste disposal, and food production are the potential activity-related bioaerosol sources, which are a potential health risk to workers and individual in neighbor communities [25,27]. These bioaerosols may also transport to urban area though the risk of exposure decreased with the increasing distance for the source. Many challenges remain in evaluating the health effects of aerosolized pathogens and allergens in outdoor environments [27].

5. Strategies on the Air Emission Control for Rural Areas

With the rapid development of modern agriculture, the impact of pollutants emitted by agricultural activities on the atmosphere is gradually non-negligible, and more and more relevant studies have been conducted to reduce the threat of agricultural air pollution [1]. In this Special Issue, six of these papers developed, summarized, or recommended different mitigation strategies for several agricultural activities.

(1) Poultry and livestock production

Using a 3D modeling system, Choi and Sunwoo [13] estimated the effects of emission control polices of agro-livestock and industrial emission of $PM_{2.5}$ in an agriculturally active region in Korea. Their study verified that the management of agricultural NH_3 emissions could be a more efficient way for reducing $PM_{2.5}$ concentrations rather than the current policy, mostly focused on industrial emissions for certain regions. Therefore, in agriculture-dominated cities, a policy targeting ammonia management could be a safer choice to significantly improve air pollution mitigation effects unless the target area has a limited amount of HNO_3.

Targeting at the mechanical ventilated housing of livestock and poultry feeding operations, Guo et al. [15] summarized various strategies applied for reducing outlet air pollutants and purifying inlet air to reduce the negative effects of indoor air pollutants on the ambient atmosphere and outdoor bio-airborne on the indoor air, respectively. They concluded that supply filtration systems can greatly reduce the amount of airborne PM (the carrier of pathogens) and microorganism transmission, which should reduce the potential risk of animal infections in a given house. Meanwhile, since each filter targets a different specific contaminant, the single-stage filter for mitigating emissions at the outlet is limited. By contrast, combination filters can remove multiple pollutants effectively. Zhang et al. [12] suggested that the height of ventilation fans of layer house can be appropriately increased in Northeast China to reduce the concentration of PM diffusing towards ground, since the PM can be diluted as it descends (effectively improving the air quality around the livestock and poultry house).

The control approaches primarily aimed at the dust emissions are also applicable to mitigating bioaerosol releases. The minimum setback distances for the sitting of composting facilities and landfills were recommended generally based on odor and dust emissions without expressly considering potential emissions of bioaerosols and their metabolic products [25].

(2) Residual treatment and biomass burning

Gao et al. [18] indicated that returning residue to soils may reduce the air pollution caused by residue burning and affect greenhouse gas emission by increasing soil carbon sequestration potential. They studied the effects of different maize residue treatment (no residue addition, on the soil surface, and into the soil layer of 0–10 cm) on the nitrogen turnover process, and proved that incorporating the residue into soil was the best measure to promote N transformation and supply as well as enhance residue-derived N release and uptake in maize. The residues may be also removed from the field to be used for other purposes, such as mushroom plantation, animal feed, fermentation, as diesel and biochar, and for sales to baling operators to avoid open burning [4,22].

In the case of air pollution events caused by agricultural residues field burning, governments should intervene quickly to reduce air pollution though a National Air Pollution Prevention and Control Law and other government documents. Under unfavorable meteorological conditions, the ban on agricultural field burning upwind of cities should be rigorously enforced [4].

(3) Residential combustion

Compared with industrial sources, rural residential combustion is more harmful to air quality and human health under the same emission values of air pollutants. Zhu, et al. [28] indicated that the statistics data of coal and solid biomass consumption for rural households were significantly underestimated, which has a negative impact on the air pollution control. Jiao et al. [14] pointed out that more than 1500 million tons of bituminous raw coal chunk are used annually for rural heating in China, accounting for 60% of residential energy consumption. The incomplete combustion of coal in inefficient stoves resulted in significant air pollution and human health problems. Therefore, they designed a new type of bituminous coal pellet fuel using an automatic prototype pellet stove. Compared with raw coal chunk, turning bituminous coal into pellets and burning them in automatic stoves could significantly reduce $PM_{2.5}$ and CO emission by 83–90% and 61–76%, respectively, effectively improving rural air quality.

