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Taiwan Association for Aerosol Research

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Date August 31 2024

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Announcement

- The 16th joint board meeting was held on June 22, 2024. Five new individual members, nine junior members, and one regular annual member were reviewed and became permanent members and junior members of the Taiwan Aerosol Research Association. Let's welcome them !
- The term of the 16th Board and Committee members is coming to an end. We extend our deepest gratitude for their voluntary service to the society over the past two years. The development of the society relies on the enthusiastic participation of all our esteemed members.
- The 17th Board of Directors and Supervisors election will take place on September 20, 2024, at National Ilan University. Voting and ballot counting will be conducted on that day, followed by the 17th Taiwan Association for Aerosol Research General Assembly and the first meeting of the Board and Supervisory Committee

The 8th Joint Meeting of the Board and Supervisory Committee included a site visit to National Ilan University.

Announcement

Permanent Individual Member

Yu-Chen Cheng

PhD Research Assistant

Graduate Institute of Environmental Engineering, National Taiwan University

Shu-Yuan Pan

Associate Professor

Department of Bioenvironmental Systems Engineering, National Taiwan University

Jhao-Hong Chen

Researcher

Washington University in St. Louis

Shih-Yu Pan

Postdoctoral Researcher

Institute of Environmental and Occupational Health Sciences,National Yang Ming Chiao Tung University

Aji Kusumaning Asri

Master Degree Student

Department of Geomatics,National Cheng Kung University

Announcement

Junior Member

Dinh Chi Thien

PhD Student

International Graduate Program in Medicine, Taipei Medical University

Fefi Eka Wardiani

PhD Student

Environmental Engineering, Chung Yuan Christian University

Firdian Makrufardi

PhD Student

International Graduate Program in Medicine, Taipei Medical University

Wei-Chen Lu

Bachelor's degree student

Department of Environmental Engineering, National Ilan University

Le Thi Hieu

PhD Student

Marine Environmental Engineering,National Kaohsiung University of Science and Technology

Announcement

Junior Member

You-Jia Huang

Master Degree Student

Department of Environmental Science and Engineering,National Pingtung University of Science and Technology

Yu-Cheng Lin

Postgraduate

National Institute of Environmental Health Science, National Health Research Institutes

Tzu-Chi Lin

PhD Student

Graduate Institute of Environmental Engineering, National Taiwan University

Zhen-Lun Tseng

Bachelor's degree student

Departmen of Pharmacy, Chia Nan University of Pharmacy & Science

Regular Annual Member

Chia-Wei Hsu

PhD Student

Department of Geomatics,National Cheng Kung University

Calendar of Events

Date
September 20-21, 2024

Conferences
The 31st International Conference on Aerosol Science and Technology

Location
National Ilan University

Yilan, Taiwan

Website
https://2024-icast.taar.org.tw/

Date
November 3-7 , 2024

Conferences
13th Asian Aerosol Conferenc

Location
Sarawak, Malaysia

Website
https://www.asianaerosol2024.com/

The 10^{th} T&T- The 1^{st} IAA Conference 2024

The T&T_IAA conference was held at the Institute of Technology Bandung. Over 100 faculty members and students attended the event, with more than 50 participants from Taiwan, including faculty, students, and industry representatives.

The 10th T&T- The 1st IAA Conference 2024

Opening remarks by Prof. Ir. Puji Lestari, Ph.D., from the Institute of Technology Bandung, who is also the founding president of the IAA.

Opening remarks by Dr. Ying-I Tsai, President of the Taiwan Association for Aerosol Research.

The 10th T&T- The 1st IAA Conference 2024

A group photo of the attending scholars was taken after the opening ceremony.

A group photo of the faculty and students at the conference venue.

The 10th T&T- The 1st IAA Conference 2024

The conference was chaired by Professor Lin-Chi Wang and Dr. Arie Dipareza Safei. A total of 66 oral presentations were delivered during the symposium.

