November 2017

Tackling the health burden of air pollution in South Asia

Bhargav Krishna
Public Health Foundation of India, Gurgaon, India

Kalpana Balakrishnan
Sri Ramachandra University, Chennai, India

Amna R. Siddiqui
Aga Khan University, rehana.siddiqui@aku.edu

Bilkis A. Begum
Atomic Energy Centre, Dhaka, Bangladesh

Damodar Bachani
Public Health Foundation of India, Gurgaon, India

See next page for additional authors

Authors
Bhargav Krishna, Kalpana Balakrishnan, Amna R. Siddiqui, Bilkis A. Begum, Damodar Bachani, and Michael Brauer

Tackling the health burden of air pollution in South Asia

Bhargav Krishna and colleagues call for health driven, multisectoral policy making with defined air quality targets to curb the impact of air pollution exposure in South Asia

Air pollution exposure is the second most important risk factor for ill health in South Asia, contributing to between 13% and 21.7% of all deaths and approximately 58 million disability adjusted life years (DALYs) through chronic and acute respiratory and cardiovascular illnesses.[1] Of the top 30 cities in the world with the poorest air quality in 2016, 17 are in South Asia.[2] The impact of air pollution transcends boundaries. The "brown cloud"—caused by pollution from carbon aerosols—is a phenomenon captured in satellite images of atmospheric haze over South Asia, as well as China. South Asia has one of the highest concentrations of black carbon emissions from cars and trucks, cooking stoves, and industrial facilities. In addition to their effect on health, black carbon particles are a short lived climate pollutant with a possible impact on precipitation patterns and on the Himalayan glacier system, which threatens water resources in the region.[3]

Collective regional action to monitor air quality and implement evidence based policies and interventions is needed. While countries have introduced promising initiatives in recent years, comprehensive health centred strategies are lacking. We present the status of air pollution and health effects in South Asia, and propose urgent, concerted action across sectors to achieve recommended air quality standards for the people of the region.

Air pollution exposure and trends

Household (indoor) and ambient (outdoor) air pollution both contribute to ill health.

KEY MESSAGES

- Air pollution is a major risk factor for ill health in South Asia
- The interconnected nature of the South Asian airshed necessitates regional cooperation
- Tackling the sources of air pollution requires systematic collection of air quality data and a scientific approach to air quality management
- Tackling the health burden of air pollution will require coordinated, multisectoral response, using a "health in all policies" framework

Box 1: Air quality standards recommended by WHO[9]

	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
	Annual mean concentration	24 h concentration	Annual mean concentration	24 h concentration
Interim target-1	70	150	35	75
Interim target-2	50	100	25	50
Interim target-3	30	75	15	37.5
Air quality guideline*	20	50	10	25

[1] PM_{10}: Airborne particulate matter smaller than 10 µm (includes both coarse and fine particles that enter the respiratory tract).
[2] $PM_{2.5}$: Airborne particulate matter smaller than 2.5 µm.
[3] Interim targets represent incremental steps in a progressive reduction of air pollution. Annual mean concentrations provide an estimate of long term exposure for comparison.
[4] *Lowest levels at which total, cardiopulmonary, and lung cancer mortality have been shown to increase in response to long term exposure to $PM_{2.5}$.

Rural and urban areas are both affected by poor air quality. However, the sources and pollutant profiles vary. For instance, use of cooking fuels varies between urban and rural households, vehicular density is higher in cities, and different climate and geography across the region affect levels of air pollution.

Household air pollution

Approximately 74% of South Asian households use solid fuels such as wood, dung, or coal for cooking and heating.[4-6] These are inefficient fuels and their use in open fires or leaky stoves contributes to high levels of indoor smoke. Studies on indoor air pollution in South Asia show average daily $PM_{2.5}$ concentrations range from 300 µg/m³ to 3000 µg/m³, [5 7 8] which is much higher than is recommended by the World Health Organization (box 1).[9] The proportion of households relying on solid fuels has decreased over the past few decades (fig 1); however this decrease has largely been offset by the increase in population.[10]

