HEALTH AND SOCIAL IMPACTS OF AIR POLLUTION ON WOMEN AND CHILDREN IN BISHKEK, KYRGYZSTAN

EXECUTIVE SUMMARY

November 2022

From the People of Japan

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Acknowledgements

This report was prepared by Rufus Edwards, Jay Turner, Rahat Sabyrbekov, Ajay Pillarsetti and M-Vector, Air Pollution consultants to UNICEF Kyrgyzstan. While all team members contributed to all sections, conceptualization, principal drafting of the report, policy frameworks, exposure estimation and overall co-ordination were led by Rufus Edwards; residential outdoor, indoor and ambient air pollution were led by Jay Turner, economic analysis was led by Rahat Sabyrbekov, health impact estimates were led by Ajay Pillarsetti, and field work and surveys were led by M-Vector. Guidance and support were provided by the Bishkek Mayor's Office, Kyrgyzstan government representatives from Ministry of Health of Kyrgyzstan and Ministry of Natural Resources, Ecology and Technical Oversight of the Kyrgyz Republic, with special thanks to Maria Osbeck, Alex Heikens and Ariuntungalag Danielsson whose assistance made this report possible. Rapid Assessment interviews were conducted by Rufus Edwards and Jay Turner assisted by a team from UNICEF and M-Vector. A debt of gratitude is owed to UNICEF staff in Kyrgyzstan Christine Jaulmes, Yulia Oleinik, Tomoya Sonoda, Muktar Minbaev, Nazgul Sharshenova, Cholpon Imanalieva and Bermet Sydygalieva for their assistance.

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Acronyms

DALY	Disability-adjusted life year
MICS	Multiple Indicator Cluster Surveys
PM2.5	Particles which are small enough to pass through a size-selective inlet with a 50 % efficiency cut-off at 2.5 µm aerodynamic diameter
UNICEF	United Nations Children's Fund
WASH	Water, sanitation and hygiene
AQI	Air quality index

EXECUTIVE SUMMARY

Purpose

All countries in which households use solid fuels in urban areas for winter space heating have an air pollution problem that contributes significantly to burdens of disease. Kyrgyzstan is no exception. The Kyrgyz Republic National Development Strategy 2018-2040 sets forth three main goals, namely: (i) economic well-being of the people; (ii) social welfare; and (iii) security and favorable environment for the lives of citizens. Law No. 51 on "protection of atmospheric air" states that citizens have the right to atmospheric air favorable for life and health, to receive reliable and timely information about the state of atmospheric air and measures taken to protect it, including compensation for damage in case of damage to their health and property caused by emissions of pollutants.

With increasing concerns over high wintertime fine particle (PM2.5) air pollution concentrations experienced in Bishkek that are far in excess of those known to have major adverse health effects in urban populations, UNICEF initiated this study in partnership with M-Vector and international experts in air pollution and health. The purpose of the analysis is to examine the health and social impacts of PM2.5 air pollution on children and women in Bishkek and develop recommendations on appropriate disease prevention measures based on the most up-to-date assessment of the theme.

To respond to some of the gaps in the evidence base, primary data were collected on spatial variability in PM2.5 air pollution concentrations in the urban area, prevalence of primary and additional household space heating fuels, impacts of heating types on infiltration of outdoor pollution into indoor environments, knowledge of clean and sustainable options and willingness to pay for an increase in years of healthy life without illness due to air pollution. Health impacts were assessed using baseline health incidence data reported by Kyrgyz Republic combined with integrated exposure response curves for PM2.5 used in Global Burden of Disease estimates1 which relate exposure to PM2.5 with the population attributable fraction of disease risk. The assessment had the following key activities: 1. Rapid situational analysis; 2. Validated low-cost sensor measurements of indoor and outdoor household air pollution; 3. Urban scale air quality assessment of outdoor PM2.5 gradients within Bishkek; 4. Exposure and health impact assessment; 5. Household survey with contingent valuation subsample; 6. Economic analysis of impacts of air pollution; and 7. Recommendations on appropriate disease prevention measures.

Key Findings

Unfortunately, the current analysis shows that the right to atmospheric air favorable for life and health is far from the current reality for residents of Bishkek. Between 7/1/2021 and 6/30/2022, spatially weighted average annual ambient PM2.5 concentrations in Bishkek were 44 μg/m^3, a level far in excess of those known to have major adverse health effects in urban populations. Figure 1 shows the spatial distribution of annual average ambient PM2.5 concentrations in Bishkek for the ADB/Kyrgyzhydromet Clarity sensor network, bias adjusted. Annual average PM2.5 concentrations vary by a factor of four across the Bishkek network (17-75 μg/m^3), with concentrations lowest in the south and central business districts consistent with prevailing

southerly winds during the winter, intermediate in the east and west districts, and highest in the north. Across the city of Bishkek, therefore, residents are exposed to annual average concentrations that range from moderately elevated to far in excess of concentrations known to cause major health impacts in populations as a result of the prevalence of residential winter heating types in different spatial locations in the city.