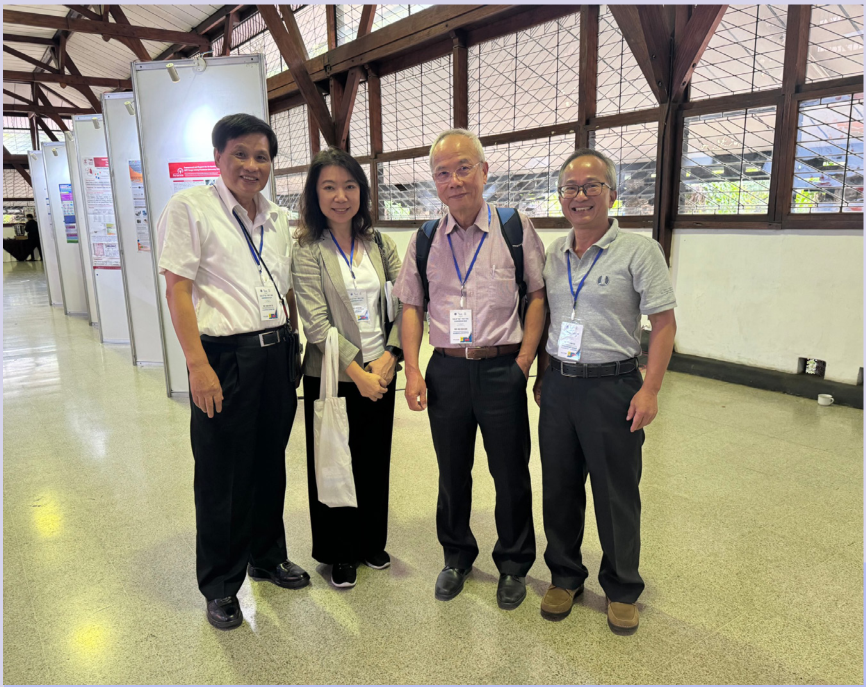
The conference poster session featured 22 posters on display.

A group photo of the student presenters with the session chair was taken after the conference presentations.

A group photo of faculty and students was taken on the shuttle bus.

The 10th T&T- The 1st IAA Conference 2024

A group photo of Taiwanese scholars and representatives.



A group photo of the honorary presidents.

Wei-Lun Hsu[1] ， Aji Kusumaning Asri [1] , Chih-Da Wu[1,2*]

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1 Introduction

Air pollution is a critical global issue, posing significant threats to human health and sustainable development. It is closely associated with various diseases, including respiratory disorders, cardiovascular diseases, and cancer, highlighting the urgent need to address air pollution issues. Air pollutants are primarily categorized into particulate matter and gaseous pollutants. Particulate matter mainly consists of suspended particles, while gaseous pollutants include sulfur oxides, nitrogen oxides, among others. The sources of air pollution are closely linked to both human activities and the natural characteristics of different regions, resulting in variations in pollutant concentration and composition across different areas. Understanding the distribution of air pollution concentrations is crucial for identifying the sources of different pollutants and provides valuable insights for environmental policy-making and public health planning.

2 Traditional air pollution estimation methodology

Air pollution concentrations are typically measured using air quality monitoring stations, which are equipped with high-precision instruments to provide accurate data. However, the coverage of these monitoring stations is limited, leaving many areas without direct pollution measurements. Therefore, a significant challenge in air pollution research is to estimate pollution concentrations in areas lacking monitoring stations by leveraging existing data and applying suitable modeling methods.

Early air pollution estimation methods mainly relied on spatial interpolation techniques, such as kriging interpolation. These spatial methods use air quality monitoring data and estimate pollution levels across an area based on distance weights. However, spatial interpolation only considers distance factors and does not fully account for variations in regional emission sources, leading to less accurate estimations in areas with sparse monitoring coverage. To improve the accuracy of air pollution estimations, researchers have developed various methodologies, broadly categorized into two main types: Chemical Transport Models (CTMs) and Statistical Models. CTMs simulate the transport, transformation, and deposition of pollutants in the atmosphere and require extensive atmospheric and chemical parameters. Due to difficulties in obtaining local data, these models often involve assumptions that can increase uncertainty. In contrast, Statistical Models create regression prediction models by analyzing the relationship between air pollution concentrations and influencing factors such as meteorology, topography, and land use emissions. Recent studies have increasingly favored Statistical Models for air pollution modeling due to their ability to integrate multiple influencing factors.