(4) Tillage practice

Huang et al. [19] studied the fate of fertilizer nitrogen (N) in the soil-plant-atmosphere to better understand the mechanism of N distribution, absorption, utilization, and loss in fertilizer under different tillage practices. The results showed that the average and cumulative N_2O emission and soil fertilizer ^{15}N-N_2O emission under no tillage (NT) practice was significantly lower than that moldboard-plow (MP) tillage. About 15% and 23% of N_2O emissions came from fertilizer N under NT and MP, respectively. On average, 0.1–0.16% of fertilizer N was lost in the form of N_2O. Therefore, NT was a better tillage practice compared with MP, for mitigating air emissions caused by fertilizer utilization.

6. Further Research Needs

This Special Issue provides information regarding recent advances in our understanding of the atmospheric pollution of agricultural regions or cities, which provides a significant contribution to further research in various research areas. Although the studies presented in this Special Issue are a snapshot of the characterization and mitigation of air pollutants from agricultural activities, they open additional scientific questions and challenges for reducing the emission impact on rural area or adjacent cities. Here, we formulate the following main directions for further research.

(1) The air pollutants emissions from agricultural activities are very complex. More detailed studies on their chemical and physical characteristics as well as their interactions with other gaseous or in different environment are needed for predicting, prevention, and abatement technology selections.
(2) It will be useful to develop specifical methodology and comprehensive observations in primary practices to improve the accuracy of assessments of environmental hazards and human/animal health risks.
(3) It is suggested that future researchers should develop abatement technologies suitable for heating and cooking in rural areas to improve the existing energy systems and promote the development of effective air pollution strategies [28].
(4) The characterization and variations of air pollutants from different agricultural activities in different areas provides the ground work for predicting and control policy making of air emissions. Therefore, more effective measures to monitor and control in high polluted area need to be investigated. In addition, a variety of agricultural activities beyond those mentioned in this Special Issue may release air pollutant to atmosphere [29,30]. It is necessary to establish or upgrade precise inventory of those air emissions from each agricultural practice in rural areas or agriculture-dominated cities.
(5) The knowledge and findings available so far are insufficient to allow a final assessment of the efficiency of control measures, and proposals for mitigation measures are still required.

In general, there are many gaps of knowledge in agricultural air emissions, leaving open opportunities for future research and technology development.

