COMMENTARY

Threat of air pollution in the cleanest plateau

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Received: November 14, 2022; Accepted: February 5, 2023; Published Online: February 7, 2023; https://doi.org/10.1016/j.xinn.2023.100390

Citation: Huang T., Liu M., Xing R., et al., (2023). Threat of air pollution in the cleanest plateau. The Innovation **4(2)**, 100390.

The Qinghai-Tibet Plateau (QTP), known as "the Third Pole" and "the Roof of the World," is a region with unique geographical conditions and contains many areas exceeding 4,000 m. A major section of the plateau is in the Qinghai province and Tibet Autonomous Region, China. Although the temperature in the QTP region has been increasing at a rate slightly higher than the global average since 1979, the temperature in this region is considerably lower than those in the surrounding areas, and many parts of the QTP have annual average temperatures below 0°C. The plateau has a very low population density of ~2.97 persons/km^2 compared to the Chinese national value of 148.3 persons/km^2, affording low levels of human activities and limited anthropogenic impacts on the natural ecosystem. Consequently, the plateau is believed to be one of the cleanest areas in the world, as documented by many field-observation experiments and satellite-based studies. However, some studies have highlighted that the ambient concentrations of hazardous air pollutants such as volatile organic compounds, ozone, and aerosols, mostly in urban regions, may pose potential risks to the local population and should be paid more attention.[1] Accompanied by rare local anthropogenic emissions, ambient air quality in the QTP region is strongly affected by exogenous atmospheric pollution from surrounding regions through air transport, especially under the influence of monsoon and westerlies.[1]

Despite the well-recognized phenomenon of clean ambient air, household air pollution (HAP) closely associated with combustion sources in the QTP has been seriously underappreciated. The term "HAP" was introduced as a terminology specially focused on indoor but also outdoor air pollution associated with the inefficient combustions of household energies. This is different from the broader term "indoor air pollution" which focuses on indoor air pollution issues arising from combustion and non-combustion sources. Burning of traditional solid fuels in inefficient stoves causes serious HAP, and because many residents spend longer time indoors, HAP associated with solid fuel use has been one leading environmental risk factor causing millions of premature deaths globally every year. Heavy reliance on biomass fuels for daily cooking and/or heating in the QTP region is unsurprisingly associated with bad indoor air quality in many households. From a literature search on available studies in the QTP region, we extracted quantitative data on daily average fine particulate matter ($PM_{2.5}$) and CO levels from 13 publications published between 2000 and 2018 in English (from the Web of Science) or Chinese (from the Chinese National Knowledge