The type of fuel and stove, kitchen area ventilation, quantity of fuel, age, gender, and time spent near the cooking area influence exposure within and between households. Women and children tend to have higher exposure. Use of solid cooking fuels also contributes to ambient air pollution as a result of emissions carried outdoors. In densely populated communities of India, household air pollution has been estimated to contribute to nearly 27% of ambient air pollution.[11]

Since few studies report direct measures of household air pollution,[7] trends are estimated (for purposes of comparative risk assessment) using spatiotemporal Gaussian process regression modelling that incorporates data on the proportion of solid fuel use in each country from nationally representative household surveys and select co-variates, including maternal education and proportion of population living in urban areas[12]

Ambient air pollution

The population in South Asia, with the exception of Sri Lanka, is among the most highly exposed to $PM_{2.5}$ in the world (table 1). Estimates from the Global Burden of Disease Study 2015 (GBD) indicate that the population weighted mean ambient $PM_{2.5}$ concentration in South Asia* was 73 µg/m³, compared with the global average of 44 µg/m³. Nearly 99.9% of the South Asian population is living in areas with poorer air quality than the minimum standards recommended by WHO (box 1).

Population weighted $PM_{2.5}$ concentrations have increased by 24% in South Asia between 1990 and 2015, with an increase in all countries except Pakistan and Sri Lanka (fig 2). Ozone concentrations

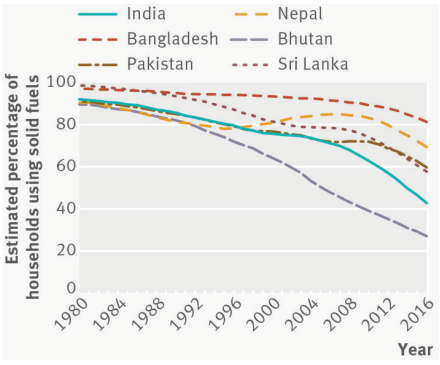

Fig 1 | Trends in estimated percentage of households using solid fuels in South Asian countries

Table 1 | GBD 2015 estimates of exposure to ambient air pollution in South Asia

Country	Population (millions)	Population weighted mean annual ambient $PM_{2.5}$ (2015)	Percentage increase in population weighted mean annual $PM_{2.5}$ (1990 to 2015)	Percentage of population in 2015 living in areas exceeding WHO IT-1	Population weighted seasonal mean ozone (2015)	Percentage increase in population weighted seasonal mean ozone (1990 to 2015)
India	1282.3	74	23	89.9	76	23
Bangladesh	148.9	89	39	99.9	74	25
Pakistan	202.8	65	−4	94.5	69	17
Nepal	31.3	75	34	90.6	78	26
Bhutan	0.9	56	40	81.6	69	25
Sri Lanka	19.5	28	−7	21.9	54	17
South Asia*	1693.8	73	24	91.2	74	21
Global	7155.5	44	10	50.2	61	7

* Here and elsewhere South Asia refers to the GBD regional definition which includes Bangladesh, Bhutan, India, Nepal, and Pakistan. Data for Sri Lanka added separately. WHO IT-1 is World Health Organization $PM_{2.5}$ Interim Target −1 of 35 μg/m^3 (annual average).

have also increased across the region at a rate exceeding the global increase.

The sources of ambient air pollution vary across the region, and across rural and urban settings. Vehicular emissions, construction and road dust, residential biomass use, and industrial emissions are major contributors.[13-16] The main sources of fuel used for power generation such as coal, natural gas, and oil can influence air quality. In Bangladesh, localised sources like brick kilns and motorised transport contribute to the base pollution load throughout the year. Additionally, in winter, transboundary transport of particulate matter across the Indo-Gangetic Plain airshed contributes to higher levels of $PM_{2.5}$.[14] Similarly, in Pakistan, transboundary transport of dust and pollutants from the Arabian Peninsula[15 16] and from India[17] is noted to cause episodic spikes in PM_{10} and $PM_{2.5}$ levels.

Impact on health

Exposure to ambient $PM_{2.5}$ was the third ranking risk factor for mortality (1.4 million deaths, 10.6% of total deaths) and DALYs (5.8% of total DALYs) in South Asia in 2015. Household air pollution ranks fourth (5.5% of DALYs and 1.2 million deaths, 9.6% of total deaths).[18] No studies to date have evaluated the health impacts of co-exposure to household and ambient air pollution.

