ASIA-PACIFIC NETWORK FOR
GLOBAL CHANGE RESEARCH

FINAL REPORT

Impacts of the COVID-19 pandemic on air quality of the Monsoon Asia region: Cross-country assessment and Facilitating Policy

CRRP2021-02MY-Latif

2024

Universiti Kebangsaan Malaysia
The National University of Malaysia

MANGO
Monsoon Asia and Oceania Networking Group

NUS National University of Singapore

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1. Summary

The Monsoon Asia region, which includes Southeast Asia (SEA) and South Asia, is widely known for its high levels of air pollution. The air quality assessment was conducted in this project to investigate the impact of COVID-19 pandemic lockdowns on air pollution levels by analyzing the consequences of restrictions on movement and economic activities. The investigation revealed substantial enhancements in air quality during the periods of lockdown. Significant reductions in levels of prominent pollutants such as nitrogen dioxide (NO_2), which serves as an indicator for traffic-related emissions, were observed in the majority of cities. The decrease in traffic can be linked to the fact that people stayed at home and limited economic activities during the lockdown. Metropolitan areas experiencing severe traffic congestion witnessed the most substantial reductions in NO_2 levels, often reaching a remarkable decline of more than 50%. The study also noted decreases in aerosol optical depth (AOD) and fine particulate matter ($PM_{2.5}$), a toxic pollutant associated with respiratory problems. AOD and $PM_{2.5}$ emissions commonly originate from several sources, such as vehicle exhaust, industrial operations, and biomass combustion. The implementation of lockdown measures resulted in a decline in industrial operations and vehicular movement, leading to a notable decrease in AOD and $PM_{2.5}$ levels in numerous urban areas. The reductions of AOD and $PM_{2.5}$ seen in certain major cities across the Monsoon Asia region up to 39%. Nevertheless, the effect of lockdowns on air quality varied around the region. Certain nations, especially those that share a border with China, continue to face pollution originating from sources that cross national boundaries. The transportation of pollutants through wind from nearby countries can hinder the efficacy of local initiatives aimed at enhancing air quality. This research provides useful insights that can be utilised by policymakers to reduce air pollutant concentrations in the Monsoon Asia region. The notable enhancements in air quality witnessed during lockdowns exemplify the noteworthy impact of human activities, namely transportation and industry, on air pollution in the area. The air quality assessment conducted in this study by using air quality data from satellite-based and ground-based measurements was able to determine the shifting of air quality levels across the Monsoon Asia region during the implementation of COVID-19 lockdowns. The study highlights the necessity of implementing stringent strategies that can effectively enhance air quality over the region based on the implementation impacts from various types of COVID-19 control measures, especially in translating the research findings for policy development. Collaboration among different countries in the Monsoon Asia region and the exchange of information can play a vital role in addressing these air pollution challenges in a comprehensive way.

2. Objectives

There are three key objectives:

- To quantify the changes in major air pollutants due to the effect of COVID-19 lockdowns in the Monsoon Asia region
- To evaluate the dominant factors affecting resultant air quality during COVID-19 pandemic lockdowns

- To build closer interactions with stakeholders (policymakers and public) focusing on urban air quality

3. Outputs, Outcomes and Impacts

Outputs	Outcomes	Impacts
Collaborative research meetings with researchers across the Monsoon Asia region during the initial stage of the project	- Documented comprehensive framework outlining the research plan for the project specific to research questions, methodologies, data collection strategies, and timelines for each participating country - A project website that contains the research background, list of collaborators, and project activity is developed	- Enhanced communication and collaboration among researchers from diverse Monsoon Asian countries by exchanging expertise and perspectives on air quality issues in the region - Identification of existing data gaps and research needs specific to different Monsoon Asian countries, which allows for a more targeted and efficient research strategy
First APN Training Workshop on Satellite Technologies (21-25 March 2021)	Hands-on training on satellite measurement data retrieval from different sources of satellite, as well as spatial mapping of air pollutant distribution	- Provides young and senior scientists with valuable skills and tools for retrieving satellite data - Increased capacity for air quality monitoring which expands the pool of researchers and professionals capable of monitoring air quality in Monsoon Asia - Improved data sharing and collaboration more effectively on future air quality research projects - Enhanced understanding of air pollution distribution through hands-on experience in

		spatial mapping, allowing to visualize air pollutant concentrations across Monsoon Asia
Second APN Training Workshop on Data Interpretation Combining Satellite and Ground-Level Observations (16-20 October 2022)	Hands-on training on data analysis and interpretation combining satellite and ground-Level observations	- Enhanced data analysis and data interpretation skills of young and senior scientists - Standardized data analysis technique to ensure consistency across research teams in the Monsoon Asia region, allowing for more robust comparisons and collaboration
Air quality assessment by using satellite technologies to measure air pollutant concentration in the Monsoon Asia region, particularly during the implementation of COVID-19 control measures	- A comprehensive data set containing air pollutant concentrations measured by satellite-based and ground-based measurement across the Monsoon Asia region during the COVID-19 lockdowns include information on various pollutants like AOD, NO_2, and $PM_{2.5}$, along with timestamps and geographical coordinates - Detailed research reports that include visualizations like maps and charts showing changes in air quality across the region during the lockdowns	- Increased knowledge about the relationship between human activities and air pollution in Monsoon Asia - Improved understanding of how COVID-19 control measures, especially lockdowns can affect air quality
Third APN Training Workshop on Engagement of Scientists and Policymakers across Monsoon Asia region for	The project's research findings have led to the development of documented collaborative action plans for improving air quality across the Monsoon Asian	- Enhanced Communication Skills: The workshop can equip scientists and policymakers with improved communication

Better Air Quality (6-7 June 2023)	countries where these plans are based on concise policy briefs and recommendations from scientists and policymakers who participated in the workshop	skills. Scientists can learn to present complex air quality data in a clear and concise way for policymakers, while policymakers can develop better skills to understand and interpret scientific findings

4. Key facts/figures

- A project website has been developed that includes research background, list of collaborators, and project activity.
- Researchers (senior and young scientists) from fourteen different countries (Bangladesh, Pakistan, India, Sri Lanka, Thailand, Vietnam, Myanmar, Malaysia, Singapore, Indonesia, Philippines, USA, South Korea, and Japan) have been trained to use satellite measurement data for air quality assessment during the COVID-19 pandemic in the Monsoon Asia region.
- Air quality assessment has been conducted using air quality data obtained from satellite-based and ground-based measurements across the Monsoon Asia region to investigate the relationship between COVID-19 pandemic lockdowns and the air quality in major cities across 14 countries within the region.
- Three regional workshops (one online workshop and two in-person workshops) on investigating the air quality shifts during the COVID-19 control measures across the Monsoon Asia region have been held to disseminate the knowledge of using satellite technologies and the project findings to scientists, collaborators and policymakers.
- One journal article in a high-impact journal has been accepted for publication, and one article is in the final phase of submission.
- Four presentations have been made at the conference.