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References

1. Ge, P.; Chen, M.; Cui, Y.; Nie, D. The research progress of the influence of agricultural activities on atmospheric environment in recent ten years: A review. *Atmosphere* **2021**, *12*, 635. [CrossRef]
2. Xu, J.; Chen, J.; Zhao, N.; Wang, G.; Yu, G.; Li, H.; Huo, J.; Lin, Y.; Fu, Q.; Guo, H.; et al. Importance of gas-particle partitioning of ammonia in haze formation in the rural agricultural environment. *Atmos. Chem. Phys.* **2020**, *20*, 7259–7269. [CrossRef]
3. Milllner, P.D. Bioaerosols associated with animal production operations. *Bioresource Technol.* **2009**, *100*, 5379–5385. [CrossRef]
4. Lyu, Y.; Jaeger, C.; Han, Z.; Liu, L.; Shi, P.; Wang, W.; Yang, S.; Guo, L.; Zhang, G.; Hu, X.; et al. A sever air pollution event from field burning of agricultural residues in Beijing, China. *Aerosol Air Qual. Res.* **2015**, *15*, 2525–2536. [CrossRef]
5. Michiels, A.; Piepers, S.; Ulens, T.; Van Ransbeeck, N.; Del Pozo Sacristán, R.; Sierens, A.; Haesebrouck, F.; Demeyer, P.; Maes, D. Impact of particulate matter and ammonia on average daily weight gain, mortality and lung lesions in pigs. *Prev. Vet. Med.* **2015**, *121*, 99–107. [CrossRef] [PubMed]
6. Balasubramanian, S.; Domingo, N.G.G.; Hunt, N.D.; Gittlin, M.; Colgan, K.K.; Marshall, J.D.; Robinson, A.L.; Azevedo, I.M.L.; Thakrar, S.K.; Clark, M.A.; et al. The food we eat, the air we breathe: A review of the fine particulate matter-induced air quality health impacts of the global food system. *Environ. Res. Lett.* **2021**, *16*, 103004. [CrossRef]
7. Herrero, M.; Henderson, B.; Havlík, P.; Thornton, P.K.; Conant, R.T.; Smith, P.; Wirsenius, S.; Hristov, A.N.; Gerber, P.; Gill, M.; et al. Greenhouse gas mitigation potentials in the livestock sector. *Nat. Clim. Chang.* **2016**, *6*, 452–461. [CrossRef]
8. Lu, X.; Ye, X.; Zhou, M.; Zhao, Y.; Weng, H.; Kong, H.; Li, K.; Gao, M.; Zheng, B.; Lin, J.; et al. The underappreciated role of agricultural soil nitrogen oxide emissions in ozone pollution regulation in North China. *Nat. Commun.* **2021**, *12*, 5021. [CrossRef]
9. Han, W.; Li, Z.; Guo, J.; Su, T.; Chen, T.; Wei, J.; Crib, M. The urban-rural heterogeneity of air pollution in 35 metropolitan regions across China. *Remote Sens.* **2020**, *12*, 2320. [CrossRef]
10. Long, F.; Liu, J.; Zheng, L. The effects of public environmental concern on urban-rural environmental inequality: Evidence from Chinese industrial enterprise. *Sustain. Cities Soc.* **2022**, *80*, 103787. [CrossRef]
11. Zhao, Y.; Xu, R.; Xu, Z.; Wang, L.; Wang, P. Temporal and spatial patterns of biomass burning fire counts and carbon emissions in the Beijing–Tianjin–Hebei (BTH) region during 2003–2020 based on GFED4. *Atmosphere* **2022**, *13*, 459. [CrossRef]