3 Application of Geographic Information Systems in Land Use Regression

The distribution of air pollutants is closely linked to land use types. By integrating local emission sources with land use data, air pollution estimation models can more accurately capture the pollution characteristics of different areas, thereby enhancing the precision of pollution estimations. Collecting and processing land data often involves various sources of spatial information, including emission source locations, traffic network distributions, land use classifications, and satellite imagery. Geographic Information Systems (GIS) effectively integrate these different types of spatial data and use spatial analysis tools to analyze and interpret information on land use and emission source distributions (**Figure 1**). This spatial information on emission sources is crucial for improving air pollution estimation models and exploring the relationships between pollutants and surrounding land-based emission sources.

Refer to this point, Land-Use Regression (LUR) model, which integrates GIS emission source data with multiple linear regression, has been widely utilized for air pollution estimation. In LUR, air pollutant concentrations measured at monitoring stations served as the dependent variable, while meteorological factors, land use types, and emission source distributions obtained through GIS spatial analysis are used as explanatory variables. Multiple linear regression is then employed to describe the relationship between air pollutants and these land use and environmental factors. For areas without monitoring stations, the model can estimate potential air pollutant concentrations by substituting local land use and environmental factor values into the model. The advantages of LUR lies in its consideration of local emission sources and its flexibility to adapt to the characteristics of specific pollutants or regional differences. However, the relationship between air pollution and land use or environmental factors is often highly complex, and linear models may not always provide satisfactory explanations. In response, Artificial Intelligence (AI) technologies, which can capture complex relationships between data, have emerged. When integrated with GIS land emission source information, this has led to the development of innovative "Geospatial Artificial Intelligence" (Geo-AI), which is increasingly being applied in air pollution modelling to enhance the accuracy of estimations.

