BAMS

Meeting summary

State of air pollution and potential mitigation mechanisms for the greater Punjab region

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Regional workshop on Two Punjabs, One Atmosphere

What: 256 researchers, practitioners, and experts from 83 institutions, including 50 speakers from 35 institutions. Each of the four days focused on a different theme: air pollution monitoring and its health impacts, public understanding and social dimensions of air pollution, prominent air pollution sources and potential solutions, winter fog and smog, and regional collaboration.

When: 31 January to 3 February 2022, with 3-hour online sessions daily

Where: Virtual on Zoom, hosted by ICIMOD (www.icimod.org)

KEYWORDS: Air pollution; mitigation; regional collaboration; Greater Punjab; Hindu Kush Himalaya

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Air pollution is a key environmental issue of our time with impacts on health, environment, economy, and food security. It is the fifth leading risk factor for mortality globally (Boogaard et al., 2019). An estimated 9 out of 10 people worldwide are exposed to air pollutants that exceed the World Health Organization's air quality guidelines (WHO, 2021a). Pollution in India and Pakistan has hit record levels with fine particulate matter concentrations reaching over 1000µg/m^3 and nearly 700 µg/m^3 in Lahore and Delhi, respectively (Miro et al., 2019). Data from the State of Global Air shows that annual $PM_{2.5}$ concentrations for India, Pakistan and entire South Asia is 5-9 times higher than WHO annual ambient $PM_{2.5}$ standards and has increased significantly in the last two decades (Figure 1) (Health Effects Institute. 2020). Most of the polluted cities (49 out of 50) fall in four HKH countries (India, China, Bangladesh and Pakistan) in 2020 (IQAir, 2020). Regionally, this is also a transboundary issue for the fragile ecosystems in the Hindu Kush Himalaya (HKH).