Over the past 25 years, deaths attributable to ambient $PM_{2.5}$ exposure have increased, with some acceleration since 2010 (fig 3). Increase in $PM_{2.5}$ levels, population growth, and ageing contribute to this trend. Bangladesh, India, and Pakistan have a higher burden because of larger populations, high exposures, and increasing numbers of people affected by chronic diseases. Common diseases affected by air pollution include ischaemic heart disease, stroke, acute lower respiratory infections, chronic obstructive pulmonary disease, and lung cancer. Deaths attributable to household air pollution have remained high and relatively stable with only a modest increase from 1.1 million to 1.2 million between 1990 and 2015.

The age standardised attributable death rates indicate a small decrease, from 158 deaths per 100 000 in 1990 to 133 per 100 000 in 2015, while there has been a large decrease in the rate of attributable DALYs (fig 4) between 1990 and 2010, possibly driven by a decrease in the incidence of acute lower respiratory infections. Deaths attributable to ozone exposure, while much lower than those attributable to $PM_{2.5}$ exposure, have increased sharply throughout South Asia from 48 000 in 1990 to 122 000 in 2015 (a 154% increase) driven by increased exposure and increasing rates of chronic obstructive pulmonary disease in the region, and in India especially.

Air pollution propagates existing environmental vulnerabilities.[19] Children and older people are particularly vulnerable. Air pollution exposure results in low birth weight,[20] poor lung development in children,[21] mortality from respiratory infections,[22] and may also affect cognitive development.[23] Older people are more likely to develop chronic respiratory and cardiac illnesses, and are more susceptible to heart attacks and strokes from long term exposure, and during episodic high pollution events.[24] Lower socioeconomic groups are more susceptible to insults from air pollution exposure for a variety of reasons including occupation and housing.[2 5 19]

Fragmented efforts to reduce air pollution

With the lack of high quality data on air pollution and on health effects in South Asian countries, interventions are usually ad hoc, and their impact cannot be assessed. Public

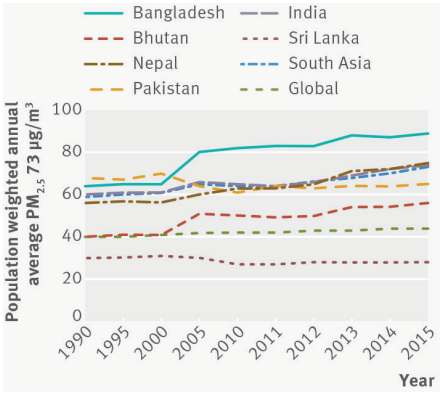

Fig 2 | Trends in annual average population weighted $PM_{2.5}$ exposure in South Asia, 1990 to 2015. These figures were adapted from estimates developed for the Global Burden of Disease (2015) study

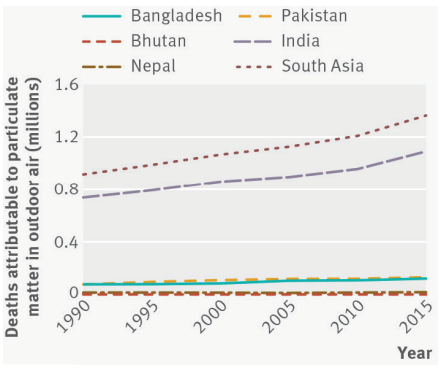

Fig 3 | Trends in deaths attributable to ambient $PM_{2.5}$ in South Asia, 1990 to 2015. These figures were adapted from estimates developed for the Global Burden of Disease (2015) study.

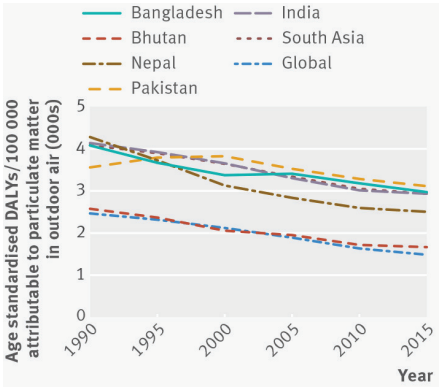

Fig 4 | Trends in age standardised DALYs/100 000 attributable to ambient $PM_{2.5}$ exposure in South Asia, 1990 to 2015. These figures were adapted from estimates developed for the Global Burden of Disease (2015) study

doi: 10.1136/bmj.j5209 | *BMJ* 2017;359:j5209 | thebmj

and media attention on levels of air pollution in South Asian cities have led to sporadic measures; however, a robust strategy with targeted reductions in pollutant levels is lacking.