12. Zhang, S.; Zhou, L.; Jia, L.; Li, J.; Liu, B.; Yuan, Y. Numerical simulation on particulate matter emissions from a layer house during summer in Northeast China. *Atmosphere* **2022**, *13*, 435. [CrossRef]
13. Choi, H.; Sunwoo, Y. Environmental benefits of ammonia reduction in an agriculture-dominated area in South Korea. *Atmosphere* **2022**, *13*, 384. [CrossRef]
14. Jiao, M.; Yan, M.; Liu, Y.; Mawusi, S.K.; Shrestha, P.; Xue, C.; Song, H.; Wang, H.; Liu, Z.; Xu, Y.; et al. Laboratory performance evaluation of novel bituminous coal pellet combustion in an automatic heating stove. *Atmosphere* **2022**, *13*, 159. [CrossRef]
15. Guo, L.; Zhao, B.; Jia, Y.; He, F.; Chen, W. Mitigation strategies of air pollutants for mechanical ventilated livestock and poultry housing—A review. *Atmosphere* **2022**, *13*, 452. [CrossRef]
16. Oh, S.; Kim, S.-G.; Lee, J.B.; Park, J.; Jee, J.-B.; Hong, S.-W.; Kwon, K.-S.; Song, M. Spatial distributions of atmospheric ammonia in a rural area in South Korea and the associated impact on a nearby urban area. *Atmosphere* **2021**, *12*, 1411. [CrossRef]
17. Rzeznik, W.; Mielcarek-Bochenska, P. Odour emissions from livestock buildings. *Atmosphere* **2022**, *13*, 254. [CrossRef]
18. Gao, Y.; Liang, A.; Zhang, Y.; McLaughlin, N.; Zhang, S.; Chen, X.; Zheng, H.; Fan, R. Dynamics of microbial biomass, nitrogen mineralization and crop uptake in response to placement of maize residue returned to Chinese mollisols over the maize growing season. *Atmosphere* **2021**, *12*, 1166. [CrossRef]
19. Huang, D.; Chen, X.; Zhang, S.; Zhang, Y.; Gao, Y.; Zhang, Y.; Liang, A. No-tillage improvement of nitrogen absorption and utilization in a Chinese mollisol using 15N-tracing method. *Atmosphere* **2022**, *13*, 530. [CrossRef]
20. Yan, X.; Ma, J.; Ren, J.; Cui, M.; Chen, X.; Qiu, D.; Lei, M.; Li, T.; Guo, L.; Chen, C.; et al. Concentrations, size distribution, and community structure characteristics of culturable airborne antibiotic-resistant bacteria in Xinxiang, central China. *Atmosphere* **2021**, *12*, 1077. [CrossRef]
21. Rincon-Riveros, J.M.; Rincon-Caro, M.A.; Sullivan, A.P.; Mendez-Espinosa, J.F.; Belalcazar, L.C.; Aguilar, M.Q.; Betancourt, R.M. Long-term brown carbon and smoke tracer observations in Bogota, Colombia: Association with medium-range transport of biomass burning plumes. *Atmos. Chem. Phys.* **2020**, *20*, 7459–7472. [CrossRef]
22. Junpen, A.; Pansuk, J.; Kamnoet, O.; Cheewaphongphan, P.; Garivait, S. Emission of air pollutants from rice residue open burning in Thailand, 2018. *Atmosphere* **2018**, *9*, 449. [CrossRef]
23. Dennis, A.; Fraser, M.; Anderson, S.; Allen, D. Air pollutant emissions associated with forest, grassland, and agricultural burning in Texas. *Atmos. Environ.* **2002**, *36*, 3779–3792. [CrossRef]
24. King, M.D.; Lacey, R.E.; Pak, H.; Fearing, A.; Ramos, G.; Baig, T.; Smith, B.; Koustova, A. Assays and enumeration of bioaerosols-traditional approaches to modern practices. *Aerosol Sci. Tech.* **2020**, *54*, 611–633. [CrossRef]
25. Kummer, V.; Thiel, W.R. Bioaerosols-sources and control measures. *Int. J. Hyg. Environ. Health* **2008**, *211*, 299–307. [CrossRef]
26. Li, X.; Chen, H.; Yao, M. Microbial emission levels and diversities from different land use types. *Environ. Int.* **2020**, *143*, 105988. [CrossRef]
27. Dungan, R.S. Boared-invited review: Fate and transport of bioaerosols associated with livestock operations and manures. *J. Anim. Sci.* **2010**, *88*, 3693–3706. [CrossRef]
28. Zhu, M.; Liu, L.; Yin, S.; Zhang, J.; Wang, K.; Zhang, R. County-level emission inventory for rural residential combustion and emission reduction potential by technology optimization: A case study of Henan, China. *Atmos. Environ.* **2020**, *228*, 117436. [CrossRef]
29. Chen, W.; Tong, D.Q.; Zhang, S.; Zhang, X.; Zhao, H. Local PM_{10} and $PM_{2.5}$ emission inventories from agricultural tillage and harvest in northeastern China. *J. Environ. Sci.* **2017**, *57*, 15–23. [CrossRef]
30. Maffia, J.; Dinuccio, E.; Amon, B.; Balsari, P. PM emissions from open field crop management: Emission factors, assessment methods and mitigation measures—A review. *Atmos. Environ.* **2020**, *226*, 117381. [CrossRef]