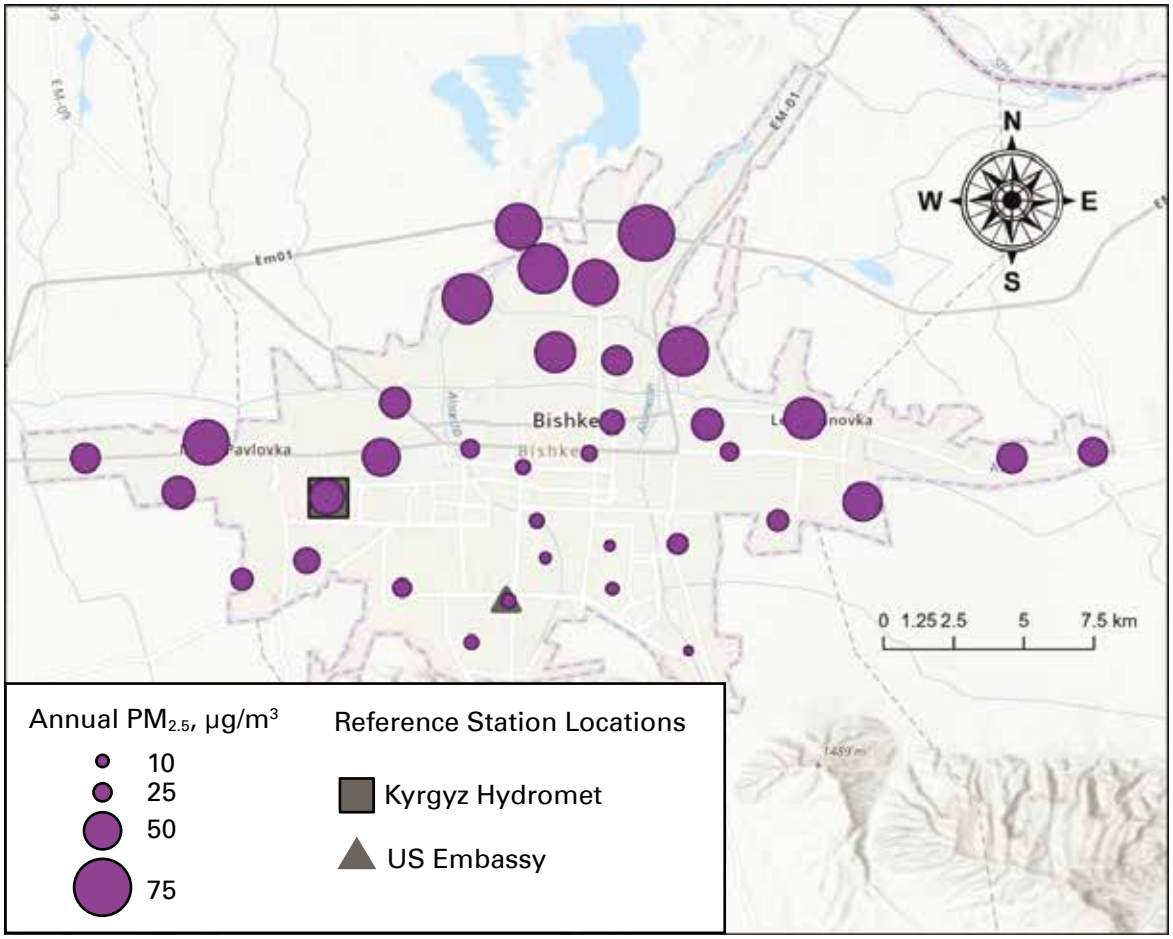

Figure 1. Annual average PM2.5 concentrations (July 2021-June 2022) for the ADB/ Kyrgyzhydromet Clarity sensor network, bias adjusted. The size of the circle represents the annual average PM2.5 concentration in µg/m^3.

Figure 2 shows spatial interpolation of wintertime concentrations of the ADB/Kyrgyzhydromet sensor network to obtain the PM2.5 concentration surface for the city of Bishkek. Superimposed on this map are columns that represent the fraction of houses in the household survey enumeration area using coal stoves. This map visually demonstrates the relationship between higher PM2.5 concentrations and the neighborhood use of raw coal stoves for space heating. The spatially weighted annual average concentrations were a factor 1.75 times higher than averages reported for the US Embassy monitoring site for the same time period due to location of the US Embassy monitoring site in the southern area of the city which has lower ambient concentrations of PM2.5. While representing the urban area is not the primary purpose of the US Embassy monitoring site, the difference between the averages highlights the importance of site location of fixed monitoring sites and sensor arrays in spatially representing the urban area as the Government of Kyrgyzstan expands its monitoring capacities.