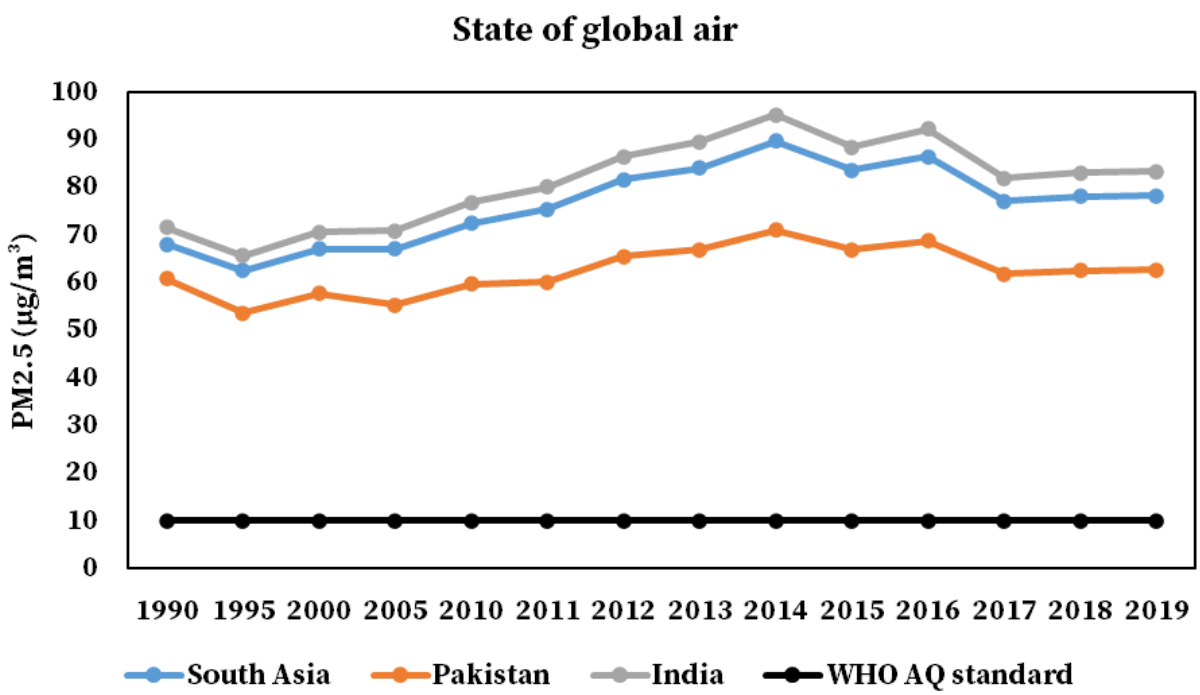

Figure 1: Annual PM2.5 over India, Pakistan and South Asia for year 1990 to 2019 (Data source: State of global air)

The regional workshop on Two Punjabs One Atmosphere, organized in collaboration with the U.S. State Department, brought together researchers and practitioners from diverse sectors and

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disciplines to discuss the multidimensional issue of air pollution. The issue is linked to industrial, urban, and economic growth with other factors like individual behavior, public perception, gender and social inclusion, education, and economic conditions adding to its complexity. The workshop was designed to discuss and unpack all the relevant aspects like monitoring, impacts, public understanding, and potential solutions of air pollution as well as nurturing regional collaborations between stakeholders, experts from the region and beyond. Moreover, it also served as a platform to support the establishment of a network of specialists to assist in development of a regional perspective that has the potential to influence decision makers across the Greater Punjab region (constituting the Indian state of Punjab and state of Punjab in Pakistan).

Overview of sessions and discussions

Each of the four days followed a standard three-session format, beginning with three to five thematic keynote presentations, followed by four-to-five-member panel discussions moderated by a subject expert. The discussions and the conclusions and recommendations are detailed below.

Air pollution monitoring

Ground-based monitoring stations, low-cost sensors, satellite data, and air quality models are used to generate air quality data in and around the region. In combination, these tools have significantly improved our understanding of air pollution sources, contributions of different sectors, and overall air pollution. It was noted that there are still extremely few monitoring stations in the region, and little investment from governments (local, state, federal) despite the scale and urgency of the problem. Ground-based monitoring capabilities are inadequate in terms of numbers (only 0.2 monitors per million population), as well as spatial representation (Martin et al., 2019). Low-cost sensors are emerging as useful and cost-effective tool for indoor/outdoor monitoring and exposure measurements, and can fill existing gaps (Snyder et al., 2013; Zheng et

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al., 2018). Satellite based observations provide continuous or periodic air quality information with regional to global coverage. These can be used to estimate pollutant load, movement of aerosol plumes, and annual seasonal or intra-seasonal trends in pollution level (Acharya & Sreekesh, 2013; Rajeev et al., 2000; van Donkelaar et al., 2016; Zeb et al., 2019). Air quality models are filling existing data gaps as well as producing important air pollution information for emission control strategies, addressing regional pollution transport, and future projections through chemistry-climate simulations, model sensitivity experiments, process analysis, and tagged tracer experiments.

Table 1: A detailed status of air pollution monitoring methods in the region.

Status of air pollution monitoring methods	
Ground-based monitoring stations	Currently, Central Pollution Control Board of India, along with State Pollution Control Boards and Pollution Control Committees across the whole of India are monitoring ambient air quality at 804 locations (CPCB, 2021). In the state of Punjab (India) there are 37 stations, and EPA Punjab (Pakistan) measures and release advisory for 6 monitoring stations - Town Hall, Township, National Hockey Stadium Gulberg Lahore, University of Punjab Lahore, Mobile AQMS Rawalpindi, and Rahim Yar Khan (EPD, 2022)
Low-cost sensors	There are many kinds of low-cost sensors with varied accuracy. With proper calibration and relative humidity correction low-cost sensors can be very accurate (Zheng et al., 2018). It is possible to build reliable monitoring networks using low-cost sensors,

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	existing reference networks, and mathematical algorithms.
Satellite based observations	Aerosol types can be characterized using satellite data, for example OMI-UVAAI in combination with MOPITT/AIRS CO total columns. Such remote sensing data can now categorize aerosol into smoke, dust and sulfate (Khokhar et al., 2016; Torres et al., 2013). Progress is also being made in the usage of satellite images and other measurements with deep learning algorithm to develop high resolution (~200 m) air pollution information.
Air quality models	Despite some uncertainty, models are helping decision-makers across the world for better air quality management. Forecasting air pollution through air quality models is important to take short term measures from a public health perspective. Chemical data assimilation and incorporating aerosol radiation interaction has been found to be effective in improving air quality forecasts (Kumar et al., 2020).