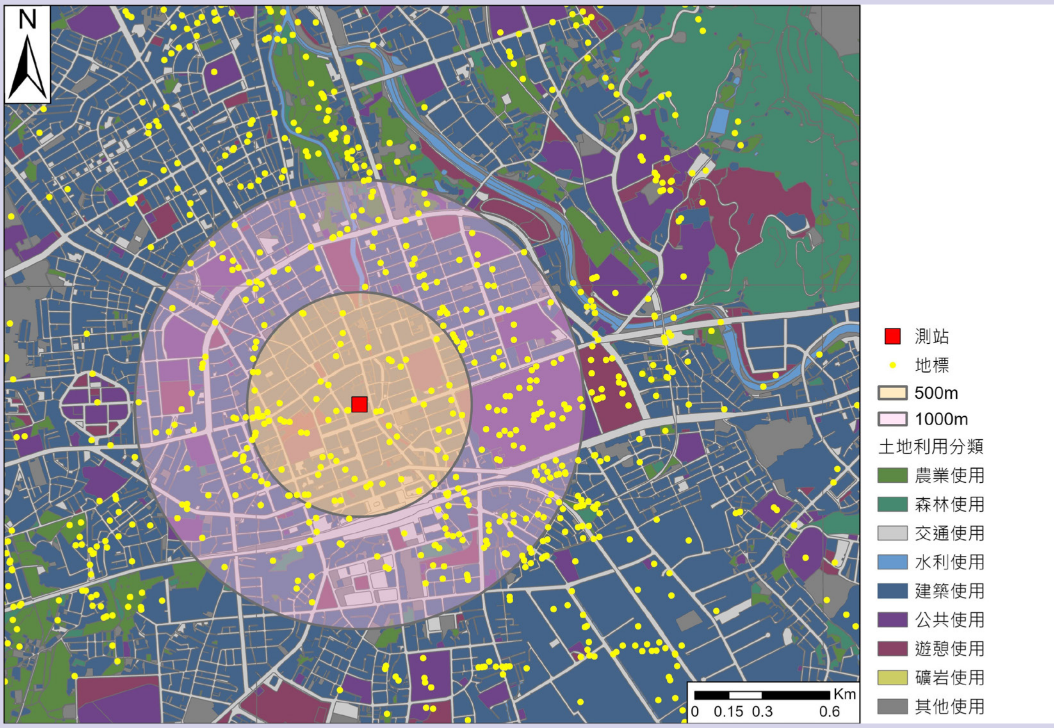

Figure 1. Illustration of how GIS is used to obtain distribution information for surrounding land emission sources

4 Geospatial Artificial Intelligence (Geo-AI)

The main concept of Geo-AI lies in combining the strengths of GIS and AI. By utilizing spatial analysis tools and techniques, Geo-AI processes and integrates diverse environmental and spatial data. It employs machine learning and ensemble learning methods, which combine various algorithms to enhance predictive accuracy. This approach allows for automatic learning from large datasets, capturing the complex relationships between pollution concentrations and emission factors, and creating more accurate models to address complex air pollution simulation challenges.

Our team has extensively explored the application of Geo-AI in air pollution modeling. Leveraging the concept of Geo-AI, we have published 24 research papers on various methodologies for air pollution estimation. In our most recent study, published in 2023, we introduced a method known as Ensemble Mixed Spatial Models (EMSMs). This approach integrates four air pollution estimation techniques discussed in this paper: kriging interpolation, land-use regression, machine learning, and ensemble learning. We used this method to analyze variations in fine particulate matter ($PM_{2.5}$) concentrations over the past two decades in Taiwan, focusing on daytime, nighttime, and daily average concentrations. In practical, the study utilized $PM_{2.5}$ data from the National Air Quality Monitoring Stations of the Environmental Protection Administration, Taiwan as the dependent variable. Independent variables included data on other air pollutants, meteorological data from the Central Weather Bureau (i.e., temperature, rainfall, wind speed, wind direction), and land use data (i.e., land use classification lists, landmarks, digital traffic networks). Additionally, we incorporated satellite-derived Normalized Difference Vegetation Index (NDVI) data to represent vegetation conditions. Using this comprehensive dataset, we applied four machine learning algorithms: gradient boosting, extreme gradient boosting, light gradient boosting machine, and categorical boosting. We then combined the outputs of these individual algorithms to develop an ensemble learning model for spatially estimating $PM_{2.5}$ concentrations (i.e., day, night, and daily average).

Figure 2 illustrates the distribution of $PM_{2.5}$ concentrations across Taiwan using the Ensemble Mixed Spatial Models. The models achieved over 90% accuracy in simulations across all three temporal resolutions. It accurately and effectively captured daily $PM_{2.5}$ concentration variations in Taiwan at a 50m × 50m grid resolution. The modeling process also included identifying key influencing factors and emission sources, providing valuable insights for air pollution prevention. These results offer a critical scientific foundation for formulating effective air quality management policies.