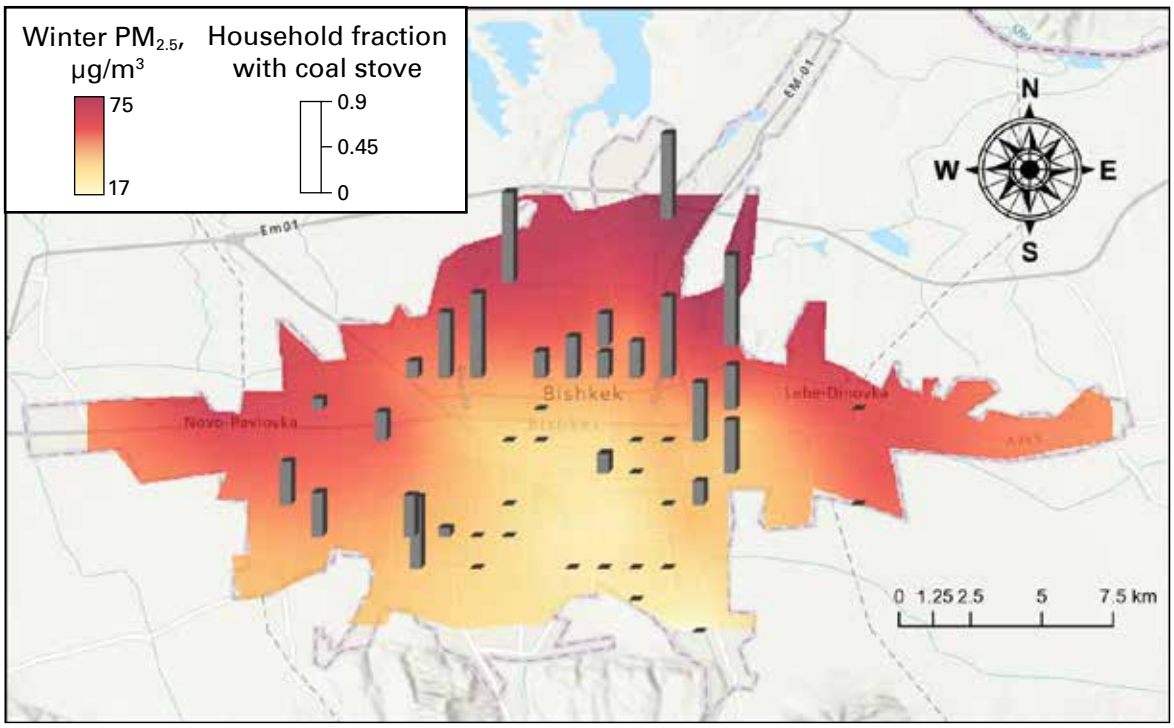

Figure 2. Contours: winter average PM2.5 concentrations (November 2021-January 2022) for the ADB/Kyrgyzhydromet Clarity sensor network, bias adjusted. Columns: Fraction of households using raw coal stoves from the household survey. The two zones to the east with no stoves are apartment areas adjacent to neighborhoods with detached homes using raw coal stoves.

Primary space heating in Bishkek reported in the household survey was approximately 48% central heating, 26% raw coal stoves, 17% gas, 8% electric (Figure 3). Burning raw coal for space heating decreased up income strata from 40% in the lowest income strata to 17% in the highest income strata, however continued prevalence of coal stoves in upper income strata represents a clear target for clean and sustainable alternatives, given that initial purchase price and affordability are lower constraints in these groups. Since MICS 2018 use of gas as primary fuel for space heating increased by over 12% and use of raw coal in stoves decreased by 14%, which represents a move in the right direction, although much still remains to be done. Approximately 23% of homes reported using additional fuel types for space heating with wood accounting for 60% of additional fuel used in stoves, which highlights the need for additional survey questions on space heating fuel use in MICS surveys. The household surveys also demonstrated lack of awareness of the use of clean and sustainable heating options (Figure 4) and the relative costs compared to burning raw coal.