5. Publications

Latif, M.T., Purhanudin, N., Afandi, N.Z.M., Cambaliza, M.O.L., Halim, N.D.A., Hawari, N.S.S.L., Hien, T.T., Hlaing, O.M.T., Jansz, W.R.L.H., Khokhar, M.F., Lestari, P., Lung, S.C.C., Naja, M.K., Oanh, N.T.K., Othman, M., Salam, A., Salim, P.M., Song, C.K., Fujinawa, T., Tanimoto, H., & Crawford, J.H. (2024). In-Depth Analysis of Ambient Air Pollution Changes due to the COVID-19 Pandemic in the Asian Monsoon Region. Science of The Total Environment. (Accepted for publication)

6. Media reports, videos and other digital content

https://sites.google.com/view/apntrainingworkshop/home
https://www.ukm.my/talib/news/apn-workshop-and-igac-mango-meeting-on-the-front-page-of-igac-news/
https://twitter.com/MTalib_Latif/status/1665951833150603264/photo/1
https://twitter.com/MTalib_Latif/status/1582642513466527744/photo/1
https://twitter.com/MTalib_Latif/status/1507697399246254092/photo/1

7. Pull quotes

"*This APN project has brought together researchers from the Monsoon Asia and Oceania Networking Group (IGAC-Mango) and contributed to the knowledge on air quality assessment during the COVID-19 pandemic in this region."*

Prof Dr Abdus Salam, IGAC Project Co-Chair

"*This APN project has encouraged early career scientists to find alternative methods for determining air quality in this region through collaboration and training by trainers from NASA and EUMETSAT.*"

-Prof Dr Mohd Talib Latif, Universiti Kebangsaan Malaysia, MALAYSIA

"The APN projects have successfully gathered several members from various countries in the Monsoon Asia region to facilitate policy making on reducing air pollutant concentrations in this region. Many interesting activities have been performed, including the participation of young scientists for capacity building and table discussions between scientists and policymakers. In summary, this project has provided a scientific approach to reducing air pollution and strengthening collaboration for countries in the Asian Monsoon region."

-Dr. Murnira Othman, Universiti Kebangsaan Malaysia, MALAYSIA

8. Acknowledgments

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9. Appendices

Appendix 1: First APN Training Workshop (Online Platform), 21-25 March 2021.

The Asia Pacific Network for Global Change Research (APN-GCR) grant funded a successful first APN Training Workshop, a five-day online training workshop held from 21st March 2021 until 25thMarch 2021. The workshop, titled "Impacts of the COVID-19 Pandemic on Air Quality of the

Monsoon Asia Region: Cross-country Assessment and Facilitating Policy," focused on equipping researchers with the skills to retrieve air quality data from satellite measurements. This collaborative effort, organised alongside NASA and EUMETSAT, addressed a crucial need. Satellite technology offers a valuable alternative for air quality monitoring, especially for countries facing limitations in ground-based measurements due to COVID-19 restrictions. Additionally, the workshop introduced researchers to the latest advancements in satellite-based air quality monitoring, fostering collaboration across the Monsoon Asia region.

Opening the Dialogue: Importance of Satellite Technologies

The workshop commenced with opening remarks by Prof. Dr. Mohd Talib Latif, the project leader. He emphasised the golden opportunity for researchers to learn about satellite technologies and their potential to improve air quality in the region. He expressed his hope that the APN project, integrating satellite imagery with ground-based measurements, would revolutionise air quality research across the Monsoon Asia region. The first day continued with a series of insightful sessions. Dr. Melanie Follette-Cook, Dr. Ana Prados, and Dr. Pawan Gupta from NASA ARSET offered an insider's look at how NASA measures air pollution. Dr. Federico Fierli from EUMETSAT presented on the observational advantages and drawbacks of Sentinel-4 and 5, followed by Dr. Anu-Maija Sundström from the Finnish Meteorological Institute discussing satellite monitoring trends, variability, and limitations.

Deep Dive into Satellite Techniques

The second day delved deeper into technical aspects of satellite technologies. The morning session, led by Dr. Follette-Cook and Dr. Gupta, focused on "Sensing of NO2 with OMI." Participants received hands-on training in downloading OMI data. The workshop also introduced "Introducing TROPOMI: High-Resolution NO2 Observations from Space," again led by Dr. Follette-Cook and Dr. Gupta, with practical exercises on downloading Sentinel-5P NO2 data.

Expanding the Toolkit: Workflows and Services

Day three featured a session by Sabrina Szeto from EUMETSAT on workflows for NO2 data retrieval using GOME-2, OMI, and Sentinel-5P. Dr. Mark Parrington from ECMWF presented on the Copernicus Atmosphere Monitoring Service (CAMS) and its associated workflows.

Data Analysis and Applications

The fourth day built upon the previous sessions. Dr. Gupta, Dr. Follette-Cook, and Dr. Prados revisited air pollution measurement techniques employed by NASA. Participants learned how to read, map, and analyse Level 2 MODIS AOD data and VIIRS aerosol products using Python scripts. They also received practical assignments to solidify their understanding.