Despite these improvements, there is still a lack of reliable data on air pollution and exposure. An important knowledge gap identified was the dearth of studies and research around source apportionment and emission inventories for the region. Another major challenge noted by

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participants was the lack of openness and transparency about available data. There is also limited standardization and quality assurance of the data, which then also hinders policymaking and legislation on the issue. An assessment of existing data also shows that there is an urban bias in terms of the research, with very little data/studies on rural and peri-urban areas.

There is an important role for institutions from within and outside the region to help collect data. For example, Duke University, together with United States State Department, and in collaboration with universities in the HKH are installing sensors across the IGP to help bolster monitoring capabilities. Other than collaboration among authorities and institutions, there is also an important role for citizen science. Involvement of people in the science around air pollution can also potentially help change behaviors on the ground.

Health impacts of air pollution

There is an increasing trend in the total levels of air pollution as well as negative health and environmental impacts caused by it in recent decades. Over these same decades, science has also linked air pollution to cardiopulmonary conditions, cancer, diabetes, tuberculosis, neurodegenerative disorders, mental health, pregnancy losses, reduced birth weight, and life expectancy (Balakrishnan et al., 2018; Dockery et al., 1993; Pope III et al., 2002).

While air pollution gathers a lot of attention during the winter months (October–March) when it peaks, air quality in the region is in the unhealthy and hazardous for human health range almost year round. The AQI at any point in time is higher than acceptable WHO standards. Approximately 33% of annual mortality attributed to exposure to air pollution and particulate matter is recorded in South Asia (Mcduffie et al., 2021). India and Pakistan are ranked 2nd and 4th in the excess mortality rate attributed to air pollution, with 1.8 million and 0.2 million excess deaths annually in India and Pakistan, respectively (Lelieveld et al, 2015). Residential sector is responsible for 50% and 31% of the deaths attributed to outdoor air pollution in India and Pakistan (Lelieveld et al., 2015). Countries in the region top the world in air pollution related deaths; the economic losses resulting from air pollution are also the highest in this region.

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While the links between air pollution and negative health outcomes is clearly established, air pollution's impacts are also longer term. As a result, policymakers require longitudinal data and research to justify government spending as well to formulate necessary legislation.

Monitoring capabilities targeted at health impact assessments, such as personal exposure monitoring, are important for accurate assessment of human health risks and to identify susceptible populations. Such information aids decision-makers to mobilize targeted mitigation and adaptation actions. However, the research and data linking air pollution to health in the two Punjabs, and in the region overall, is limited. The major limitation is lack of epidemiological and toxicological studies around air pollution, lack of proper biomarkers for exposure, and local level data to better understand the linkages and impacts between air pollution and health. One way to understand these linkages and impacts is through modeling, but modeling of human exposure to air pollutants is yet to be done.

Social dimensions and public understanding of air pollution

The sources and impacts of air pollution play out at the societal level. Research has clearly established that there is a disproportionate impact of air pollution on socio-economically marginalized communities and groups in the Punjabs and the wider IGP, with clear gendered impacts as well. Moreover, studies on atmospheric changes and air pollution indicate that effective communications can determine public understanding and action on air pollution (RichBord et al., 2000). There seems to be little understanding of the risks, hazards and socio-economic interlinkages associated with air pollution at the ground level in the Greater Punjab, and the IGP, with limited knowledge dissemination around it and related issues.