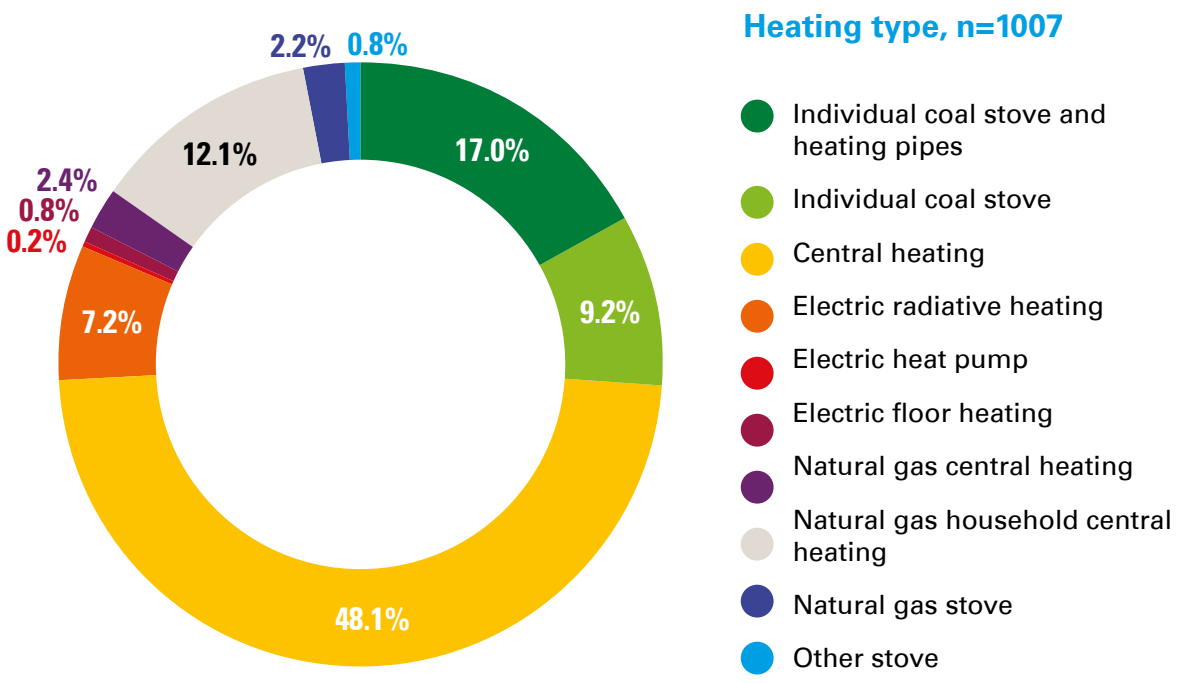

Figure 3. Primary source of winter space heating.

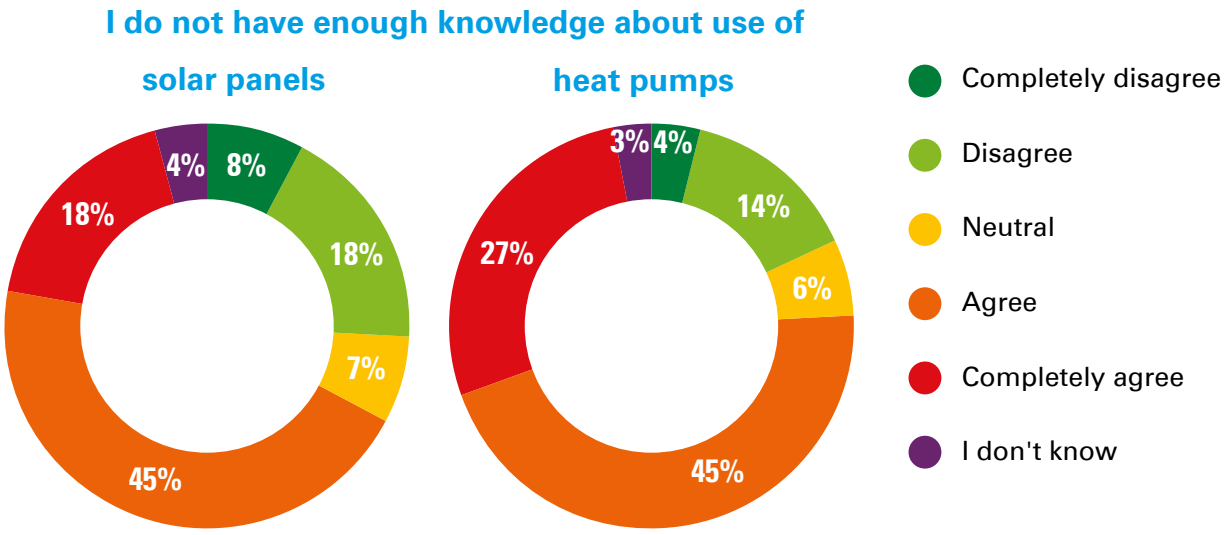

Figure 4. Perceptions of household residents about use of solar panels and heat pumps.

Based on time activity data collected by the Government of Kyrgyzstan and indoor-outdoor monitoring of households with different heating types, population weighted annual average exposures for the household survey representative sample were estimated to be 18.0 μg/m^3, with annual average population weighted exposures for children under 10 years old 18.5 μg/m^3, and for adults 17.7 μg/m^3. Figure 5 shows that average household exposures during winter reflect the prevalence of neighborhood residential winter heating types. Children and youths

living in homes that burn raw coal for space heating are more exposed by on average 33% (7.5 μg/m^3) during the year and 37% (17 μg/m^3) during the winter because of the neighborhood-scale pollution from raw coal stoves that infiltrates their homes, compared to children with central heating. Children that live in apartment buildings, however, are still exposed to urban level ambient air PM2.5 concentrations that infiltrate into their indoor environments. Thus all children in Bishkek would benefit from measures to reduce air pollution emissions.