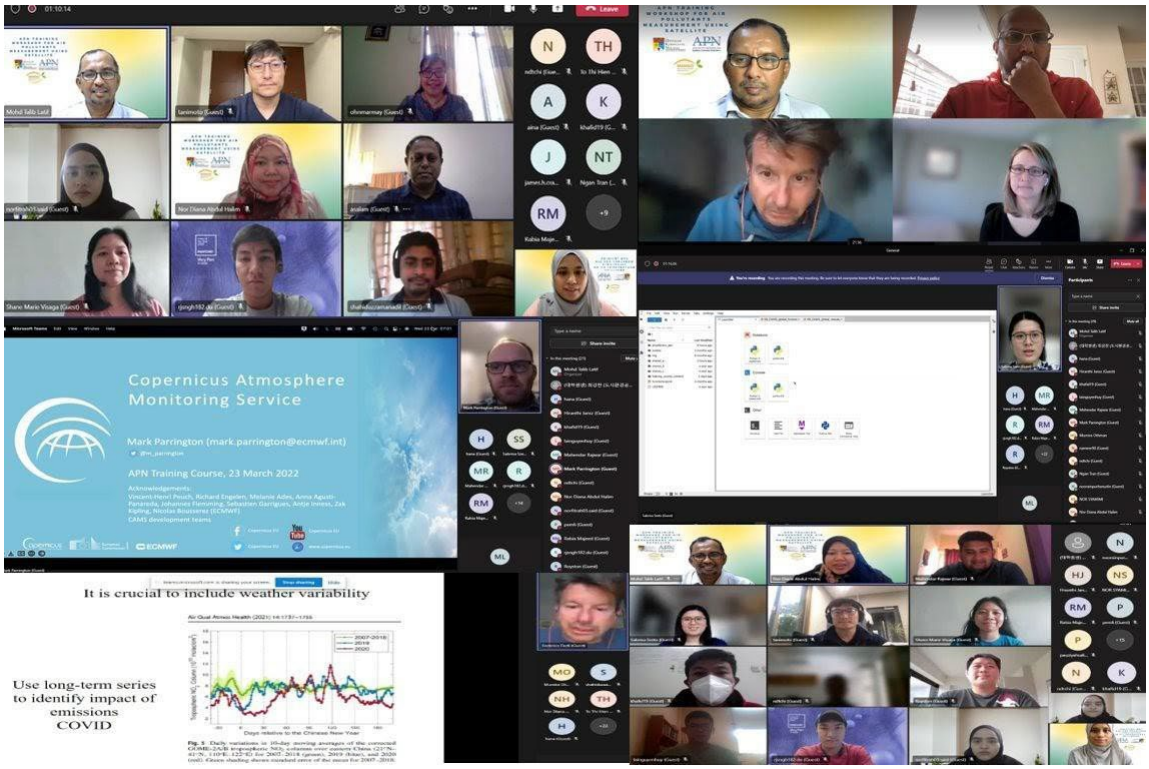
Sharing Regional Expertise - Applications Beyond Air Quality

The final day included a session by Myungje Choi from Yonsei University, South Korea, on aerosol observations from HIMAWARI, GOCI, and GEMS satellites over Asia. Sabrina Szeto from EUMETSAT wrapped up the workshop with a presentation on satellite data discovery for monitoring smoke impacts from wildfires in Indonesia.

Concluding Remarks and Looking Forward

Prof. Dr. Mohd Talib Latif delivered closing remarks during the ceremony, expressing his hope that participants would utilise the acquired knowledge and information to implement comprehensive air quality monitoring programs in their respective Monsoon Asian countries.

Some glimpse of the first APN training workshop that conducted on an online platform



Appendix 2: Second APN Training Workshop on "Data Interpretation Combining Satellite and Ground-Level Observations in The Asian Monsoon Region", 16 - 20 October 2022 in Kuala Lumpur, Malaysia

The second APN training workshop, titled "Data Interpretation Combining Satellite and Ground-Level Observations in the Asian Monsoon Region," took place from 17th October - 20th October 2022, at Hotel Maya in Kuala Lumpur, Malaysia. This workshop aimed to equip young scientists

with hands-on experience in interpreting satellite and ground-level air quality data using specialised tools. Senior scientists, meanwhile, focused on collaborative activities like developing research publications, planning future research directions, fostering network collaborations, and strategizing effective communication of project findings to policymakers.

Opening Remarks and Setting the Stage

The workshop commenced with welcoming remarks by Prof. Dr. Mohd Talib Latif, the project leader. Following this, Dr. Hiroshi Tanimoto provided an overview of the workshop's objectives and the broader APN research project. The day continued with plenary sessions featuring Dr. Barry Lefer from NASA discussing air quality during COVID-19 lockdowns and Mr. Wan Aminordin Wan Kamaruddin from Malaysia's Department of Environment (DOE) presenting on the current state and future plans for air quality management in Malaysia. These sessions concluded with a group discussion on air quality challenges across Monsoon Asia. The afternoon concluded with presentations by senior scientists representing each Monsoon Asian country, particularly on air quality monitoring and current research projects.

Tailored Training for Different Roles

The second day offered separate training tracks for young and senior scientists. Young scientists participated in technical sessions like "Exploring and Visualizing Datasets using R" and "Estimation of PM2.5 using Machine Learning in R," led by Dr. Amalin Fatihah from Universiti Teknologi Malaysia (UTM). Meanwhile, senior scientists engaged in discussions on a review paper summarising key project findings and explored potential journal manuscripts for publication. The afternoon continued with an IGAC-MANGO Committee Meeting for senior scientists while young scientists continued to hone their skills with hands-on activities related to machine learning for air pollutant concentration estimation.

Collaboration, Communication, and Moving Forward

Day three featured parallel sessions. Senior scientists participated in discussions led by Dr. James Crawford and Dr. Hiroshi Tanimoto, focusing on fostering research collaborations and strategizing how to effectively deliver project findings to policymakers across the Monsoon Asia region. Young scientists, on the other hand, attended a session on "Data Discovery with Python" led by Sabrina Szeto from EUMETSAT. This session introduced participants to the Metop-B IASI carbon monoxide time series and AERONET time series training platforms, followed by hands-on exercises. The afternoon concluded with poster presentations showcasing the work of young scientists.

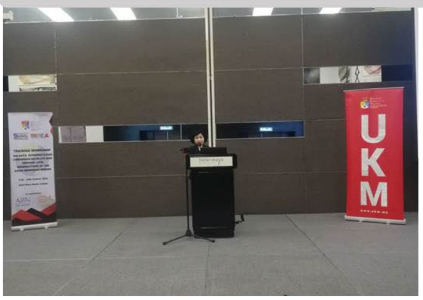
Wrap-up and Recognition

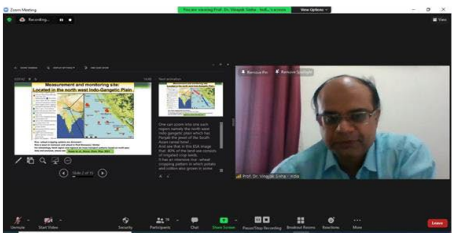
The final day focused on brainstorming future collaborations and research grants aimed at improving air quality across Monsoon Asia. The workshop concluded with a closing ceremony led by Prof. Dr. Mohd Talib Latif. He highlighted the workshop's success and the strong engagement among participants. The ceremony also featured an award presentation to the young scientist with the best poster presentation.