Socially and economically marginalized people tend to be the most impacted although they contribute very little to overall air pollution. They do not have the luxury or the choice to stop working when air pollution levels are deemed hazardous, as they must tend to their fields, work as daily wage laborers, or ply their trades in the open. They have very little leverage in negotiating for workspaces with lower exposure to air pollution thereby increasing their chances of falling ill, adding to their expenses, and weakening their economic situation. Hence, the burden of disease

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at household level is so high for the poor that they are often trapped in a self-reinforcing vicious vulnerability cycle of exposure to air pollution. Therefore, there is an urgent need to investigate the environmental injustice dimension of air pollution exposure and impacts to develop protection mechanisms for vulnerable populations. There is a gap in research on the economic and social costs of air pollution at household level. Based on observations of other pressing issues in the region, when atmospheric monitoring studies are reinforced with economic cost studies, it tends to help push policy more urgently and significantly. An issue gets attention from public and policymakers only when there are clear numbers and associated costs. It also helps nudge behavioral change in society.

In addition to socio-economic status, air pollution exposure and impacts are also determined by gender in the HKH region, within and outside the household. Prevalent gender norms in the region, which strongly places the burden of cooking and collecting fuel on women and children, means they are at higher risk from the negative impacts of air pollution within the household.

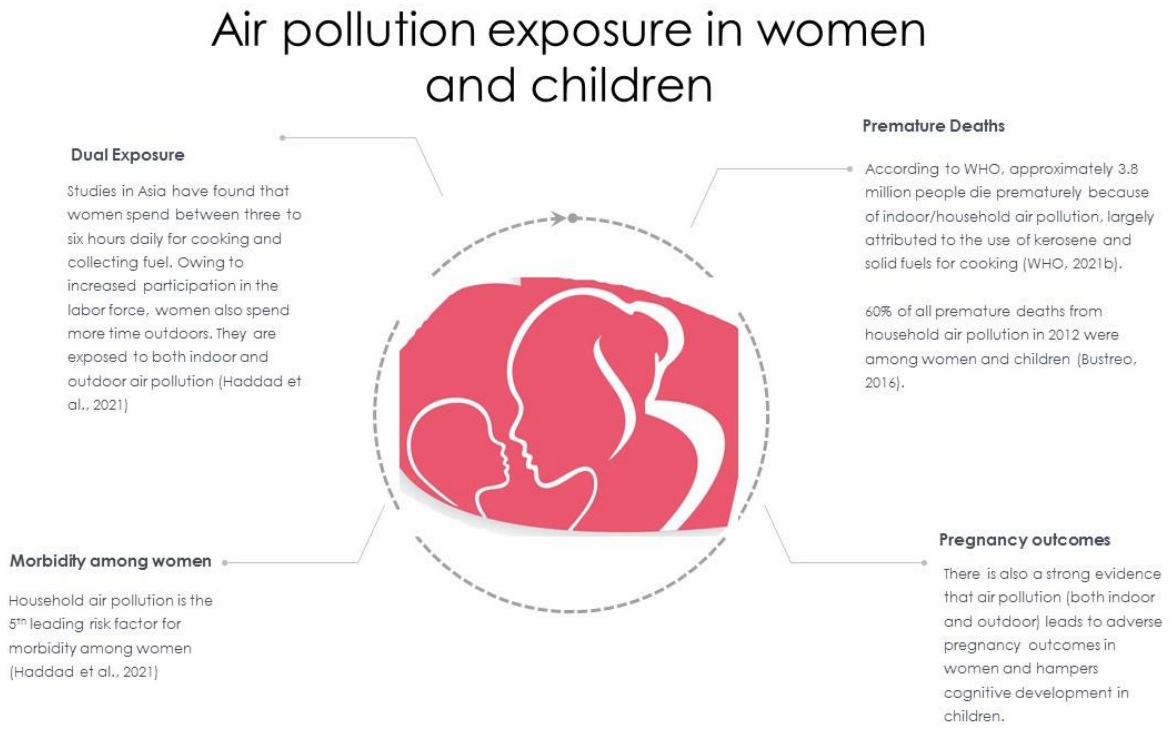

Figure 2: Impact and status of air pollution exposure in women and children.