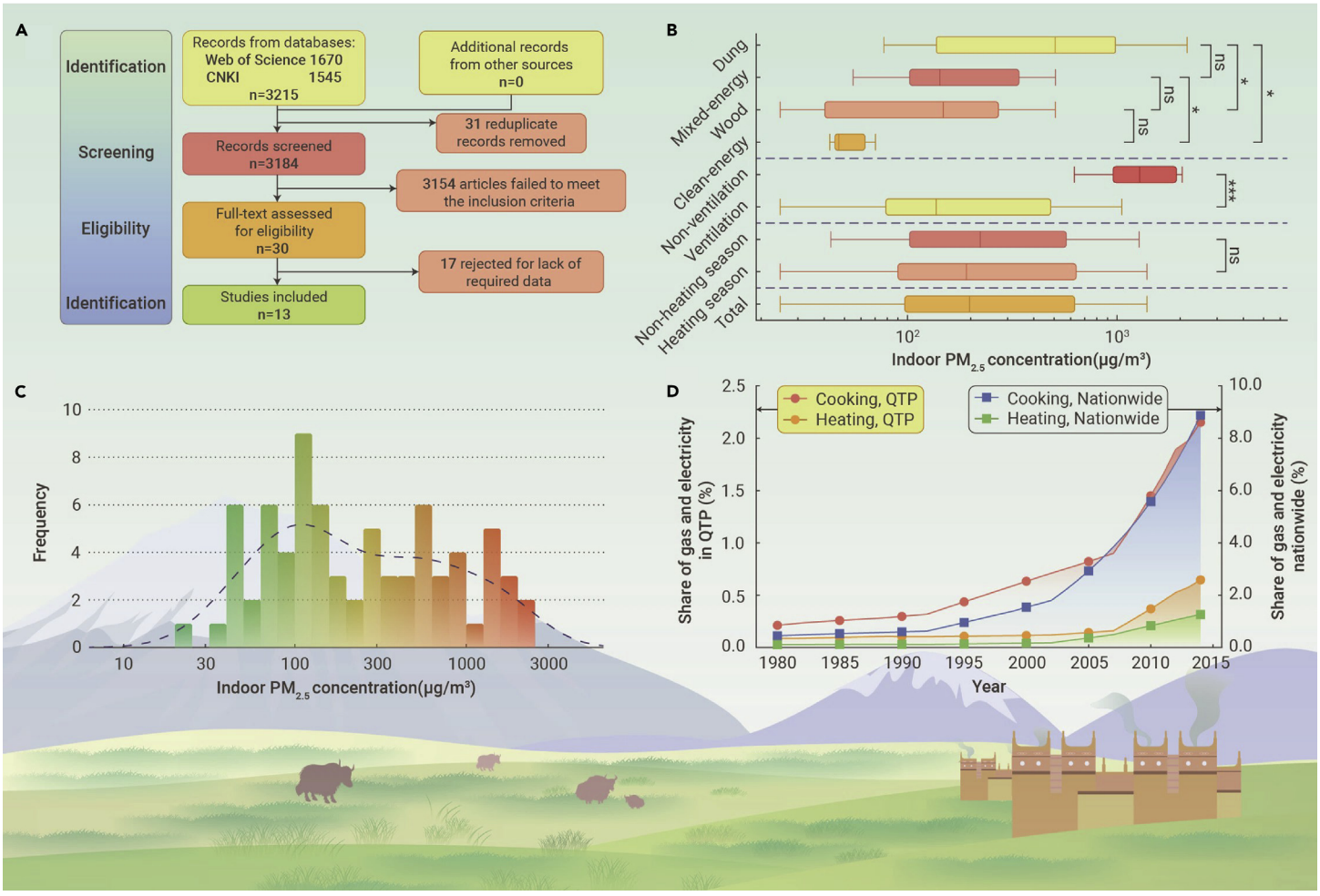

Figure 1. Available study results of household $PM_{2.5}$ and fractions of modern household energies in the QTP (A) Flowchart of the literature search for household air pollution, (B) effects of different fuel types, seasons, and ventilation conditions on indoor $PM_{2.5}$ (data shown are means and ranges from literature studies), (C) frequency histogram of 24 h average indoor concentrations of $PM_{2.5}$, and (D) share of gas and electricity in the Qinghai-Tibet Plateau region.

Infrastructure) (Figure 1A). The indoor $PM_{2.5}$ in the QTP region described in literature ranged from 24.7 to 4,964 $\mu g/m^3$, with a mean value of 518 $\mu g/m^3$ and an interquartile range of 97–627 $\mu g/m^3$ (Figure 1C). Nearly all studies reported severe $PM_{2.5}$ levels exceeding the World Health Organization (WHO) guideline value of 15 $\mu g/m^3$, and >80% reported high pollution levels exceeding the interim target of 75 $\mu g/m^3$. HAP of $PM_{2.5}$ varied considerably in different homes and study periods, and the levels appearred to be higher than many other regions in the country.[2] For example, a literature review, including scarce data in the QTP region, summarized the national average values of $PM_{2.5}$ in kitchens and bedrooms as being 338 and 275 $\mu g/m^3$, respectively.[2]