Availability and quality of air pollution data

Continuous ground monitoring of air quality across a range of locations is essential to understand the concentration of pollutants at different time points and implement control strategies. South Asian countries lag far behind global standards in the density and coverage of air quality monitoring networks. Routine monitoring of $PM_{2.5}$ and ozone in the region is minimal. Epidemiological studies currently rely on modelled exposure estimates based on satellite data.

In India, for example, the National Air Quality Monitoring Program collects pollutant data twice a week from 629 stations across 264 cities, with 35 cities also hosting continuous air quality monitoring stations.[26] Monitoring is restricted to urban areas with virtually none carried out in rural areas. There are also challenges with the data collected, including calibration errors, gaps in data, and wide variation in uptime of monitoring stations.

Research on health outcomes

A growing body of literature from South Asia indicates an association between short term exposure to air pollution and a range of health outcomes such as decrease in lung function, respiratory symptoms, emergency department visits, and mortality. To date, however, no direct epidemiological studies of long term exposure to ambient $PM_{2.5}$ and mortality from chronic diseases in South Asia have been published. The evidence on acute and chronic health effects at the high levels of exposures commonly encountered in South Asian countries needs to be strengthened.[27 28]

Large scale household surveys, census, and vital registration systems are the primary sources of data on mortality in South Asia. Incomplete or inconsistent recording of cause of death, and structural deficiencies in data collection result in under-reporting of deaths, especially in rural areas, and thereby provide little understanding of the impact of air pollution.

Air quality management and exposure reductions

South Asian countries have taken some steps to address specific categories of emissions and exposures (table 2) and improve air quality. There is no coherent strategy, however, with defined targets for air quality and regular monitoring to understand the impact of these measures.[29] Political will and effective governance are central to tackling the problem.

Table 2 | Sector specific policies and interventions undertaken to reduce emissions and exposures

Country	Target sector	Policies or interventions
Pakistan[30-34]	Transport	Introduction of Euro IV standards for exhaust emissions from passenger cars Retrofitting diesel buses and trucks with PM emission controls
	Power	Coal gasification, carbon sequestration
	Industry	Gas to replace fuel oil and coal Low sulphur furnace oil and diesel
	Domestic	Promote cleaner cooking and increased use of natural gas
India[35-40]	Transport	Introduction of Euro VI equivalent standards for vehicles and fuels
	Industry and power	Emissions standards for various industries
	Domestic	LPG connections to 50 million rural households by 2019
	Localised action plans	Graded Response Action Plan for Delhi Comprehensive Action Plan for pollution control in the National Capital Territory
	Brick kilns	Transition to "induced draft zig-zag" technology
Bangladesh[41-43]	Transport	Ban on 2-stroke engines, introduction of compressed natural gas vehicles in Dhaka
	Brick kilns	Introduction of Hybrid Hoffman kilns
	Multiple sectors	Air Pollution Reduction Strategy for Bangladesh
Sri Lanka[44]	Transport	Phasing out 2-stroke engines Introduction of vehicular testing programmes
Nepal[45]	Transport	Vehicle inspection and emissions testing Ban on 2-stroke engines Pollution cess on fuel
	Brick kilns	Ban on movable bull trench kilns
	Dust control	Road improvement and footpath development in Kathmandu

Health centred environmental policy making is required

With the multiplicity of sources, modes of exposure, and complexity of outcomes, there is no easy solution to the problem of air pollution in South Asia. While household air pollution needs targeted interventions with substitute fuels, tackling ambient air pollution, with its varied sources, requires a broader approach. Systematic collection of air quality data and a scientific approach to air quality management are essential to tackle the varied sources of emissions. South Asian countries can learn from and adapt evidence based initiatives implemented in other parts of the world such as the Clean Air Act in the US[46] and China's five year, targeted 10 point action plan to improve air quality in three provinces.[47] Local solutions and policies must be designed to tackle the major sources and contributors. Box 2 provides an example of a recent programme launched in India to reduce household air pollution by expanding access to clean cooking fuel.

