氏名	陸　夢倩(Mengqian LU)
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主査	筑波大学教授	博士（農学）	張　振亜
副査	筑波大学准教授	工学博士	雷　中方
副査	筑波大学准教授	博士（農学）	清水　和哉
副査	国立研究開発法人産業技術総合研究所 安全科学研究部門　上級主任研究員	博士（工学）	林　彬勒

論　文　の　要　旨
Abstract of thesis

Ammonia has been widely applied in agricultural and industrial sectors, and in recent years it has been also applied in energy sector. Due to its multiple applications and technology maturity, ammonia production expanded during the last century. However, volatilization and poor use efficiency lead to ammonia emission. In addition to being toxic, gaseous ammonia is a precursor of secondary fine particulate matters ($PM_{2.5}$). $PM_{2.5}$ not merely impacts the atmospheric visibility, but also negatively affects public health by inducing respiratory/cardiovascular diseases. To alleviate $PM_{2.5}$-related environmental problems, the government of Japan has enacted an air quality standard in 2009. However, limited achievement has been obtained. Compared with other $PM_{2.5}$ precursors (SO_2 and NO_x), there is still a lack of policies for controlling ammonia emission, especially from the perspective of secondary inorganic $PM_{2.5}$. Therefore, the author pointed out that appropriately understanding the current situation of the ammonia emission and ammonia-related $PM_{2.5}$ would be very important. With a better understanding of the recent situation, effective emission abatement options for controlling ammonia-related $PM_{2.5}$ should be explored. Moreover, suggestions could be provided in order to establish the ammonia-related strategies. Furthermore, since ammonia has extended its application in electric power generation, it is also necessary to assess the future trends and potential impacts of ammonia emission discharged from energy sector.

To achieve the above-mentioned objectives, this research used atmospheric models to conduct the atmospheric simulations. $PM_{2.5}$ resulted from the chemical reactions among the precursors was estimated by a chemical transport model: ADMER-PRO (modified version). ISORROPIA II, which is now embedded in ADMER-PRO, was used to simulate the thermodynamic equilibriums between the secondary inorganic $PM_{2.5}$ (nitrates, sulfates and ammonium). Typical weather patterns in July to August and December to January were selected as the study period, which reflected the meteorological conditions in winter and summer. The author selected Kanto Region as the study domain, for the large population and energy consumption compared with other areas throughout Japan.

The dissertation is divided into 5 chapters. In the chapter 1, the author introduced the background and the current problems related with ammonia emission. The author addressed that until now, there is still a lack of integration policies and experiences of ammonia-related $PM_{2.5}$ abatements. And the expanded applications of ammonia in energy sector would lead to potential environmental impacts. In the chapter 2, the author carried out comparative study on ammonia emission and ammonia-related $PM_{2.5}$ in 2000 and 2010 in Kanto Region. According to the results, annual ammonia emission slightly decreased during 2000~2010 by 13%. Adversely, SO_2 and NO_x enormously decreased 32.5% and 32.9%, respectively. Responding to the declines of the precursor emissions in this decade, the average $PM_{2.5}$ concentration reduced 44.8% in summer and 16.1% in winter. However, the achievements might be benefitted from the reduction of SO_2 and NO_x. In the chapter 3, the author explored the most efficient emissions control emission abatement options. The first scenario was established to investigate the $PM_{2.5}$ reduction efficiency of the individual precursor emissions (SO_2, NO_x and ammonia). It could be obtained that when same emission abatement policy was applied to the secondary $PM_{2.5}$ precursors, SO_2 showed the best efficiency in reducing $PM_{2.5}$ concentrations. Following that, ammonia also showed a certain efficiency of $PM_{2.5}$ reduction. Controlling NO_x emission indicated an unstable performance, especially in winter. The second scenario was established to investigate the $PM_{2.5}$ reduction efficiency of ammonia emission discharged from different emission sources (all sources, agricultural sources, urban sources). Although agriculture has been always regarded as the major emission source, when applied the same emission reduction strategy, cutting down agricultural emissions presented a very low efficiency of $PM_{2.5}$ reduction. Adversely, controlling the ammonia emission from vehicle sources would be very effective for reducing $PM_{2.5}$ concentrations. In the chapter 4, the author pointed out that although the current ammonia emission is mainly contributed by agricultural sources, in future, ammonia would expand its new applications in energy sector. Therefore, the author then investigated the potential $PM_{2.5}$-related health impacts of utilizing ammonia for power generation in future. When using ammonia-hydrogen energy to supply 20% of the energy in Kanto Region, the $PM_{2.5}$ would increase by 11.7% (0.16 $\mu g \cdot m^{-3} \cdot y^{-1}$) in winter and 3.5% (0.08 $\mu g \cdot m^{-3} \cdot y^{-1}$) in summer, resulting in 351 premature deaths per year. In the chapter 5, the author summarized the major results of this study. Future work plans related with cost-benefit analysis of the ammonia abatement options are also represented in this chapter.

審 査 の 要 旨

Abstract of assessment result

In this research, a series of simulation experiments were conducted to develop a better understanding of ammonia emission and ammonia-related secondary $PM_{2.5}$ in Kanto Region, Japan. According to the results, the following issues have been noted and discussed: (1) the emission status of $PM_{2.5}$ precursors (SO_2, NO_x and ammonia) in 2000 and 2010; (2) the changes in ammonia emission and ammonia-related $PM_{2.5}$ according to the existing emission sources; (3) the efficiency of $PM_{2.5}$ reductions corresponding to the three of precursors; (4) the efficiency of $PM_{2.5}$ reductions corresponding to different ammonia sources; and (5) the potential $PM_{2.5}$-related health impacts caused by the possible applications of ammonia in energy sector. The results of this research proved that controlling ammonia emission showed a certain efficiency in lowering secondary $PM_{2.5}$ levels, which would be even more effective than controlling NO_x emission. When compared with the limited potential for further controls of SO_2 and NOx emissions, the policy for ammonia emission is still extensible. Since ammonia has extended its applications as one of the renewable energy sources, further in-depth research on the establishment of safety standards in energy sector is necessary.

The final examination committee conducted a meeting as a final examination on 17 January, 2018. The applicant provided an overview of dissertation, addressed questions and comments raised during Q&A session. All of the committee members reached a final decision that the applicant has passed the final examination.

Therefore, the final examination committee approved that the applicant is qualified to be awarded the degree of Doctor of Philosophy in Environmental Studies.