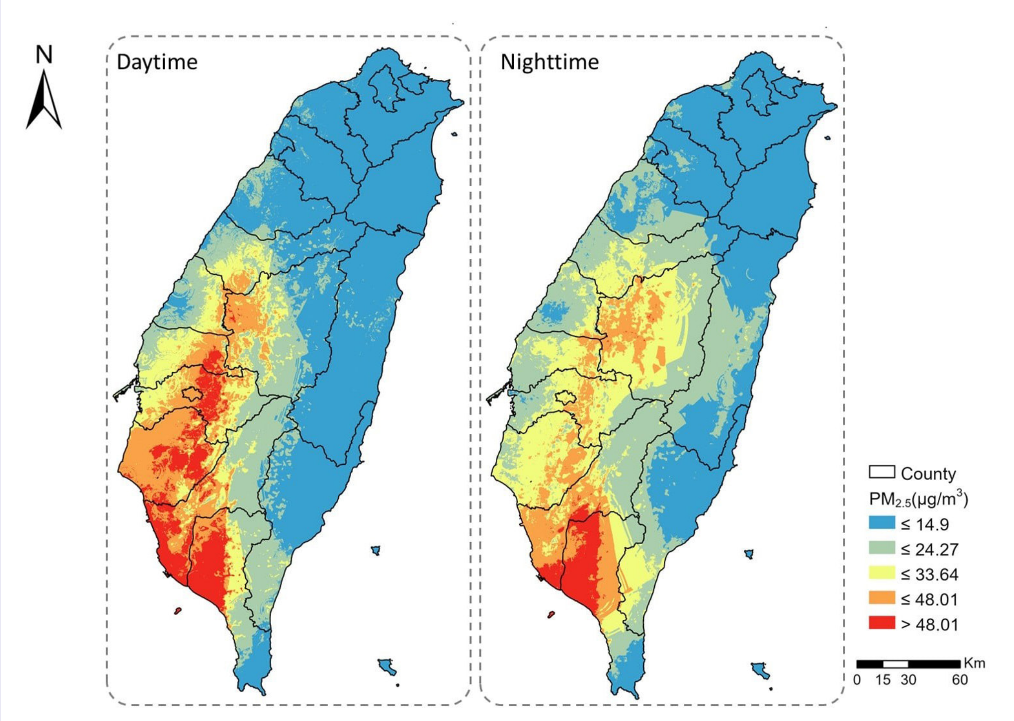

Figure 2. $PM_{2.5}$ concentration distribution across Taiwan generated using the Ensemble Mixed Spatial Learning Model (example from December 31, 2016)

5 Conclusion

This study presents innovative solutions for environmental challenges through the application of Geo-AI. Our research team developed an "Ensemble Mixed Spatial Learning Model" that integrates various geographic spatial data with advanced machine learning algorithms. This model not only demonstrates robust predictive capabilities but also offers a scientific foundation for environmental policy development. Additionally, the methodologies have been broadly applied to different types of air pollutants, including particulate matter, gaseous pollutants, and volatile organic compounds, demonstrating the promising potential of Geo-AI in effectively addressing air pollution issues in the future.

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Application of AI Technology in Air Quality Forecasting

Sheng-Hsiang Wang, Huynh Duy Tran

Department of Atmospheric Sciences, National Central University

In recent years, many studies have utilized various numerical methods to predict pollutant concentrations, generally categorized into two types: physical models and statistical models. Physical models primarily simulate the diffusion of air pollutants based on emission inventories, atmospheric chemistry, and dynamic processes. Common models in Taiwan include Gaussian dispersion models (AEROMOD, ISC), and atmospheric chemistry models (CAMx, WRF-Chem, and CMAQ). On the other hand, statistical models are based on the correlation or statistical relationships between air pollutant concentrations and other influencing factors. These models learn from historical data through a set of statistical programs and improve over time, also known as machine learning (which can be considered a part of AI). This technology helps predict the temporal and spatial variations of future pollutant concentrations. With advancements in technology, various machine learning models have been developed, which can be categorized into three main branches: supervised learning, unsupervised learning, and reinforcement learning.