An evidence informed, multisectoral approach to policy making is required.[54] While the health sector can play a convening role on initiatives to minimise exposure and ameliorate health impacts, the onus of action lies outside, with the implementation of policies and programmes across the ministries of environment, energy, industry, and finance, among others.

The emphasis on "health in all policies" laid out in the 68th World Health Assembly's resolution on air pollution provides a roadmap to tackle a cross sectoral issue like air pollution where health is adversely affected as a result of ineffective policy making across sectors. The resolution emphasised the need for health related benchmarks of progress in air pollution control measures, and advocated health impact assessments in policy design, implementation, and evaluation related to air pollution.[55] In the context of growing energy use, rapid urbanisation, and increased demand for personal and public transport, the health

Box 2: Increasing access to clean cooking fuel in India

The Indian government has historically provided a subsidy for liquefied petroleum gas (LPG). Access to this subsidy, however, was skewed heavily in favour of the urban population.[48]

To tackle this imbalance, the Pradhan Mantri Ujjwala Yojana was launched in May 2016 with the aim of providing 50 million rural households with subsidised LPG connections by 2019, where hitherto they had been using solid fuels for cooking (fig 5).

This was coupled with a campaign to encourage urban recipients to give up their subsidy, and the PAHAL scheme for direct transfer of LPG subsidies to beneficiaries' bank accounts.[49 50] The programme exceeded its connection targets in the first year.[51] The investment both by way of political will and finances is vital. The question, however, of whether access equates with usage remains—newspapers have recently reported on beneficiaries dropping out after initial refills.[52 53]

Fig 5 | An advertisement for the Pradhan Mantri Ujjwala Yojana (Source: www.assams.info/images/2016/05/PMUY.jpg)

impacts of air pollution can be a conscience keeper for the principles of sustainable urbanisation and development.

While localised sources and emissions are important to tackle exposure, it is also vital to recognise the role of long distance and transboundary transport of air pollution in an interconnected airshed like the Indo-Gangetic Plain which links Bangladesh, India, and Pakistan. Existing political platforms, such as the South Asian Association for Regional Cooperation, must be leveraged to drive action on air quality. WHO's multisectoral action plan on non-communicable diseases provides a platform through which national and regional consensus can be fostered on the health impacts of air pollution. In addition to the nine traditional risk factors outlined in the action plan, member states of WHO's South East Asia region included the reduction of exposure to household air pollution from biomass as a target for the region. This platform can be the basis for coordinated and innovative regional action to reduce exposures and improve health outcomes.

Sources and methods

We used data from the Global Burden of Disease Study (GBD) 2015 on ambient and household exposure to air pollution and health burden estimates. Details on the methods for exposure estimation are described elsewhere.[29 30]

We do not know of any other study that provides national level estimates for the purpose of comparison across different countries. In this context, we acknowledge the need to strengthen the local evidence base by conducting more direct epidemiological studies on the health effects of ambient and household air pollution which would accord greater confidence to the burden estimates.

During the preparation of this manuscript, the GBD estimates for 2016 were released. We believe that the minor revision in overall numbers did not necessitate shifting to the 2016 estimates for this article.

For other information covered in this article, we conducted searches on PubMed, Google Scholar, and Science Direct for relevant reviews and reports published in the region, and drew on our collective experience in this field.

Contributors and sources: BK and DB developed the outline for the paper, to which all other authors contributed. BK, MB, KB, ARS, DB, and BAB contributed sections to the paper, drawing on their previous work and research from their respective countries. BK consolidated drafts. BK and MB coordinated revisions. All authors reviewed and approved the final manuscript.

Competing interests: We have read and understood BMJ policy on declaration of interests and have no relevant interests to declare.

