

A Thesis for the Degree of Ph.D. in Engineering

Development of effective and affordable particulate matter  
sampling devices for toxicity analyses in arid regions

October 2022

Graduate School of Science and Technology  
Keio University

ALIMOV, Zikrilla Bobamuratovich

## 主 論 文 要 旨

No.1

| 報告番号                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 甲 乙 第 号 | 氏 名 | アリモフ, ジクリラ |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|-----|------------|
| 主 論 文 題 名: Development of effective and affordable particulate matter sampling devices for toxicity analyses in arid regions<br>(乾燥地域における粒子状物質の有害性評価のための効果的かつ安価なサンプリングデバイスの開発)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |         |     |            |
| (内容の要旨)<br>本論文は、発展途上地域の大気環境問題の解決に向けて、先進的なエアロゾル技術を効果的かつ安価に最適化し実際の利用に資することを目的とした。<br>第1章では、粒子状物質の定義、物理化学的性質、異なる気候地域での毒性について説明した。さらに対象とする発展途上地域の例として、経済的に余裕がなく大気汚染監視システムが非常に貧弱な中央アジアを挙げてその現状を説明した。<br>第2章では、粒子状物質濃度および化学成分の正確な測定のために、同時に複数の均質なエアロゾル試料を得るための低コストな多連サンプラーの設計とその性能評価について示した。流量計の代わりに臨界ノズルを使用してコストを半減させた。気温、相対湿度、気圧、フィルター材料などの条件が流量に与える影響を調べ、これらの要因は分析結果に大きな影響を与えないことを見出した。<br>第3章では、乾燥地域であるウズベキスタンにおける大気エアロゾルの挙動と特性に関するフィールド調査の結果を示した。本研究で開発した装置を用いてサンプルを採取した。無機元素、水溶性イオン、有機炭素、酸化能の分析を行い、エアロゾル粒子の発生源と有害性について議論した。<br>第4章では、バイオエアロゾルサンプラーの運転条件と捕集効率の評価について述べた。複数のフィルターへの捕集効率をパーティクルカウンターと蛍光X線分析で評価した。気中微生物分析のために一般的に用いられているバイオエアロゾルサンプラーの粒子捕集効率は高くなく、得られた結果の解釈には注意を要することを指摘した。<br>第5章では、サイクロンのサイズと流量の違いによる分離性能の評価と、サイクロンのサイズが捕集エアロゾル粒子の化学組成と有害性評価への影響について示した。様々なサイズや形状を持つ粒子のサイクロンの粒子透過率、化学組成、酸化能、エンドトキシン分析、および細胞曝露実験を実施した。大小のサイクロンを用いることで、得られる粒子サイズを変えることが可能であり、それが化学成分や細胞応答に大きく影響を与えることを見出した。<br>第6章では、本論文で得られた知見に基づき、まとめを行った。 |         |     |            |

# Thesis Abstract

No. 1

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                        |      |                  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|------|------------------|
| Registration<br>Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <input checked="" type="checkbox"/> “KOU” <input type="checkbox"/> “OTSU”<br>No.                                      *Office use only | Name | Alimov, Zikrilla |
| Thesis Title<br>Development of effective and affordable particulate matter sampling devices for toxicity analyses in arid regions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                        |      |                  |
| Thesis Summary<br><p>This thesis aims to optimize advanced aerosol technology for solving environmental problems in developing and underdeveloping countries in effective and affordable way.</p> <p>In Chapter 1, the background and aim of this thesis are described. In response to the fundamental question in the environmental sciences, the definition of particulate matter, physicochemical properties and toxicity in different climate regions have been explained. To study further arid regions, Central Asia has been chosen and investigated, where air pollution is one of the most serious problems for human health, and the air pollution monitoring system is very poor due to low incomes.</p> <p>In Chapter 2, the design and lab evaluation of a low-cost and simultaneous low volume air sampler controlled with sonic venturi to obtain multiple simultaneously homogeneous aerosol samples for the precise measurement of the concentration of various chemical species are shown. The use of critical nozzle instead of mass flow meter reduces the cost of the sampler by half. The impact of meteorological conditions such as ambient temperature, relative humidity, atmospheric pressure, and filter materials on the flow rate was examined. Results showed that these parameters do not seem to affect the precise analysis of elemental concentrations in the air using the sampler. The coefficient of variance for major inorganic elements ranging 15% or less shows that the precision is sufficient for reliable measurement.</p> <p>In Chapter 3, the results of the experimental study of aerosol behaviors and characteristics in the ambient air of arid regions are shown. PM samples were collected using the newly developed sampler in this study. The inorganic elements, water-soluble ions, organic carbons, and oxidative potential analysis were conducted to investigate the impacts of pollutant on surrounding environment and develop a suitable and affordable particulate matter sampler.</p> <p>In Chapter 4, the evaluation of the flow rate and collection efficiency of a bioaerosol sampler to collect bioaerosols and PM are described. The designed flow rate of the bioaerosol sampler was compared using the developed experimental system, and the flow rate chart has been drawn to confirm the actual flow rate of the sampler during sampling. The collection efficiency of the bioaerosol sampler on various filter materials for PM was evaluated using particle counters and XRF fluorescence analysis.</p> <p>In Chapter 5, the evaluation of the separation performance of different cyclone sizes, the effects of cyclone size on the chemical compositions of the collected aerosol particles, and its impacts on toxicity analyses are shown. To design optimal cyclone dimension, particle penetration of cyclones of varied sizes, chemical composition, oxidative potentials, endotoxin analyses, and cell exposure were conducted primarily to evaluate the separation performance of the cyclones.</p> <p>In Chapter 6, a summary was given based on the findings in this thesis</p> |                                                                                                                                        |      |                  |