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Effective communication is vital to inform the public regarding air pollution. Coverage of the issue is increasing in mass media, although the messaging around adverse impacts and gravity of this issue for public health appears inadequate. It has also been observed that the region is lacking in locally appropriate communications and outreach around air pollution. Most outreach tends to focus on stopping/prohibiting certain behaviors (e.g., open agricultural burning; using biomass for cooking; burning garbage), without offering viable alternatives or even understanding the reasons for such practices. There is a major disconnect in the level of understanding of the issue among the public and the policymakers. Information in the public sphere does not present the bigger picture, or correspond to the official government position. For example, the agriculture sector currently contributes much less air pollution than the residential sector in the Indian context, yet this aspect is hardly highlighted despite formal government statements that agriculture-based pollution, especially straw burning, contributes less than 10 per cent and happens in the winter months. Moreover, the issue continues to only be seen as a seasonal issue when air quality in the region becomes visibly bad. In addition to this, industrial sources of air pollution such as petroleum coke appear to be largely overlooked in the public air pollution discourse. Therefore, it is vital to integrate outreach around air pollution to policy and regulatory mechanisms if behavior change campaigns are to be effective. Two-way communications with communities on the ground are also critical to first understand nuances around such practices, and address it through viable solutions.

Prominent air pollution sources and potential solutions

Sources and drivers of air pollutions in the region

The transport sector, industrial combustion, and open burning have been listed as the major contributors to deteriorating air quality across the Greater Punjab in India and Pakistan. It is also estimated that particulate emissions, especially PM 2.5, would increase significantly from brick making, open burning, and transport sectors by 2030 if mitigation measures are not implemented in India (TERI, 2015). Pakistan is also expected to experience a similar fate, especially when its air has already been flagged as being amongst most polluted globally.

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Emissions from the brick sector have increased significantly due to the construction boom and the continued use of old technologies for firing bricks. Open burning of agricultural residue and vehicular emissions has been a persistent problem and continues unabated despite various measures to curb it. These trends and increasing incidence of air pollution are projected to increase rapidly because of economic growth and development.

A large proportion of air pollution in the region can be directly linked to unsustainable development. Lack of proper land use planning, waste management, lack of proper masterplans for urban development, transport and mobility network planning, and power planning, currently all directly and indirectly lead to air pollution.

Mitigation actions and potential solutions

There are some examples of effective local interventions to address air pollution in the HKH/ South Asia region. The city of Surat in western India addressed air pollution from the ground-up, by tackling waste management to curb open burning. After the success of this initiative, attention is now focused on the construction sector, which is also one of the major contributors to air pollution. Emergence of zig-zag technology use in the brick industry in Nepal and Pakistan has paved the way in reducing emissions. There is also work ongoing on developing greener construction codes, which is expected to further help air quality in the city. Another set of examples from the region where local municipalities have intervened to minimize air pollution, come from Gujarat and Uttarakhand in India. Local authorities in these states have retrofitted old towns and industrial areas to ensure there are green corridors, open spaces, and new technologies to minimize air pollution and other negative environmental impacts which have resulted from rapid development. There has also been a boom in the use of electric vehicles in recent years, which is a welcome sign towards green mobility in urban centers. These would require significant support from governments in the region to facilitate take-up. Moreover, countries like Bhutan and Nepal have hydropower surplus which presents the potential to adopt induction based clean cooking in the region.

As the region prepares for the eventuality that much of the population will be urban relatively soon, it is going to be important for authorities to start understanding and better tackling urban

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sources of air pollution immediately. There is an opportunity for proper urban planning, and waste, mobility and energy planning for urban centers which will come up soon. There are good examples from within the region and beyond to learn from.

Sustaining the solutions will require buy-in and involvement of the private sector. There is a need to demonstrate to the private sector that investing in environmental solutions like air pollution is going to be profitable in the long run. It is already clear that the costs of inaction on environmental solutions outweighs any type of investment. This is also going to be important to mainstream solutions and minimize the reliance on grants and funding from donors/NGOs for solutions in the region.