Bhargav Krishna, manager (technical)

Kalpana Balakrishnan, associate dean (research) and director

Amna R Siddiqui, associate professor

Bilkis A Begum, chief scientific officer

Damodar Bachani, director

Michael Brauer, professor

[1]Centre for Environmental Health, Public Health Foundation of India, Gurgaon, India

[2]Department of Environmental Health Engineering, Sri Ramachandra University, Chennai, India

[3]Department of Community Health Sciences, Aga Khan University, Karachi, Pakistan

[4]Chemistry division, Atomic Energy Centre, Dhaka (AECD), Dhaka, Bangladesh

[5]School of Population and Public Health, University of British Columbia, Vancouver, Canada

Correspondence to: Bhargav Krishna
bhargavkrishna@gmail.com

1 Gakidou E, Afshin A, Abajobir A, et alGBD 2016 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017;390:1345-422. doi:10.1016/S0140-6736(17)32366-8
2 World Health Organization. WHO Global Urban Ambient Air Pollution Database (Update 2016). 2016.
3 Shindell D, Borgford-Parnell N, Brauer M, et al. A climate policy pathway for near- and long-term benefits. *Science* 2017;356:493-4. doi:10.1126/science.aak9521
4 Global Alliance for Clean Cookstoves. GACC Country Factsheets. http://cleancookstoves.org/country-profiles/64-sri-lanka.html.
5 Siddiqui AR, Lee K, Bennett D, et al. Indoor carbon monoxide and $PM_{2.5}$ concentrations by cooking fuels in Pakistan. *Indoor Air* 2009;19:75-82. doi:10.1111/j.1600-0668.2008.00563.x
6 Elledge MF, Phillips MJ, Thornburg VE, Everett KH, Nandasena S. A profile of biomass stove use in Sri Lanka. *Int J Environ Res Public Health* 2012;9:1097-110. doi:10.3390/ijerph9041097
7 Balakrishnan K, Ramaswamy P, Sambandam S, et al. Air pollution from household solid fuel combustion in India: an overview of exposure and health related information to inform health research priorities. Glob Health Action 2011. www.ncbi.nlm.nih.gov/pmc/articles/PMC3188887.
8 Clark ML, Peel JL, Balakrishnan K, et al. Health and household air pollution from solid fuel use: the need for improved exposure assessment. *Environ Health Perspect* 2013;121:1120-8.
9 World Health Organization. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide, and sulfur dioxide : global update 2005 : summary of risk assessment. 2006. http://www.who.int/iris/handle/10665/69477.
10 Bonjour S, Adair-Rohani H, Wolf J, et al. Solid fuel use for household cooking: country and regional estimates for 1980-2010. *Environ Health Perspect* 2013;121:784-90. doi:10.1289/ehp.1205987
11 Chafe ZA, Brauer M, Klimont Z, et al. Household cooking with solid fuels contributes to ambient PM2.5 air pollution and the burden of disease. *Environ Health Perspect* 2014;122:1314-20.
12 Forouzanfar MH, Alexander L, Anderson HR, et al. GBD 2013 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015;386:2287-323. doi:10.1016/S0140-6736(15)00128-2
13 The air pollution knowledge assessment (APnA) city program. www.urbanemissions.info/wp-content/uploads/apna/docs/apna_program_summary_booklet.pdf.
14 Begum BA, Hopke PK, Markwitz A. Air pollution by fine particulate matter in Bangladesh. *Atmos Pollut Res* 2013;4:75-86doi:10.5094/APR.2013.008.
15 Stone E, Schauer J, Quraishi TA, Mahmood A. Chemical characterisation and source apportionment of fine and coarse particulate matter in Lahore, Pakistan. *Atmos Environ* 2010;44:1062-70doi:10.1016/j.atmosenv.2009.12.015.
16 Shahid I, Kistler M, Mukhtar A, et al. Chemical characterization and mass closure of PM_{10} and $PM_{2.5}$ at an urban site in Karachi, Pakistan. *Atmos Environ* 2016;128(Supplement C):114-23. doi:10.1016/j.atmosenv.2015.12.005.