Supervised learning is a widely used machine learning method that enables computers to predict outcomes based on historical and current data. The intermediate processes often employ classification and regression algorithms. Classification algorithms are typically used to categorize pollutant concentrations into different labels or groups, allowing for the formulation of effective strategies to prevent incidents caused by air pollution. For example, Corani & Scanagatta (2016) used Bayesian network classification in supervised learning to determine the likelihood of pollutants exceeding certain thresholds, thus generating more accurate posterior probabilities. In contrast, regression algorithms aim to observe and predict input quantities based on corresponding output features. Some commonly used supervised learning regression algorithms include Support Vector Machines (SVM), Backpropagation Neural Networks (BPNN), linear regression, and Elman recurrent neural networks. Jasim et al. (2020) developed a model to predict carbon monoxide (CO) emissions by integrating SVM with Geographic Information Systems (GIS), achieving an accuracy of 81% and a minimum RMSE of 0.067 ppm. Another study combined high spatiotemporal resolution data from WRF with BPNN to forecast $PM_{2.5}$ concentrations in the Yangtze River Delta region of eastern China (Jia et al., 2019). This study showed acceptable predictive accuracy for 72-hour $PM_{2.5}$ forecasts, with seasonal correlations ranging from 0.4 to 0.52. BPNN was also used to train under severe pollution conditions, resulting in an improvement of RMSE by 44.1% compared to the original model. Regression supervised learning has been widely used in many studies related to air quality assessment, with advantages including ease of access, cost-effectiveness, and ease of implementation. However, these models often face a common drawback: under-prediction, which means that predicted values are lower than observed values. In the context of air quality assessment, this drawback may lead to an underestimation of emission outcomes, thus failing to take timely measures to prevent air quality deterioration, potentially resulting in various health-related issues.

In recent years, machine learning has been applied in multiple studies in Taiwan to assess air quality (Chang et al., 2020; Doreswamy et al., 2020; Lee et al., 2020; Liang et al., 2020; Soh et al., 2018; Wong et al., 2021; Zhou et al., 2019). For instance, a 2020 study utilized machine learning to investigate the spatiotemporal characteristics of $PM_{2.5}$ in northern Taiwan (Chang et al., 2020). The authors developed two models using BPNN with different input features, both of which performed consistently, with error variations ranging from 5 to ~14 μg/m³, and the highest correlation R^2 value reaching 0.85. Zhou et al. (2019) successfully predicted NOx, PM_{10}, and $PM_{2.5}$ levels at five monitoring sites in Taipei using Long Short-Term Memory (LSTM) algorithms. Furthermore, their model effectively identified high emission events for $PM_{2.5}$, PM_{10}, and NOx at the San Chong air quality monitoring station, with concentrations exceeding 150 μg/m³, 200 μg/m³, and 150 ppb, respectively.

In addition to the aforementioned references, the research team of this paper applied an ensemble learning model to enhance air quality assessment (Tran et al., 2023), focusing on predicting key pollutants such as O_3 and $PM_{2.5}$, as well as estimating the planetary boundary layer height (PBLH). This ensemble machine learning framework integrates LSTM, SVM, and Random Forest (RF) to optimize the prediction of $PM_{2.5}$ and O_3 concentration changes over 48 hours. The results showed that the prediction of O_3 achieved a high correlation ranging from 0.97 to 0.81, with RMSE values fluctuating between 4.77 and 11.65 ppb for 1 to 48-hour forecasts. On the other hand, $PM_{2.5}$ predictions also showed improvements, with RMSE variations between 4.8 and 11.78 μg/m³, and correlation coefficients ranging from 0.95 to 0.66. The PBLH forecast model also demonstrated good results, with the highest correlation coefficient reaching 0.97 and the lowest RMSE being only 0.0215 m.

The research findings presented in this paper emphasize the potential of machine learning in air quality forecasting. It is anticipated that future advancements in machine learning technology will provide timely and accurate air quality predictions, aiding the government in developing strategies to combat air pollution and opening new avenues for environmental governance.

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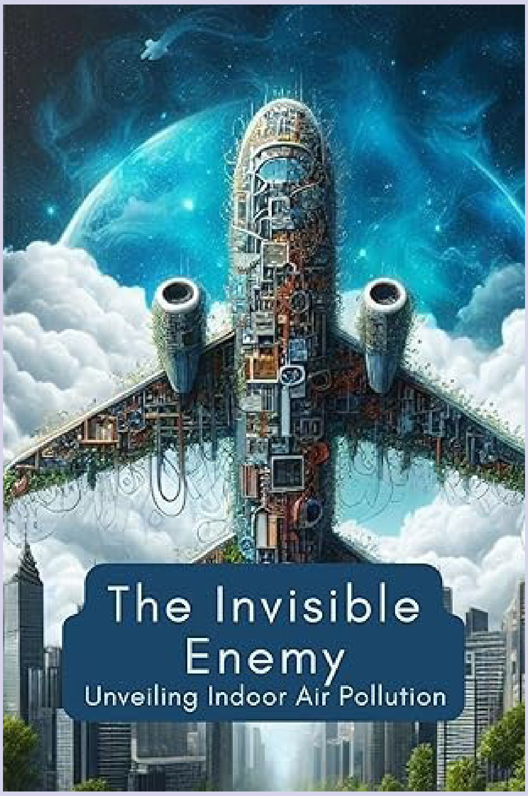
New Book on Aerosol

