Title of dissertation				
Air Quality and Environmental Impact Assessment of Industrial Activities in East Java, Indonesia				
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SUMMARY

A comprehensive study on air quality and the environmental impact assessment of industrial activities in Indonesia is still lacking. This dissertation aims to comprehensively assess the air quality across various regions of Indonesia, encompassing both urban and industrial areas, and environmental impact of industrial activities with a particular emphasis on East Java. The primary objectives of this research are to identify potentially toxic elements in airborne particulate matter using nuclear analytical techniques, determine the major sources contributing to these elements, and evaluate the environmental impact associated with health and ecological risks. Assessing the impact of industrial activities on air quality and the surrounding environment will be a key factor in better understanding and monitoring environmental challenges, especially considering the increasing number of industrial activities in the country. By achieving these objectives, this dissertation contributes to a better understanding of the environmental challenges posed by industrial activities in Indonesia. It provides crucial data on airborne particulate matter concentrations, chemical compositions, and major pollutant sources, providing a scientific basis for the development and improvement of various air quality policies.

This dissertation consist of 7 chapters and the details are described as follows:

Chapter 1 provides detailed information on the relevant background, a literature review of the increasing industrial activities, air quality monitoring status in Indonesia, the health impact of air pollution, the sources of air pollution, and the objectives of this research.

Chapter 2 presents urban air quality data from 17 sampling sites across 16 cities on the islands of Java, Sumatra, Kalimantan, Sulawesi, Maluku, and Papua, from 2010 to 2017. Over 6000 of samples of airborne particulate matter (APM) were collected in two size fractions: fine particulate matter ($PM_{2.5}$, particles with an aerodynamic diameter less than 2.5 μm) and coarse particulate matter ($PM_{2.5\text{-}10}$, particles with an aerodynamic diameter of 2.5–10 μm). These samples were collected 24 hours a week using a Gent stacked filter unit sampler and analyzed for mass concentrations, black carbon (BC) content, and elemental compositions. Surabaya, located in East Java, exhibited significantly higher concentrations of heavy metals, including Fe, Zn, and Pb, while Tangerang in Banten, Java, showed elevated levels of Pb compared to other cities. The average lead concentrations in Surabaya and Tangerang during this study period were 0.33 $\mu g/m^3$, and 0.22 $\mu g/m^3$, respectively. These values were significantly higher when compared to other cities in Asian countries and exceeded

the U.S. ambient air quality standard of 0.15 μg/m^3. It is assumed that there may be a similar source of Pb pollution in Surabaya, as was identified in the Tangerang study, which was associated with a lead battery recycling and bar production facility. Further investigation related to the heavy metal pollution in Surabaya needs to be conducted, given the adverse health effects of this element, and appropriate actions must be taken to reduce exposure in these areas.

Chapter 3 focuses on the vicinity of a lead smelter located in Lamongan, East Java. This lead smelting activity is suspected to have a correlation as a source causing the high Pb pollution in Surabaya, East Java. The research includes the characterization of $PM_{2.5}$ collected in the surrounding area of the lead smelter industry to identify the degree of Pb pollutant in the air, major pollutant sources and conduct potential risk assessments to the surrounding population. The average concentrations of Pb in Lamongan was 0.46 μg/m^3, which violated the annual lead standard of US EPA (0.15 μg/m^3), and almost reached the limit of WHO (0.5 μg/m^3).

Chapter 4 describes the investigation on the characteristics of potentially toxic elements in soils collected from the vicinity of a lead smelter in Lamongan, East Java, with the objective of assessing the lead smelter's impact on the surrounding soil ecosystem. Following the discovery of elevated Pb levels in $PM_{2.5}$, it became crucial to assess the environmental impact on the soil, especially considering its location surrounded by the rice field and one of the rice-producing regions in East Java. The research involves chemical composition analysis in soil, spatial distribution mapping, and the evaluation of potential ecological and health risks assessment through several pathways including ingestion, inhalation and dermal.

Chapter 5 describes the utilization of particle-induced X-ray emission (PIXE) in the characterization of fine and coarse particulate matter. The samples collected from two years period in Surabaya East Java were analyzed using particle-induced X-ray emission (PIXE) with a 4-MV Van de Graaff accelerator at Kyoto University. In this study, both helium and protons were employed to achieve optimal results. Both combinations provide optimal results, especially in the detection of light elements using helium and heavier elements using a proton beam, resulting in the detection of a total of 21 elements. This elemental analysis revealed major, minor, and trace elements in $PM_{2.5}$ and $PM_{2.5-10}$ providing significant and crucial information on chemical composition.

Chapter 6 utilizes the database of chemical composition in APM collected in Surabaya, which was obtained through PIXE analysis. This chapter employs various approaches for data analysis and health impact assessment. The results revealed that $PM_{2.5}$ concentrations exceeding the World Health Organization (WHO) annual standard of 5 μg/m^3. The positive matrix factorization (PMF) method was employed for source apportionment of $PM_{2.5}$. It revealed eight factors for $PM_{2.5}$ sources: galvanizing industry, ammonium chloride, secondary sulfate, biomass burning emission, soil, steel industry, traffic emissions, and lead smelting industry. Metal industries such as galvanizing, steel industry and lead smelting were found to be a significant contributor to $PM_{2.5}$ with a total of 37.3%. Conditional bivariate probability function was carried out to identify the location/direction of the possible sources.

Chapter 7 is a conclusion briefly summarizes the main finding of the study in each chapter and what can be concluded. The long-term research has shown the benefits of nuclear analytical techniques such as XRF and PIXE in characterization of airborne particulate samples and other environmental samples. These methods are still reliable and suitable methods for APM research. This research demonstrates that industrial activities, particularly those related to lead smelting and metal industries, have a substantial impact on Indonesia's air quality, resulting in elevated levels of potentially toxic elements in the atmosphere and soil. Recommendations include enhanced monitoring, source identification, community awareness,

ecological impact assessment, international collaboration, and policy development, all aimed at addressing the challenges posed by industrial pollution while promoting sustainable development.

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