17 Khanum F, Chaudhry MN, Kumar P. Characterization of five-year observation data of fine particulate matter in the metropolitan area of Lahore. *Air Qual Atmos Health* 2017;10:725-36. doi:10.1007/s11869-017-0464-1
18 Cohen AJ, Brauer M, Burnett R, et al. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *Lancet* 2017;389:1907-18. doi:10.1016/S0140-6736(17)30505-6
19 Nasir ZA, Murtaza F, Colbeck I. Role of poverty in fuel choice and exposure to indoor air pollution in Pakistan. *J Integr Environ Sci* 2015;12:107-17doi:10.1080/1943815X.2015.1005105.
20 Siddiqui AR, Gold EB, Yang X, Lee K, Brown KH, Bhutta ZA. Prenatal exposure to wood fuel smoke and low birth weight. *Environ Health Perspect* 2008;116:543-9. doi:10.1289/ehp.10782
21 Central Pollution Control Board. Study on ambient air quality, respiratory symptoms and lung function of children in Delhi. 2008.
22 Cohen AJ, Brauer M, Burnett R, et al. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *Lancet* 2017;389:1907-18. doi:10.1016/S0140-6736(17)30505-6
23 Clifford A, Lang L, Chen R, Anstey KJ, Seaton A. Exposure to air pollution and cognitive functioning across the life course—a systematic literature review. *Environ Res* 2016;147:383-98. doi:10.1016/j.envres.2016.01.018
24 Brook RD, Rajagopalan S, Pope CA 3rd, et al. American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. *Circulation* 2010;121:2331-78. doi:10.1161/CIR.0b013e3181dbece1
25 Hajat A, Diez-Roux AV, Adar SD, et al. Air pollution and individual and neighborhood socioeconomic status: evidence from the Multi-Ethnic Study of Atherosclerosis (MESA). *Environ Health Perspect* 2013;121:1325-33.
26 Central Pollution Control Board. National air quality monitoring. www.cpcb.nic.in/Network.php.
27 Cohen AJ, Brauer M, Burnett R, et al. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *Lancet* 2017;389:1907-18. doi:10.1016/S0140-6736(17)30505-6
28 Smith KR, Bruce N, Balakrishnan K, et al. HAP CRA Risk Expert Group. Millions dead: how do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution. *Annu Rev Public Health* 2014;35:185-206. doi:10.1146/annurev-publhealth-032013-182356
29 Henneman LRF, Liu C, Mulholland JA, Russell AG. Evaluating the effectiveness of air quality regulations: A review of accountability studies and frameworks. *J Air Waste Manag Assoc* 2017;67:144-72. doi:10.1080/10962247.2016.1242518
30 Sánchez-Triana E, Enriquez S, Afzal J, Nakagawa A, Shuja Khan A. Cleaning Pakistan's air: policy options to address the cost of outdoor air pollution.World Bank. 2014. http://documents.worldbank.org/curated/en/701891468285328404/pdf/890650PUB0Clea00Box385269B00PUBLIC0.pdf.
31 Ministry of Climate Change. National Climate Change Policy. 2012. www.gcisc.org.pk/National_Climate_Change_Policy_2012.pdf.
32 United Nations Environment Programme. Air quality policies: Pakistan. 2015. https://wedocs.unep.org/bitstream/handle/20.500.11822/17077/Pakistan.pdf?sequence=1&isAllowed=y.
33 Mir KA, Purohit P, Goldstein GA, Balasubramanian R. Analysis of baseline and alternative air quality scenarios for Pakistan: an integrated approach. *Environ Sci Pollut Res Int* 2016;23:21780-93. doi:10.1007/s11356-016-7358-x
34 Pakistan's intended nationally determined contribution. www4.unfccc.int/Submissions/INDC/Published%20Documents/Pakistan/1/Pak-INDC.pdf.
35 Mohile SSBSVI. challenges and opportunities for India's auto industry. 2017. www.livemint.com/Industry/b5VcxRbUqSjDLySxl4Cr0O/BS-VI-Challenges-and-opportunities-for-Indias-auto-industr.html.
36 Central Pollution Control Board, Ministry of Environment, Forest, and Climate Change, Government of India. Industry specific standards. www.cpcb.nic.in/Industry_Specific_Standards.php.