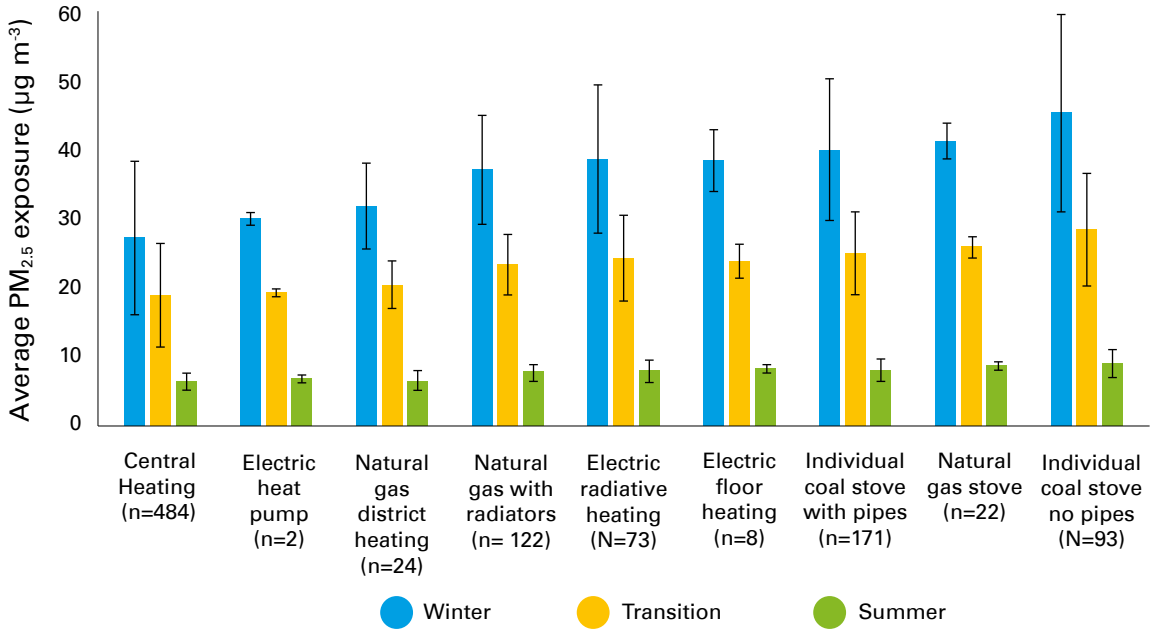

Figure 5. Average household PM2.5 exposures by primary winter heating type. Winter = November-January; Summer = May-September; and Transition = February, March, and October.

Annual average population weighted PM2.5 exposures across all household types were on average ~3.6 times those known to cause adverse health impacts in populations, causing an estimated 112 Deaths and the loss of 3,568 Disability Adjusted Life Years (DALYs) for this one-year time period. Children represented 22% of disease burdens attributable to PM2.5 air pollution exposures in 2021 and efforts to reduce exposures during pregnancy and in the first year of life should be a high priority. Air pollution is the single biggest environmental risk factor for premature death and ill-health in Kyrgyzstan.

Disability adjusted Life year (DALY)

Mortality itself is not a good indicator for disease burdens, as all individuals will die at the end of their life span, rather it is the loss of years of healthy life due to premature mortality and the years of life spent with illness that represent the impacts of disease on populations. Disability-adjusted life year (DALY) is a metric that incorporates both the number of years of life lost due to premature mortality (YLLs) and years of healthy life lost due to disability (YLDs) to estimate the number of years of full health lost due to disease.[1]

1 https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158

Figure 6 shows PM2.5 health impacts estimated for Bishkek weighted by IHME[2] age specific disease burden for Kyrgyzstan, which shows the ill health due to PM2.5 air pollution in Bishkek is primarily borne by the elderly and young children in the first days of life. The first chart (orange) is the rate of DALYs per 100,000, normalized by populations size in each age group, which shows that children in the days immediately after birth are most vulnerable to the impacts of air pollution and health effects are dominated by exposures to fine particulate matter (PM 2.5). The second chart (blue) shows that the absolute number of DALYs attributable to air pollution is high immediately after birth with the greatest impacts in the first 6 days, with a decline through childhood. Subsequently impacts of air pollution increase with age to peak around 60 years old, and decline with lower population numbers at higher ages. Pollution is costly for individuals, families, and society with an estimated welfare loss to Bishkek of 2 billion KGS (95% CI 1.7-2.4) or 24.9 million USD (95% CI 20.8-29.4) in 2021-2022.