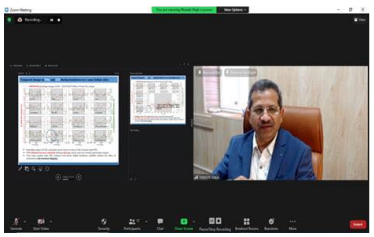
Compilation of photos on the Second APN Training Workshop in Kuala Lumpur

Day 1: 17th October 2022

OPENING CEREMONY, TALK BY INVITED SPEAKERS AND COUNTRY REPRESENTATIVES

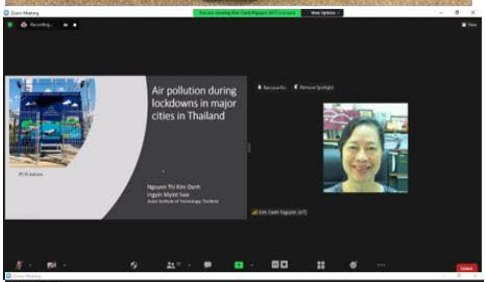






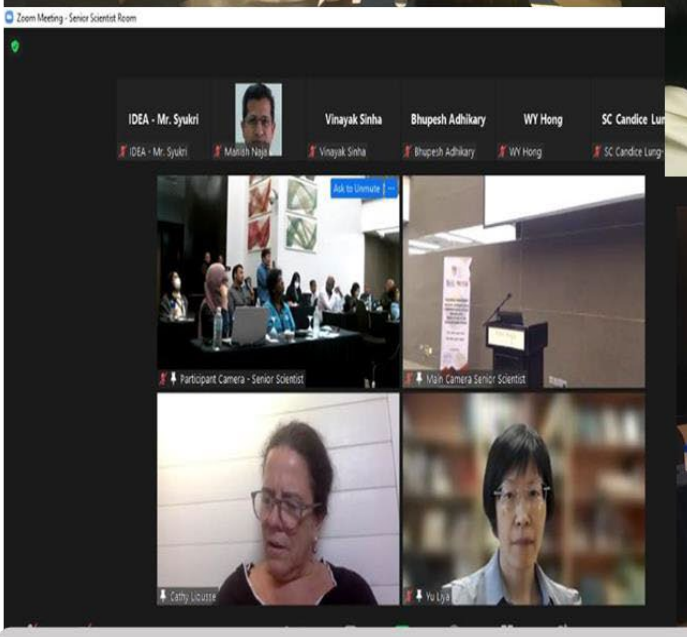
Group Photos all participants (Physical and Online attendants)


UKM


Air pollution during lockdowns in major cities in Thailand


The national monitoring network in China

Day 2: 18th October 2022



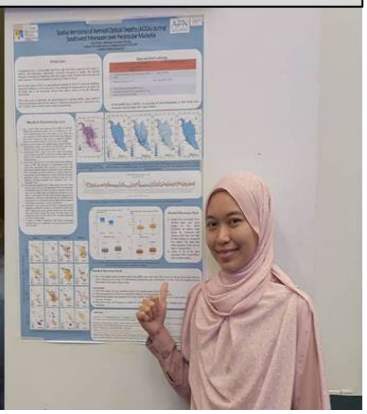
GROUP OF SENIOR SCIENTISTS



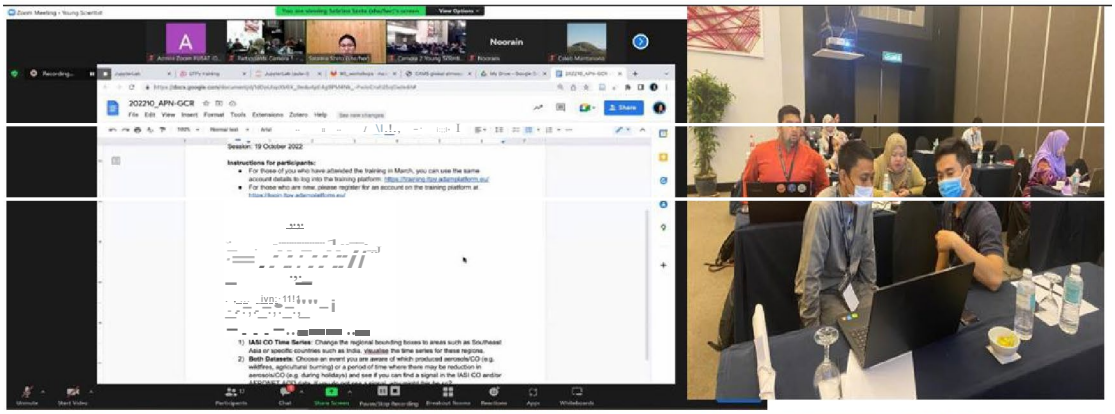


Group of Young Scientist/ Poster Viewing



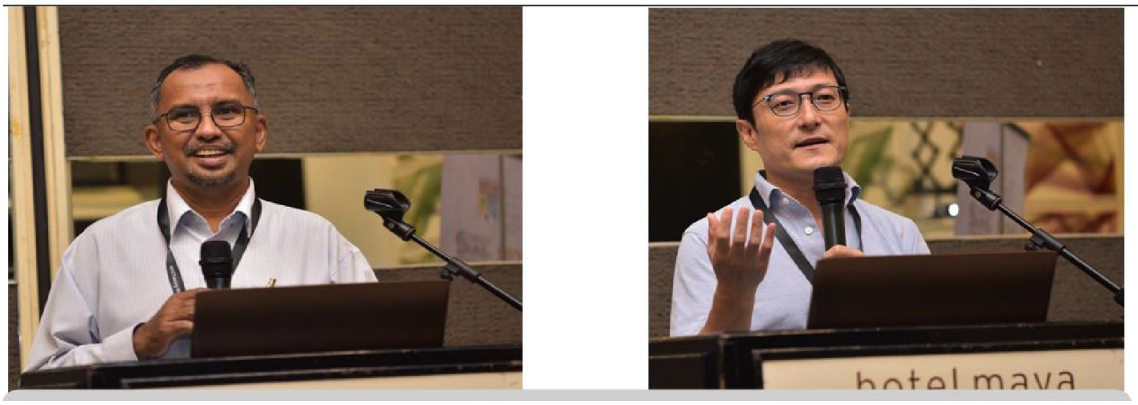


Day 3: 19th October 2022



GROUP OF YOUNG SCIENTIST

Day 4: 20th October 2022



CLOSING CEREMONY_SPEECH

3 WINNERS FOR THE BEST POSTER AWARDS_YOUNG SCIENTISTS

Appendix 3: Third APN Training Workshop on "Impact Of The Covid-19 Pandemic On Air Quality Of The Asian Monsoon Region", 6 - 7 June 2023 in Dhaka, Bangladesh

The Third Asia-Pacific Network for Global Change Research (APN-GCR) Workshop entitiled "Impact of the COVID-19 Pandemic on Air Quality of the Asian Monsoon Region," successfully convened at the University of Dhaka, Bangladesh, on 6 June to 7 June 2023. This two-day event brought together scientists and policymakers from across the Monsoon Asia region, fostering collaboration and knowledge sharing on air quality issues. The workshop was conducted in a hybrid setting with few online participants from Japan and Malaysia.