37 Ministry of Petroleum and Natural Gas, Government of India. About PMUY. www.pmujjwalayojana.com/about.html.
38 Thakur J, Halder R. Delhi finally has an action plan to combat air pollution, here's how you can help. 2017. www.hindustantimes.com/delhi-news/delhi-finally-has-an-action-plan-to-combat-air-pollution-here-s-how-you-can-help-too/story-2R8HGYVHM1BZnhtnlbbNfJ.html.
39 Environment Pollution (Prevention and Control) Authority for the National Capital Region. Comprehensive action plan for air pollution control in the National Capital Territory. 2017. www.epca.org.in/EPCA-Reports1999-1917/Report-draft-no.66.pdf.
40 Singh RK. Brick kilns shifting to cleaner technology, but progress is slow 2017. www.downtoearth.org.in/news/brick-kilns-shifting-to-cleaner-technology-but-progress-is-slow-58559.
41 Begum BA, Nasiruddin M, Randal S, Sivertsen B, Hopke PK. Identification and apportionment of sources from air particulate matter at urban environments in Bangladesh. *Br J Appl Sci Technol.* 2014;4:3930-55doi:10.9734/BJAST/2014/11247.
42 World Bank. Modern brick kilns yield development benefits in Bangladesh. 2016. www.worldbank.org/en/news/feature/2016/07/20/modern-brick-kilns-yield-development-benefits-in-bangladesh.
43 Department of Environment, Government of Bangladesh. Air pollution reduction strategy for Bangladesh. 2012. http://old.doe.gov.bd/publication_images/60_air_pollution__reduction_strategy.pdf.
44 Nandasena YLS, Wickremasinghe AR, Sathiakumar N. Air pollution and health in Sri Lanka: a review of epidemiologic studies. *BMC Public Health* 2010;10:300. doi:10.1186/1471-2458-10-300
45 Clean Air Network Nepal. Air quality status and management in Kathmandu Valley. www.cen.org.np/uploaded/AQ%20Status%20and%20Managment%20in%20KV_Maya%20Factsheet%205.pdf.
46 California Air Resources Board. History. https://ww2.arb.ca.gov/about/history.
47 Zhang C. Can China meet its 2017 air quality goals? 2017. www.chinadialogue.net/article/show/single/en/9574-Can-China-meet-its-2-17-air-quality-goals-
48 Lahoti R, Goutam P, Suchitra JY. Subsidies for whom? The case of LPG in India. www.iimb.ac.in/sites/default/files/subsidies_for_whom.pdf.
49 Ministry of Petroleum and Natural Gas. GiveItUp LPG Subsidy. www.givitup.in.
50 Ministry of Petroleum and Natural Gas, Government of India. PAHAL-direct benefits transfer for LPG(DBTL) consumers scheme. http://petroleum.nic.in/dbt/whatisdbtl.html.
51 Kumar S. Pradhan Mantri Ujjwala Yojana: 3 cr LPG connections already issued, Oil Min seeks to serve another 3 cr beneficiaries. Financial Express. 2017. www.financialexpress.com/india-news/pradhan-mantri-ujjwala-yojana-3-cr-lpg-connections-already-issued-oil-min-seeks-to-serve-another-3-cr-beneficiaries/914691/lite.
52 Jha DK. Modi's pet Ujjawala scheme wobbles as many beneficiaries drop out after their first LPG cylinder. 2017. https://scroll.in/article/839961/modis-pet-ujjawala-scheme-wobbles-as-many-beneficiaries-drop-out-after-their-first-lpg-cylinder.
53 Kishore R. India's poor are not using LPG cylinders they got under Ujjwala scheme. 2017. www.livemint.com/Politics/oqLQDFKNuMdbmLEVL88krN/Indias-poor-are-not-using-LPG-cylinders-they-got-under-Ujjw.html.
54 Ministry of Heath and Family Welfare, Government of India. Report of the steering committee on air pollution and health related issues. 2015. http://ehsdiv.sph.berkeley.edu/krsmith/publications/2015/MoHFW%20AP%20Steering%20Com.pdf.
55 68th World Health Assembly. Health and the environment: addressing the health impact of air pollution. 2015. http://apps.who.int/gb/ebwha/pdf_files/WHA68/A68_18-en.pdf

Cite this as: *BMJ* 2017;359:j5209
http://dx.doi.org/10.1136/bmj.j5209