Regional air pollution and collaborations

Air pollution in the Greater Punjab and the wider IGP is a regional issue. Tracer studies show that particulates generated in the Punjabs can and do travel across the greater IGP region (and vice versa). While local level efforts and solutions are extremely important, so are regional level ones.

Regional air pollution issues

For the IGP, winter fog and smog has become an annual feature with visibility levels dropping to less than 50 ft in the peak of winter. Research over the last two decades show that there is an increasing trend in winter fog as well as the number of days with poor visibility each year. Analysis of particulate pollution and fog in the region shows that during the crop residue burning season (October-November), elevated levels of air pollution are concentrated in the Punjab region (of both Pakistan and India) in western IGP, and slowly spread across the IGP up to Bangladesh. There appears to be a greater concentration of winter haze over eastern and central parts of IGP.

One major challenge noted by the participants was the lack of openness and transparency with regards to available data. There is very little data-sharing or regional cooperation and collaboration on air pollution, even though it is well established that air pollution affects the region on a transboundary scale. There is also limited standardization and quality assurance of data, which hinders focused policymaking and legislation.

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Despite the growing volume of data on air pollution, issues around the consensus on data remain, which directly affects policymaking. There also appears to be a general distrust of private and NGO data and data collectors. A lot of the research and studies around air pollution also relies quite heavily on modelling and simulations, which has also led to questions around the accuracy and validity of the results. Air pollution is a regional issue that requires a regional solution. There are some efforts to frame and tackle the issue from a regional perspective (Table 2)

Table 2: Existing regional collaborative mechanisms to tackle air pollution.

Regional collaborative mechanism	**Description**
Conversion of brick kilns from traditional to more efficient zig-zag technology	Following the Great Earthquake of 2015 in Nepal, many brick kilns were converted into zig-zag kilns. This transition not only reduced air pollution but was more fuel efficient and produced better quality bricks. Following the success of this intervention for brick kiln owners in Nepal, the technology has since been transferred to Bangladesh, Pakistan, and India. Many kilns in the Punjab region of Pakistan have now transitioned, with government commitment to the technology.
South Asian Association for Regional Cooperation (SAARC) studies to convert crop residue into fuel source	Based on SAARC's studies, it is estimated that from the 114 billion tons of surplus crop residue in the region every year, up to 7,600MW of power can be generated. There are now efforts ongoing to address the challenge of collection and storage of the residue, both from the government and private sectors in the region.
SERVIR (a collaboration between NASA and USAID)	SERVIR has been focusing on the Mekong region where they have developed Mekong Air Quality Explorer (MAQE), a monitoring and forecasting

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	tool. MAQE uses historical, near real time, and forecast data for tracking aerosols and fires, pollution transport, and PM2.5 concentration over the Mekong region.
The Male Declaration	The Male Declaration of 1998, brought about under the stewardship of South Asia Co-operative Environment Programme (SACEP), is a call for regional cooperation to address the increasing threat of air pollution in the region. Though dormant for many years, there are currently plans by SACEP to update and re-start the Male Declaration to help South Asian governments address air pollution issues.

Conclusion

Discussions over the four-day workshop highlighted that any effective response to dealing with air pollution must be regional and transboundary in nature. The overwhelming consensus was that the region must collectively develop a standard on pollutants and act on air pollution at the regional level, and ensure that science is an important component of foreign relations and foreign policies of all respective countries. Similarly, regional collaboration and transparency in terms of data and demonstration of effective solutions are going to be important for quick uptake and scaling of solutions. At the same time, addressing regional air pollution would also require addressing other regional issues like energy security, energy conservation, and energy efficiency.

Timely sharing of information, identification of vulnerable populations, and overall improvement in communication around air pollution, hazards and impacts can help develop effective responses and minimize harm. The topic of air pollution must be addressed and communicated as a package with unambiguous linkages to social and environmental systems – and to daily life. Greater public discourse increases the likelihood of authorities and governments acting on a particular issue.