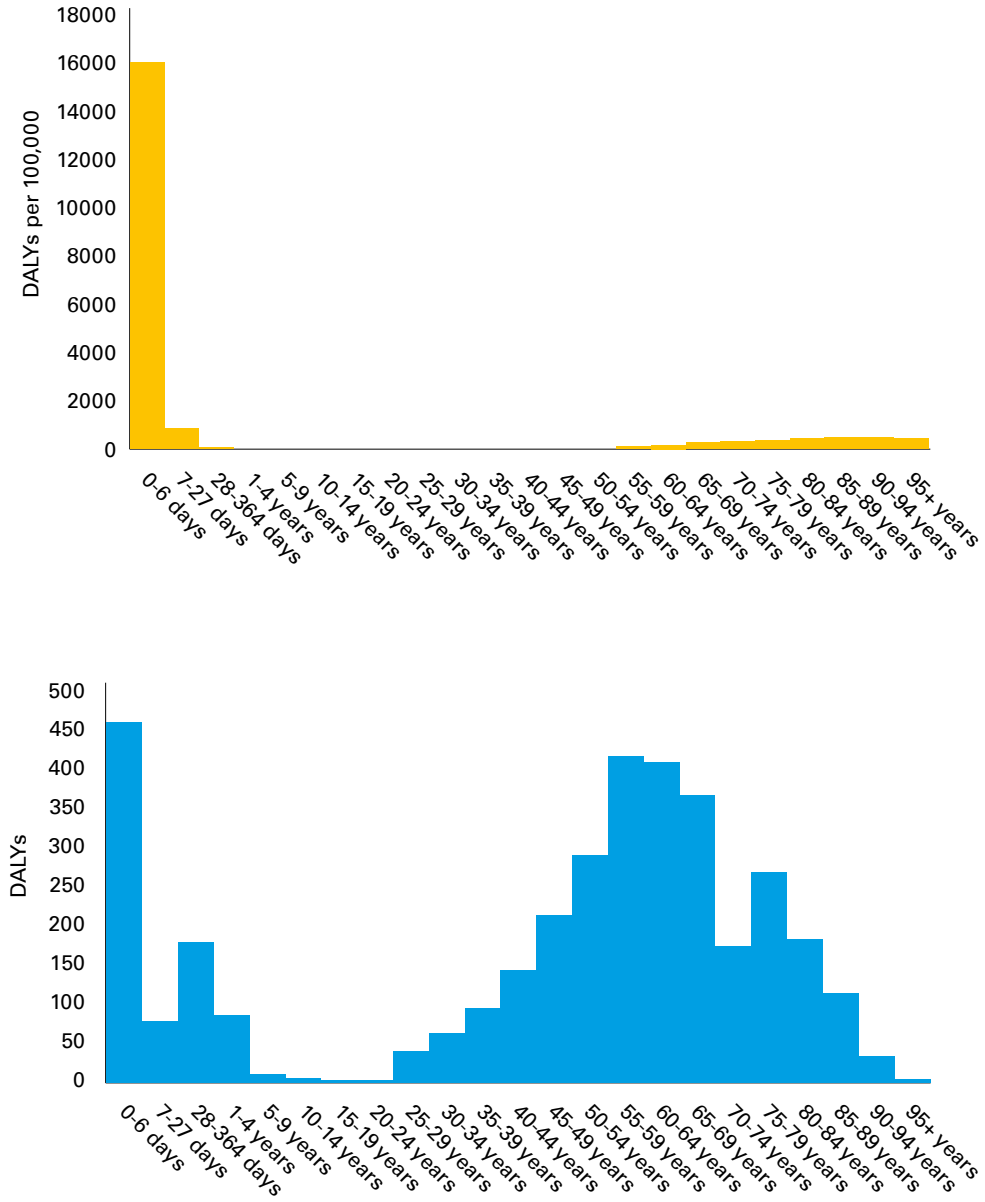

Figure 6. PM2.5 health impacts estimated for Bishkek weighted by IHME age specific disease burden for Kyrgyzstan.

2 Institute for Health Metrics and Evaluation (IHME), 2022. Available from https://vizhub.healthdata.org/gbd-results/.

Results at a glance

- Health Impacts from PM2.5 air pollution exposure were estimated to cause 112 (95% CI 97-131) Deaths and the loss of 3,568 (95% CI 2990-4220) Disability Adjusted Life Years (DALYs) between 7/1/2021 and 6/30/2022. Air pollution is the single biggest environmental risk factor for premature death and ill-health in Kyrgyzstan, with ill health due to PM2.5 air pollution primarily borne by the elderly and young children in the first days of life.
- Spatially weighted average annual PM2.5 concentrations in Bishkek between 7/1/2021 and 6/30/2022 were 43 μg/m^3, a level far in excess of those known to have major adverse health effects in urban populations. Annual average PM2.5 concentrations vary by a factor of four across the city of Bishkek (17-75 μg/m^3), with concentrations lowest in the south and central business districts and highest in the north.
- Population weighted annual average exposures for the household survey representative sample were 18.0 μg/m^3, with annual average population weighted exposures for children under 10 years old 18.5 μg/m^3, and for adults 17.7 μg/m^3. Exposures are driven by infiltration of local neighborhood PM2.5 air pollution into indoor environments and are thus borne unequally by the population in Bishkek depending on the prevalence of stoves burning raw coal in different neighborhoods in the city during the winter. Annual average population weighted PM2.5 exposures across all household types were on average ~3.6 times those known to cause adverse health impacts in populations.
- Economic Impact: The estimated welfare loss from PM2.5 air pollution in Bishkek was 2 billion KGS (95% CI 1.7-2.4) or 24.9 million USD (95% CI 20.8-29.4) in 2021-2022.
- Availability and awareness of clean household alternatives and their relative costs is a key barrier to reducing air pollution (see survey results in full report for more detailed evaluation).
- Capacity building is necessary to build institutional capabilities, technical resources, human resources, legal frameworks and informational resources.

Recommendations

The 2030 Agenda for Sustainable Development adopted at the United Nations Summit on Sustainable Development in September 2015 includes:

- Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

Meeting these goals in Bishkek will require sustained and coordinated action to change the primary energy use for 26% of the urban population. With increasing awareness there are days that air pollution concentrations in Bishkek are reported to top the list of the world's most polluted cities, and growing interest of the multilateral and bilateral agencies to address the problem, there is a need for coordination of actions through the Emergency Inter-ministerial Committee on Air Pollution to ensure programmatic consistency and cost-effective use of time and resources. A long term strategic urban plan of what primary energy choices in Bishkek will look like over the next 10 years will aid in this endeavor. The Inter-ministerial Committee on Air Pollution should be well informed of the economic burdens of air pollution, and the health and economic benefits of investing in intervention strategies quickly rather than more gradually, as these play a significant role in the choice of strategic approach and the associated cost.