Opening the Dialogue: Welcoming Remarks and Project Introduction

The workshop commenced with opening remarks from Dr. Hiroshi Tanimoto, Lead Co-Chair of IGAC-MANGO, followed by a welcoming address by Prof. Dr. Md. Abdus Samad, Dean of Faculty Science at the University of Dhaka. Prof. Samad expressed his honour in hosting researchers and policymakers and his hope that the workshop would spark further collaborations in air quality research. In an online platform, project leader Prof. Dr. Mohd Talib Latif introduced the APN project, "Impacts of the COVID-19 Pandemic on Air Quality of the Monsoon Asia Region: Cross-country Assessment and Facilitating Policy," specifically for policymakers from participating countries.

Plenary Sessions: Setting the Stage

The morning session continued with a series of plenary talks. Prof. Dr. Vinayak Sinha from the Indian Institute of Science Education and Research Mohali presented on "Air quality in an environment impacted by extremes: New perspectives from recent research over South Asia." This was followed by Dr. Mohammad Abdul Motalib from the Department of Environment, Bangladesh, discussing "Air Quality Perspectives and Initiatives in Bangladesh." Finally, a senior scientist presented on "Air Quality and COVID-19," providing insights into the pandemic's impact on air quality. Day one concluded with presentations from policymakers representing each Monsoon Asian country. These presentations provided scientists with valuable information on air quality regulations and current policy frameworks in the region. This exchange of knowledge fostered better understanding between the scientific community and policymakers.

Charting the Course for Collaboration

The second day opened with a discussion led by Prof. Dr. Muhammad Fahim Khokhar on "Regional Collaboration on Air Quality Research and Policy Inputs," exploring potential future collaborative research projects across Monsoon Asia.

Breakout Sessions: Addressing Challenges, Building Solutions

Breakout sessions divided scientists and policymakers into two groups for in-depth discussions. These sessions tackled critical questions about air quality challenges and policy implications in each country. The facilitated discussions fostered a deeper understanding of the pandemic's impact and enabled the development of effective policy strategies.

Refining Research and Moving Forward

The afternoon included a presentation by Dr. Nor Diana Abdul Halim and Dr. Murnira Othman on the ongoing progress in developing research publications based on project findings. Policymakers also provided valuable insights on how research can be improved to inform and enhance future policy development. An IGAC-MANGO Committee Meeting followed, focusing on future activities for scientists, particularly early-career researchers. Discussions explored potential research project collaborations and grant applications to secure funding for future endeavours.

Closing Remarks: A Successful Collaboration

Prof. Dr. Mohd Talib Latif delivered closing remarks, expressing his satisfaction with the workshop's success and the wealth of insights shared by policymakers. He emphasised the importance of collaboration between scientists and policymakers in translating research findings into effective policy solutions for cleaner air in the Monsoon Asia region.

Compilation of photos on the Third APN Training Workshop in Dhaka, Bangladesh

Day 1: 6 June 2023
Welcoming Speech and Opening Ceremony by Prof. Dr. Abdus Salam (Chairman of Local Organiser) Dr. Hiroshi Tanimoto (Lead Co-Chair IGAC-MANGO) Prof. Dr. Qamrul Ahsan (Chairman, Department of Chemistry, Dhaka University) Prof. Dr. Md. Abdus Samad (Dean, Faculty of Science, Dhaka University)  

Gift Giving Ceremony to Local Host (University of Dhaka, Bangladesh)