Compared to poorly ventilated households (with a mean value of 1,692 $\mu g/m^3$), indoor $PM_{2.5}$ pollution in well-ventilated households was substantially lower, with a mean value of 323 $\mu g/m^3$. Another important factor influencing indoor $PM_{2.5}$ levels is the type of household energy used. In households using clean energy sources, the average daily $PM_{2.5}$ concentration was 53.6 $\mu g/m^3$; however, for those using wood and animal dung, indoor $PM_{2.5}$ levels were as high as 167 and 751 $\mu g/m^3$, respectively. As one of the most commonly used biomass fuels in the QTP region, burning of animal dung produces much higher emissions of many incomplete combustion products, leading to higher levels compared to those using other fuels (Figure 1B), a finding that was also observed in the PURE-AIR study.[3] Indoor CO pollution in the QTP region are also a concern, where reported values ranged from 0.04 to 25.75 mg/m^3, and nearly half of those studies found daily indoor CO concentrations exceeding the WHO guideline of 4.0 mg/m^3. Indoor $PM_{2.5}$ and CO are often highly correlated, with a correlation coefficient of 0.782 ($p < 0.01$), as they are both influenced by the internal combustion sources. Results of linear mixed-effect models confirmed that the impact of ventilation was significant ($p < 0.01$), and the use of animal dung produced the highest pollution level ($p < 0.01$) after controlling for other influencing factors. Studies from different years did not show marked temporal trends in HAP in the QTP region; however, these studies were from different locations, seasons, and households using distinct energy sources. There are still no long-term studies available.

Household energy usage for daily cooking and heating (particularly for those living in cold regions) is the most fundamental issue in society development. In many developing or less-developed regions, agricultural waste, woody materials, animal dung, and coals are important household energy sources, with a global estimate of ~2.8 billion people relying on them in daily cooking . Field surveys on household energy sources in the QTP region are limited, and the results vary largely among different studies.[1,4] A recent survey reported that the fraction of time spent using modern household energy carriers, including gas and electricity, in rural households in the QTP region was <30% in 2017. This was much lower than the national average of 69% in China mainland.[4] In terms of physical quantity, the consumption of solid fuels comprised up to 99.8% of the total, whereas gas consumption was small but provided higher calorific values and energy efficiencies.[1] The household energy mix is distinct across different households and affected by many factors including accessibility, affordability, and living habits. More biomass fuels than coal were used in the Tibet. Animal dung was used for about 20%–42% of the year, comprising up to 47% of the total biomass consumed annually.[1] During the past several decades, a transition to modern energy carriers, such as gas and electricity, for daily cooking along with less use of raw biomass did occur in the QTP region, primarily as a result of socioeconomic development and increased family incomes.[4] According to the PKU-FUEL database (http://inventory.pku.edu.cn/), the proportion of clean energy sources used in the QTP region has increased substantially over the past 40 years (Figure 1D) and is expected to continue growing. However, household fuel consumption in the QTP region is still dominated by solid fuels, and this means that potential risks, especially from HAP, to environmental quality and human health remain. In Tibet, it was estimated that HAP associated with solid fuel use caused a loss of 1,804.5 disability-adjusted life years per 100,000 persons and 75.8 age-standardized deaths per 100,000 persons in 2017.[5] However, there is a lack of empirical evidence from local public health and toxicology studies on HAP in the region.

Universal access to affordable modern energy is an important goal for sustainable development. Household energy use is also closely associated with many other sustainable development goals such as human health, climate change, land use, and equality. Clean household energy transition should be a priority in promoting sustainable development of the QTP region. The transition to needs to overcome many obstacles such as high investment costs, unstable power supply, and a lack of motivation, especially among traditional locals. In traditional nomadic lifestyles, the burning of yak dung is a convenient and widely accessible source of daily energy. This may hinder the adoption and sustainable use of clean energies. Household economic condition is also an important factor affecting energy choice and consumption, while usually positive correlations were found between the household income or expenditure and the use of commercial energies (e.g., electricity, gas, and coal); and the income was negatively correlated with the use of fuelwood, animal manure, and other biomass fuels.[1] Factors such as geographic and natural conditions, family size, fuel technology, financial support, and policy are equally important. The "3E" framework of "Economy-Energy-Environment" can be applied to future work and opportunities, accompanied by investigations into social conditions and evaluations of air quality, as well as insights into factors that drive energy transitions. The promotion of clean household energy can be expected, and under the policy of carbon neutrality, there is a new era of renewable energy development and sustainable utilization of energy sources in China, including in the QTP region.

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ACKNOWLEDGMENTS

Funding for this study is partly supported by Ministry of Science and Technology (2019QZKK0605), National Natural Science Foundation of China (42077328), and undergraduate student research training program of the Ministry of Education.

DECLARATION OF INTERESTS

The authors declare no competing interests.