Although it is well established that improved population health outcomes are achieved most effectively by societal control of emissions, and that the health of all citizens will benefit from air pollution reductions, some of these transitions in other countries have been relatively rapid, while others have progressed more slowly due to political motivation and resources. In the meantime, however, it is important to recognize that there are strategies that can be implemented to reduce exposures and mitigate some of the health impacts in the current generation of children that are growing up in Bishkek. Key measures to reduce impacts include targeting pregnancy and early days of life for exposure reduction strategies such as home air filtration units during pregnancy and the first 1000 days of life, ensuring young children can learn and play in low air pollution environments that limit lung damage and growth impairment, ensuring adequate nutrition during pregnancy and during the first 1000 days, and featuring locally grown antioxidant fruit and produce in school children's nutrition. In addition, continued work to reduce prevalence of tobacco smoking in indoor environments will ensure health benefits from reducing other air pollution emissions are realized in the population.

As with many urban areas, air pollution causes and impacts are not contained within municipal boundaries as air pollution is transported downwind. As a consequence, measures to reduce air pollution should extend beyond municipal boundaries to encompass the airshed, or the greater area causing and affected by urban PM2.5 pollution, and the political and institutional mandates reflecting the larger urban airshed developed. Examples of this approach include UK pollutant specific Air Quality Management Areas (AQMAs), which are defined based on the nature and spatial extent of the problem e.g. Birmingham, or the Air Quality Management Districts (AQMD) in the United States e.g. the south coast air quality management district that covers Los Angeles encompassing 17 million people in over 162 cities in 4 counties.

A designation of "no burn zones" for raw and phasing out of coal are key priorities for long term urban planning where clean alternatives are available to ensure ambient air pollution emissions are reduced within and upwind of current high concentration areas. However, no burn zones are dependent on the affordability, availability and acceptability of clean alternatives. To ensure a smooth transition, there is a critical need to model different price points in market based tiered pricing structures to avoid unintended incentives to return to solid fuel use by the most vulnerable as energy costs move toward cost recovery levels.

With many competing uses for limited resources, there is a need to prioritize policies intended to reduce air pollution impacts identified in the action plan based on the cost effectiveness of the measure in reducing health impacts as the primary metric. Current air pollution monitoring and e-health data do not yet provide an adequate evidence base for policymaking. Improvements in the evidence base are needed both in the representativeness of environmental measurements, and also in e-health data collected in the city and surrounding areas including training of physicians in the public health objectives that can be evaluated through accuracy in International Classification of Disease (ICD10) coding. The Government has started developing the capacity to monitor environmental impacts, including expansion of monitoring networks, and has initiated plans to improve e-health data. However, expansion of technical capacity and human resources more rapidly would be beneficial in improving epidemiological surveillance, and the ability to model potential impacts of policy interventions prior to implementation. Accessibility and open sharing of data funded by taxpayers remain critical priorities in providing a transparent evidence base for policymaking.

Increasing the energy efficiency of existing infrastructure through rehabilitation, moderating demand for energy and adopting clean and sustainable technologies play joint roles in reducing emissions. Technology solutions such as air-to-air heat pumps require piloting to demonstrate affordability and acceptability that can be used to educate the wider population. Current survey results show lack of awareness in the populations of clean and sustainable household alternatives and their relative costs. Energy efficiency measures including window, wall and roof insulation are needed to reduce energy demand in single homes, which allows clean technologies to be more affordable. Purchase price incentives and finance options are a priority for newer technologies, and for energy efficiency improvements. In central urban districts retrofitting of turndown ability and thermostats for buildings served by district central heating will allow available resources to supply more homes, whilst maintaining occupant comfort. While installed in new apartments, technologies that allow retrofitting older apartments is a priority in order to expand the number of buildings district central heating can supply.

Long term ambient air quality management relies upon identifying major emission sources and quantifying their contributions to the ambient air pollution burden, however it is not necessary to wait for fine resolution on source contributions to know that residential burning of raw coal for space heating is the principal cause of the wintertime PM2.5 air pollution problem in Bishkek, and that measures to reduce this pollution should be implemented immediately. There are currently major limitations in applying conventional methods to quantify ambient PM2.5 air pollution sector contributions. There is a lack of reliable emissions estimates and fuel consumption from households, facility level heat boilers, industrial emissions, small scale industries, roadside kiosks, and transportation fleets necessary for ambient air quality modeling using spatially and temporally resolved emissions estimates together with meteorology (bottom-up approach). Modernization of emissions measurements and inventories is thus necessary before bottom-up air quality modeling will be useful for fine resolution on source contributions. While emissions data is not necessary for source apportionment using a large dataset of collected PM2.5 samples that have been analyzed for chemical composition (top-down approach) where chemical species are used to distinguish different sources, many sector contributions in Bishkek will not be resolved using this

technique because these sectors use the same raw coal as fuel and covary with meteorology. While such approaches may be able to resolve some non-coal source contributions, these are currently small compared to sectors using raw coal.