Photo Session

Welcoming Introduction by Prof. Dr. Mohd Talib Latif

Introduction by Participants



















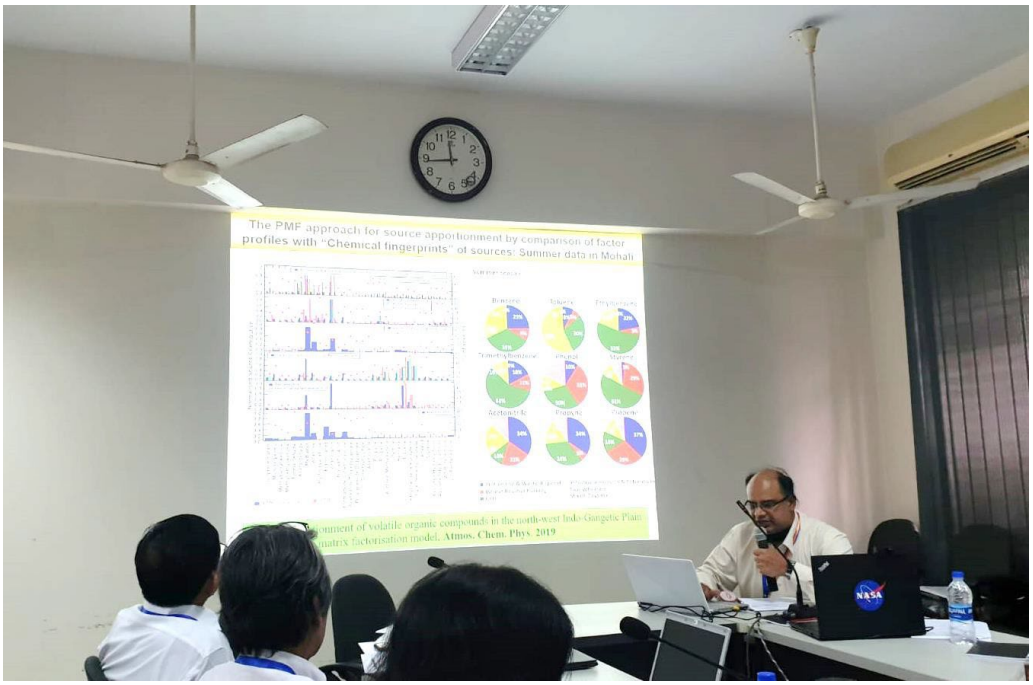




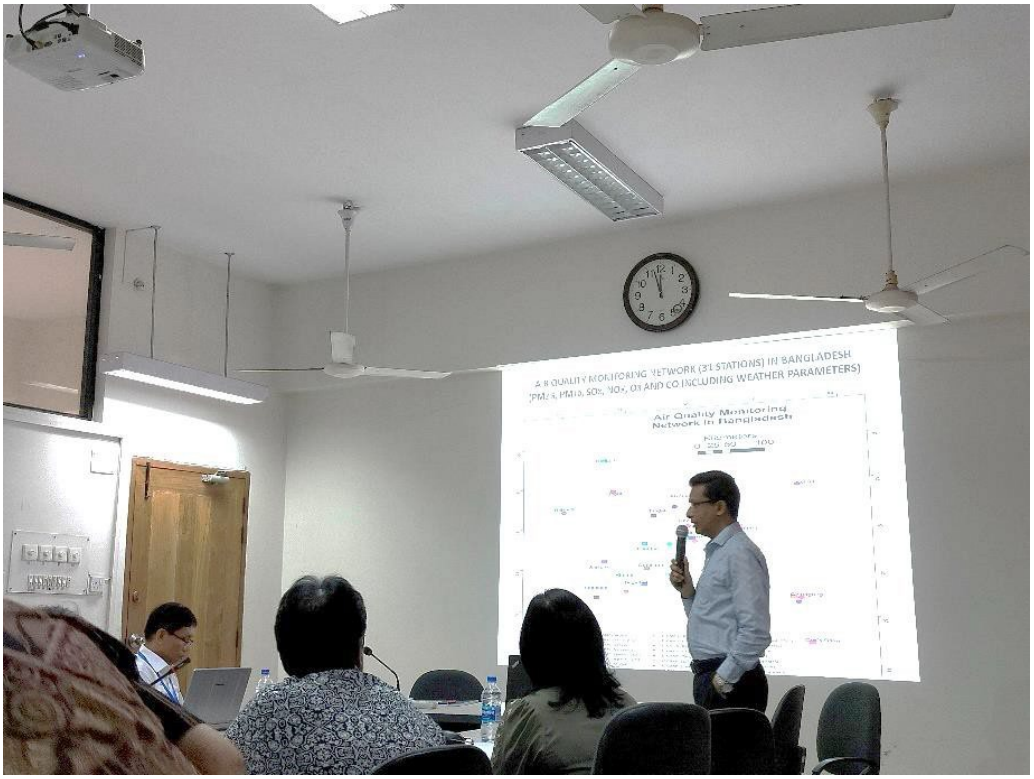
Online participants

Project Introduction by Project Leader, Prof. Dr. Mohd. Talib Latif

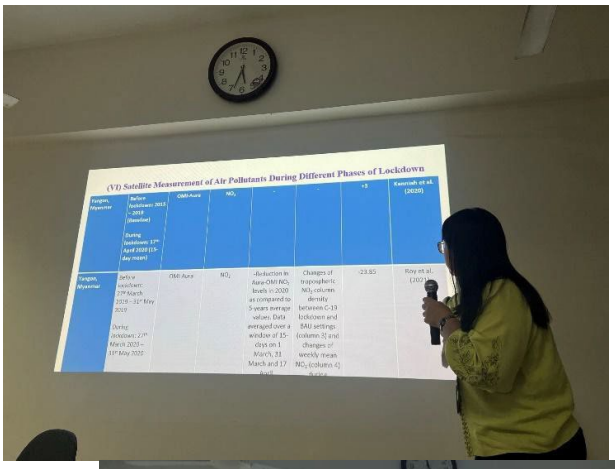
Plenary Talk I by Prof. Dr. Vinayak Sinha

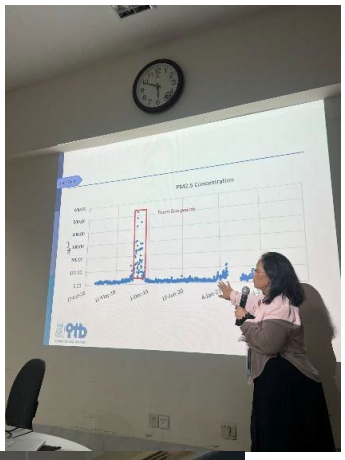


Plenary Talk II by Dr. Mohammad Abdul Motalib



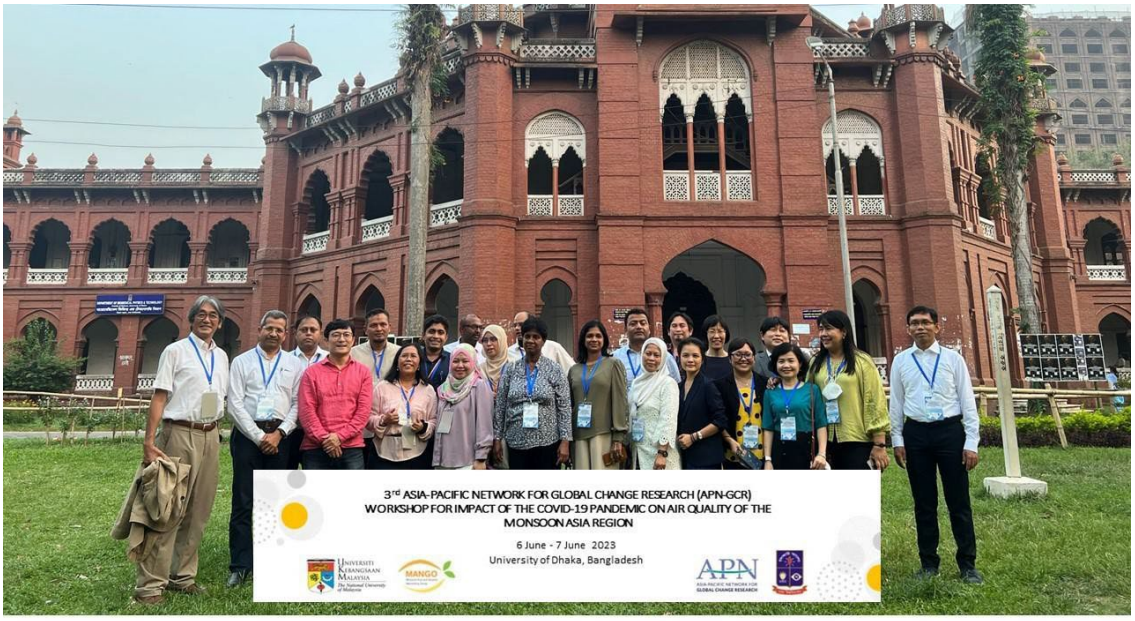
Presentation by Senior Scientists





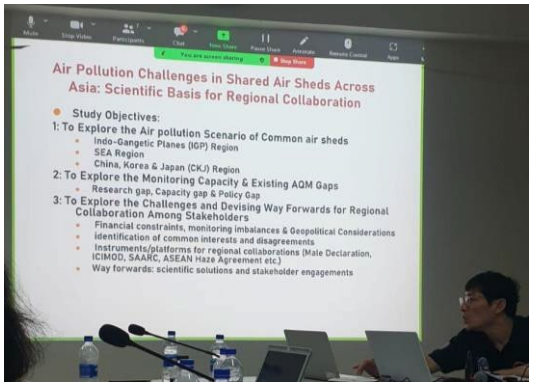
Sharing of National Approach by Policymakers