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With better understanding around air pollution, the problem with implementation of solutions can be dealt with at the community level.

There appears to be a policy lag at addressing the environmental and health impacts of growing air pollution in the Greater Punjab and IGP region over the past decades. One of the main reasons cited by policy makers and practitioners has been the technicality of the science and the subject matter. Effective communication of air pollution and atmospheric sciences to practitioners and policymakers, coupled with enabling regulatory changes, can help address this challenge.

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The list of names and affiliations of all speakers and panel members in the workshop (in alphabetical order)

1) Aaron Naeger, Research Scientist, University of Alabama in Huntsville
2) Ajay Singh Nagpure, Program Head - Air Quality, World Resources Institute (WRI) India
3) Amandeep Sandhu, Author and social/political commentator
4) Anumita Roy Chowdhury, Executive Director Research And Advocacy, Centre for Science and Environment
5) Asad Mahmood, Head of Technical Services & Company Secretary, National Energy Efficiency & Conservation Authority (NEECA)
6) Bhushan Tuladhar, Chief of Party, USAID Swachchha Hawa, FHI 360, Nepal
7) Debajit Palit, Director, Rural Energy and Livelihoods, The Energy & Resources Institute (TERI)
8) Donee Alexander, Senior Director of Evidence and Impact, Clean Cooking Alliance (CCA)
9) Eri Saikawa, Associate Professor, Department of Environmental Sciences, Emory University
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12) Farzana Altaf Shah, Director General, Pakistan Environmental Protection Agency
13) Fiona Lambe, Research Fellow, Stockholm Environment Institute
14) Gufran-Ullah Beig, Founder Project Director-SAFAR, Indian Institute of Tropical Meteorology, Pune
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16) Ihsanullah Marwat, Research Fellow (Energy Efficiency), SAARC Energy Center
17) Irfan Younas, CEO and Project Director, Kadam Communications & Consultants Private Ltd
18) Jatinder Singh Kamyotra, Ex - Member Secretary, Central Pollution Control Board and Regional Facilitator of the Malé Declaration
19) Karuna Bajracharya, Nepal Country Manager, Clean Cooking Alliance (CCA)
20) Kaye Patdu, Coordinator – Asia Pacific Clean Air Partnership, United Nations Environment Programme (UNEP)
21) Laura Djuragic, Regional Environmental Officer for South Asia, U.S. Department of State
22) Maryam Shabir, Senior Research Associate , Sustainable Development Policy Institute (SDPI)
23) Md Masumur Rahman, Director General, South Asia Co-operative Environment Programme (SACEP)
24) Mehar Abdul Haq, Senior Vice Chairman, Brick Kilns Owners' Association Pakistan and Founding Member, Federation of Asian Brick Kiln Associations (FABKA)
25) Michael Howard Bergin, Sternberg Family Professor of Civil & Environmental Engineering, Duke University
26) Muhammad Fahim Khokhar, HOD Environmental Sciences, Institute of Environmental Sciences & Engineering (IESE)
27) Nazifa Butt, Senior Manager, Climate and Energy Programme, WWF-Pakistan
28) Peter DeCarlo, Associate Professor, John Hopkins University
29) Poornima Prabhakaran, Head-Environmental Health & Additional Professor, and Deputy Director, Centre for Environmental Health, Public Health Foundation of India
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32) Raghu Babu Nukala, Project Director, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
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34) Ravindra Khaiwal, Professor, Community Medicine and School of Public Health, Postgraduate Institute of Medical Education and Research (PGIMER)
35) Ritesh Gautam, Lead Senior Scientist, Environmental Defense Fund
36) Sandeep Roy Choudhury, Director and co-founder at VNV Advisory Services
37) Uma Rajarathnam , Regional Adviser, Chemical Safety, Environment & Air Pollution, World Health Organization South-East Asia Region - WHO SEARO
38) Zulfiqar Ali, Associate Professor, University of the Punjab

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