The Invisible Enemy: Unveiling Indoor Air Pollution

Publisher : Independently published
Publication date : April 26, 2024
Language : English
Print length : 205 pages
Page numbers source ISBN : 979-8324059231

by Amal Forman (Author)



In our daily lives, we often overlook an invisible threat: indoor air pollution. This book delves into the depths of this concerning issue, shedding light on the unseen pollutants that lurk within our own homes. Starting with the fundamentals, it unravels the origins of this problem, revealing the surprising culprits responsible for contaminating our breathing spaces. From cooking fumes to cleaning chemicals, the book exposes the multitude of sources that contribute to poor indoor air quality. With a keen eye on health and well-being, the author guides readers through the potential dangers that arise from continual exposure to these pollutants. Offering insightful research and scientific studies, the book underlines the consequences that come with prolonged exposure, from allergies and respiratory diseases to other common ailments. To equip and empower readers, the book offers practical solutions to improve indoor air quality. From adopting simple habits to integrating modern technologies, it provides guidance on how individuals can create safer and healthier living environments for themselves and their families. With a mix of captivating storytelling and enlightening facts, this book deepens our understanding of air pollution and challenges us to become vigilant in the pursuit of clean and fresh air within our homes. A must-read for anyone concerned about their well-being and the quality of the air we breathe on a daily basis.

Introduction of Aerosol Researcher

Tse-Lun Chen

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Dr. Tse-Lun Chen is an Assistant Professor at the Institute of Environmental Engineering at National Sun Yat-sen University (NSYSU). He has previously worked as a postdoctoral researcher at the Institute of Environmental Engineering at National Taiwan University and the Swiss Federal Institute of Technology in Zurich (ETH Zürich). He has also been a visiting scholar at the Argonne National Laboratory in the United States and the University of Stuttgart in Germany. Dr. Chen's primary research focuses on the development of technologies for air pollution and energy, including: (1) integrated air pollution control technologies; (2) electrochemical carbon dioxide capture and utilization technologies; and (3) analysis of atmospheric aerosol size distribution and sources. Dr. Chen is the head of the Air Pollution and Energy Technology Laboratory. His research aims to develop oxidative absorption methods combined with process intensification concepts to co-remove various air pollutants, to improve interfacial mass transfer, and reactor design for the development of CO_2 electrocatalytic technology, and to establish long-term measurements of aerosol size distribution with exploring source analysis and aerosol particle evolution. He hopes to apply his research expertise and results to key domestic industries to promote co-pollutants removal and CO_2 abatement, moving towards a path of net-zero transition. In the past five years, Dr. Chen has published 28 SCI journal papers and joined the Environmental Engineering team at NSYSU in February 2024. His future research will integrate his expertise with issues related to net-zero emissions, air pollution, and climate change.

Recent research topics

1. Development of an Innovative Electrocatalytic Module for CO_2 Reduction and Conversion Technology

During his postdoctoral research at ETH Zürich in Switzerland (funded by the NSTC’s Postdoctoral Fellowship Program), Dr. Chen focused on developing negative carbon technologies using electrochemical methods. The aim was to convert CO_2 into valuable carbon products (such as CO or formic acid) through electrochemical processes. The team established electroless deposition methods to deposit nanoparticles (copper, gold, and palladium) onto nanofibers and carbon paper, conducting both 2D and 3D metal deposition. They prepared these materials as gas diffusion electrodes (GDEs), which served as working electrodes in electrochemical modules. Additionally, they designed the electrocatalytic modules to control flow field variations, enhancing the gas-phase mass transfer rate of carbon dioxide. This approach aimed to improve the overall CO_2 conversion rate, treating CO_2 as a renewable resource to advance negative carbon technology.