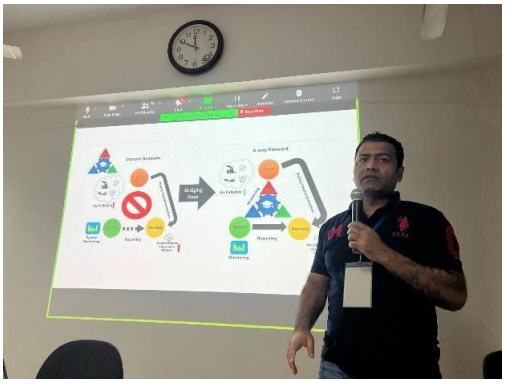
Visit to University of Dhaka, Bangladesh



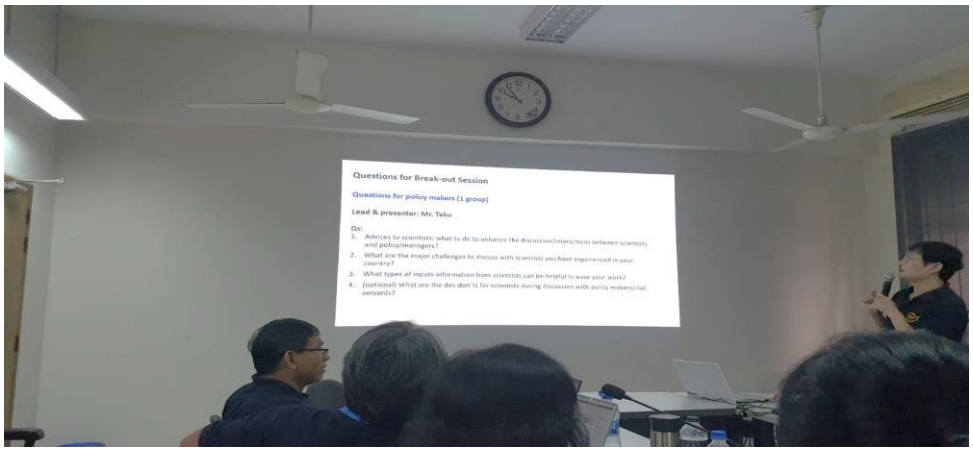
Day 2: 7th June 2023

Discussion on Regional Collaboration by Prof. Dr. Fahim Khokhar

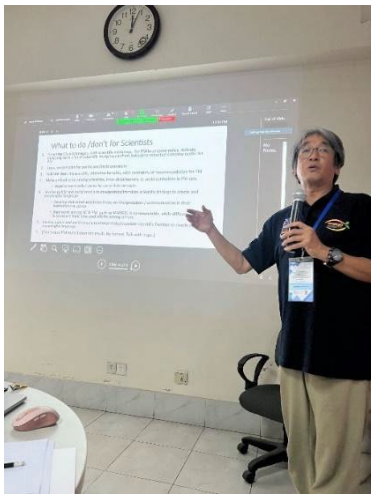


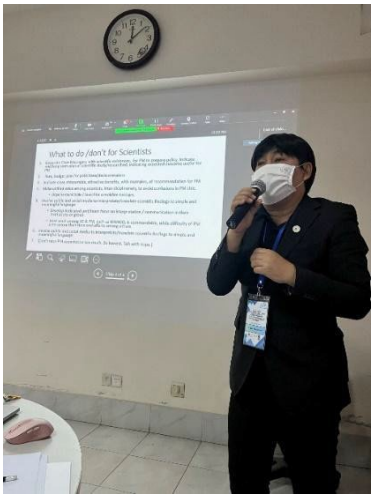


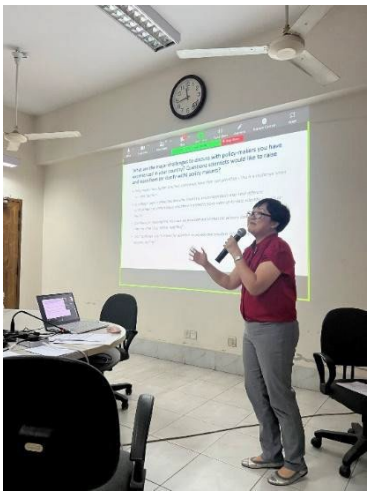
Breakout Session



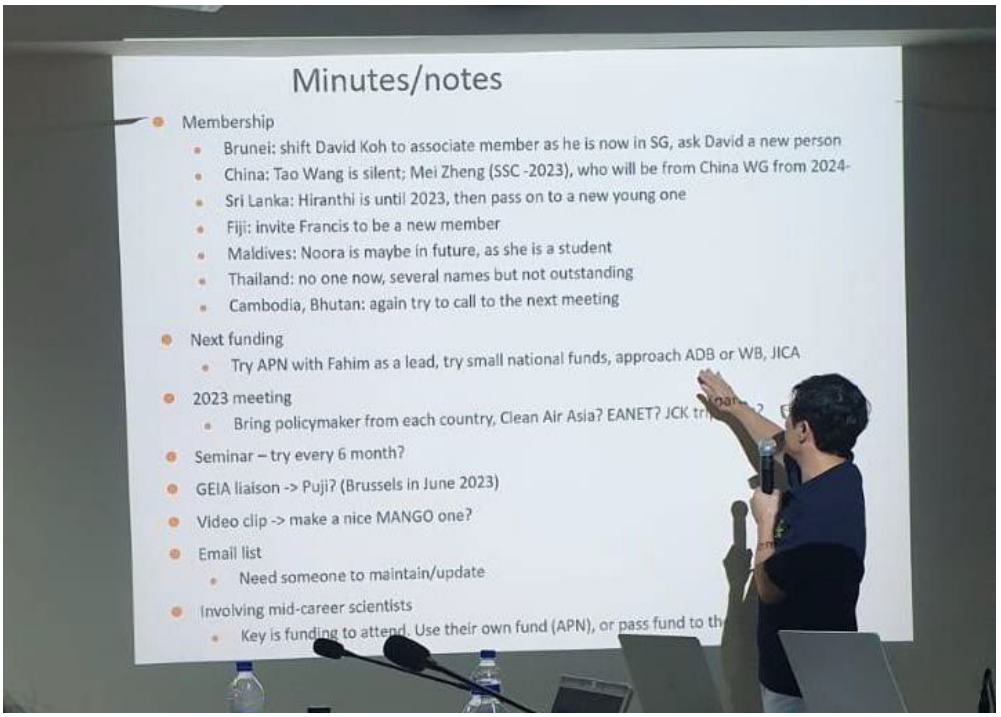
Panel Discussion by Scientists and Policymakers