Bishkek suffers from high levels of air pollution that vary widely across the city. Improved awareness that household heating can be a significant contributor to poor air quality and lead to significant health burdens in the population will assist government and civil society in taking measures to reduce these sources. Similarly incorporating a health-based Air Quality Index (AQI) that is structured similarly across Central Asian nations would greatly assist in informing the government and population in real time about air pollution hazards and personal actions that can be taken to reduce exposures. Large social transitions to reduce air pollution emissions require a well-developed communication strategy using modern communication techniques targeted at increased awareness in the population of the role played by burning raw coal in inefficient stoves and the urgency to address air pollution-related impacts. Similarly, increasing the education about the health impacts of air pollution in schools and for professional groups such as teachers in training colleges and medical professions can play a significant role in delivering messages in hard-to-reach populations. Increasing the availability of audio-visual materials on air pollution in school education programs, and promoting thematically-oriented art, essay and science fair competitions would significantly raise awareness of the hazards of air pollution among school-going children and provide information on feasible alternative measures that can be taken to reduce exposure.

Large numbers of vehicles using inefficient diesel engines not equipped with emission reduction technologies combined with ageing passenger and commercial vehicle fleets are prevalent in Bishkek. Once increased controls on household solid fuel sources, facility level boilers and industrial emissions are exercised, transportation emissions will play a greater relative role in urban ambient air pollutant concentrations. Without addressing transportation emissions, the 2030 Agenda for Sustainable Development Goals are unlikely to be met. Routine evaluation of vehicle emissions using dynamometers is not currently a feature of enforcement of vehicle emissions standards in Bishkek. Although initial attempts to implement monitoring using private laboratories were discontinued, routine (e.g., annual) testing is critical in identifying significantly polluting vehicles with a mechanical malfunction in the vehicle fleet. Experiences in other nations have shown that the 10 per cent of malfunctioning vehicles in the vehicle fleet contribute 90 per cent of the emissions, which can be controlled through vehicle emissions testing as part of routine vehicle inspection and enforcement.

Opportunities

- **Expand legal authority for control of air pollution** beyond municipal boundaries through the creation of air quality management areas that encompass the settlements on the fringes of the city that predominantly use raw coal.
- **Increase the use of objective scientific information** on the health and social impacts of air pollution in policy making.
- **Progressively target the major sources of air pollution** guided by cost effectiveness of the intervention measures in the strategic plan to improve health.
- **Centralize air pollution intervention measures** under the EcoSovet inter-ministerial steering committee to coordinate actions across sectors, and formalize the strategic road map over the next 10 years of primary energy choices.
- **Prioritize the promotion of coal-free zones** in urban areas to reduce household coal combustion, together with demonstration of cost-effective alternatives through incentive programs and financial models.
- **Pilot air pollution intervention measures** to demonstrate effectiveness in reducing air pollution and affordability prior to expenditure of limited resources.
- **Use economic modelling of pricing structures** to provide the incentive framework for wider adoption of clean alternatives.
- **Develop approaches to reduce exposures during pregnancy and in the first 1000 days of life**, such as loans of air filtration equipment as part of prenatal and postnatal care.
- **Provide air pollution messages and education resources** for incorporation into school curricula, and in teacher training colleges.
- **Incorporate existing tools developed by multilateral organizations** to allow policy makers to make informed policy decisions based on cost effectiveness of intervention measures.
- **Increase the quality of e-health data** and education of the health workforce on health impacts driven by air pollution.
- **Develop a communications strategy** to inform residents of cost effectiveness of clean heating solutions.
- **Increase the coverage** of ambient air pollution surveillance.
- **Increase incentives for energy conservation measures** in all sectors, as it remains an important tool to reduce emissions from households, industries, facility level heat boilers, and allow expansion of district heating networks.
- **Energy Transitions**: A key challenge to energy transition in Kyrgyzstan to clean household fuels is the cost and availability of clean alternatives. There is potential to address this through:
    - *expansion of existing district central heating in central urban areas though energy efficiency measures, temperature regulation and turn down ability*

- *expansion of gas distribution networks in residential urban areas*
- *pricing incentives and finance mechanisms for connection to gas distribution*
- *piloting air-to-air heat pumps together with the development of electricity pricing structures, pricing incentives and finance mechanisms to increase accessibility.*
- *increase energy conservation measures in private residences*

- **Organizational frameworks:**
  - *modernization of ambient air quality and emission standards, combined with health based AQI*
  - *increasing air quality management technical capacity, human resources and enforcement abilities*
  - *better coordination and harmonization of plans and programs across stakeholders*
- **Integrate air pollution activities with WaSH**, nutrition, environmental indicators and programming targeting the first 1000 days.
- **Advocacy for policies and systems to reduce air pollution**: Partner advocacy efforts of youth groups and NGOs with UNICEF youth programs such as upshift, start-up, podium, U-report and ponder and other national and bilateral programs such as GIZ Prospects for Youth, USAID Demilgeluu Jashtar for increasing awareness of air pollution health impacts and empowering youth to have a voice in solutions. Maintain an online resource of audiovisual material for awareness-raising and information on health impacts and best mitigation practices for use in teacher training colleges, medical education and in schools in Bishkek.

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