2. Development of High-Gravity Technology for Performance Evaluation of Various Air Pollutants

Dr. Chen has dedicated his efforts to developing high-gravity (HiGee) technology for the removal of various air pollutants, evaluating the performance, mass transfer, and kinetic models of CO_2 mineralization in municipal incinerator fly ash, as well as conducting environmental impact and economic cost assessments. His main research objectives include: (i) assessing the performance of HiGee technology in simultaneously purifying various air pollutants (e,g., SOx, NOx, and PM), (ii) establishing mass transfer models for removing these pollutants in an HiGee systems, (iii) evaluating the stabilization effects of combining high-gravity technology with CO_2 mineralization on municipal incinerator fly ash, (iv) developing reaction kinetics for CO_2 mineralization and calcium ion leaching from fly ash, and (v) assessing the technical, economic feasibility, and environmental impacts to optimize the system.

His research aims to establish demonstrations of high-gravity technology in key domestic industries, providing innovative technological development and achieving substantial reductions in air pollution emissions. High-gravity technology has rarely been applied in environmental engineering, and through this research, it is expected to become a viable option for small and medium-sized industries in Taiwan, reducing their costs and energy consumption. Related research findings have been published in international journals such as Chemical Engineering Journal, Waste Management, Journal of Environmental and Chemical Engineering, and Environmental Pollution.

3. Evaluating the Impact of COVID-19 Level 3 Alert on Air Quality in the Taipei Metropolitan Area

Dr. Chen analyzed the measurement data from the IMPACT air quality monitoring station at NTU campus to investigate the time series variations of various air pollutants, meteorological conditions, and traffic flow in Taipei City during the COVID-19 Level 3 Alert period in 2021. This study particularly focused on the changes in particle size distribution and the number concentration of aerosol particles before, during, and after the pandemic alert periods. By correlating these changes with traffic-related air pollutants and meteorological conditions, the study aimed to determine whether the reduction in traffic emissions during the alert period contributed to improved air quality. Current literature from various countries has discussed the impact of different measures on air quality on global, regional, and urban scales. The first two scales mainly use satellite retrieval data, ground measurement data, and model simulations to analyze changes in major air pollutants during COVID-19 lockdowns, such as $PM_{2.5}$, carbon monoxide (CO), nitrogen oxides (NOx, mainly NO and NO_2), and ozone (O_3).

The urban scale analyses typically use near-road or mobile measurements. Existing literature, predominantly from European and American countries, China, and India, generally concludes that COVID-19 lockdown measures effectively reduced $PM_{2.5}$, CO, and NOx levels due to decreased human activities or traffic volume. However, these measures also led to increased ground-level O_3 concentrations, primarily because the reduction in NOx might slow down the O_3 titration effect, thereby promoting O_3 formation. From a policy perspective, the observed changes in air quality during the COVID-19 control period necessitate a reevaluation of air pollution control strategies. The latest research findings have been published in the international journal Environmental International.

Important keywords and their descriptions

Gas Diffusion Electrode (GDE)

Gas diffusion electrodes (GDE) in the electrochemical systems are made from materials with high hydrophobicity, high conductivity, porosity, and a high active surface area. Under atmospheric pressure, these electrodes allow gases and electrolytes to reach equilibrium within the micro-pores, enhancing the mass transfer rate of gas molecules. This leads to the formation of a stable gas-liquid-solid three-phase interface, facilitating heterogeneous electrochemical reactions.

High-gravity Technology

This technology involves equipping traditional packed beds with mechanical rotating devices, creating a high-gravity environment through centrifugal force generated during the rotation of the bed. In air pollution control, high-gravity technology is used to enhance gas-liquid mass transfer reactions.