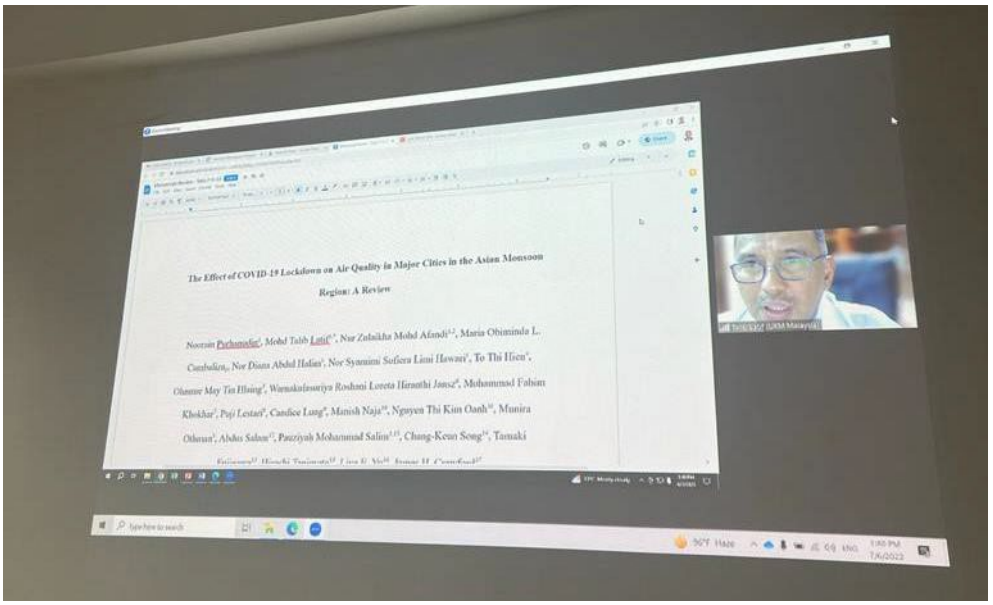




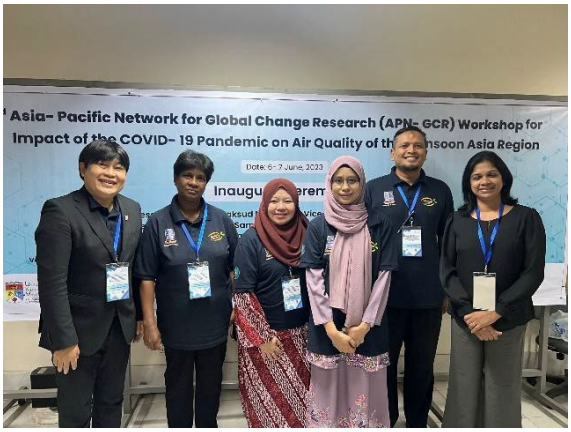
IGAC-MANGO Committee Meeting chaired by Dr. Hiroshi Tanimoto



Discussion on APN Research Project Papers



Closing Ceremony



Appendix 4: Journal Articles

In-Depth Analysis of Ambient Air Pollution Changes due to the COVID-19 Pandemic in the Asian Monsoon Region (Accepted for Publication in Science of The Total Environment, Elsevier, IF 9.8)

Abstract

The COVID-19 pandemic has provided an opportunity for researchers and policymakers worldwide to examine the effects of lockdowns on air quality in each country. This study seeks to examine the effects of activity restrictions implemented during lockdowns in the Monsoon Asia region on the main indicators of air pollution. The different forms of lockdowns enforced in each country were determined by the magnitude of the COVID-19 pandemic. During periods of total lockdown, the levels of main air pollutants, particularly particulate matter (PM) and nitrogen dioxide (NO_2), decreased dramatically in all countries, with the most notable reductions observed in South Asia, including in India and Bangladesh. There were also signs of a substantial decrease in sulphur dioxide (SO_2) and carbon monoxide (CO). Simultaneously, there were signs of rising patterns in surface ozone (O_3), likely caused by nonlinear chemical reactions linked to the decrease of oxides of nitrogen (NO_X). Satellite images also revealed a decrease in the concentration of air pollutants across the region. The aerosol optical depth (AOD) values exhibited a correlation with the PM concentrations in numerous urban areas. Satellite images showed a substantial decrease in NO_2 levels in nearly all cities in the Monsoon Asia region. The significant decrease in air pollutants was linked to a decrease in mobility. Pakistan, India, Bangladesh, Myanmar, Vietnam, and Taiwan exhibited relatively favourable gross domestic product (GDP) growth rates compared to other Monsoon Asia countries amid the COVID-19 pandemic. A positive outcome indicates that the economies of these nations, specifically in relation to industrial activities, endured throughout the COVID-19 pandemic. In general, the COVID-19 lockdowns indicate that air quality in the Monsoon Asia region can be enhanced by decreasing emissions, particularly those related to mobility, which serves as an indicator of traffic in major cities.

Keywords: COVID-19 Pandemic, Air pollutants, Monsoon Asia region, Mobility

Appendix 5: List of young researchers

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Appendix 6: List of conferences

Title	**Author**	**Conference/Symposium/ Seminar Name**	**Year**
Concentration of Major Air Pollutants during the Movement Control Order due to the COVID-19 pandemic in Malaysia	Prof. Dr. Mohd Talib Latif	Conference: 64th Annual Meeting of the Korean Society of Atmospheric Environment in 2021, Jeju Shinhwa World Landing Convention Center, SOUTH KOREA	2021
Air Quality in Greater Kuala Lumpur: Challenges toward Sustainable and Resilient City	Prof. Dr. Mohd Talib Latif	Conference Of Air Quality & 3rd Climate Change And Malaysia Air Quality Annual Symposium (1st AQCCc And 3rd MAQAS 2021)	2021
The concentration of Major Air Pollutants during the Different Phases of Movement Control Orders due to the COVID19 pandemic in Malaysia	Prof. Dr. Mohd Talib Latif	16th IFEH World Congress on Environmental Health (WCEH 2022), World Trade Centre, Kuala Lumpur, MALAYSIA	2022
Air Quality during COVID-19 Lockdown in the Asian Monsoon Region	Dr. Murnira Othman	Atmospheric Composition and the Asian Monsoon (ACAM) 2023, Dhaka, BANGLADESH	2023