environmental sciences proceedings

MDPI

Proceeding Paper

Addressing Air Pollution in Ulaanbaatar and Evaluating Indoor Air Quality in Gers with Cooking, Heating, and Insulation Packages (CHIP)†

Ana M.C. Ilie [1,2], Amarjargal Dagvadorj [2], Enkhuun Byambadorj [2], Ariundelger Ariunsaikhan [2], Azjargal Tsogtsaikhan [2], Oyun-Erdene Nyamsambuu [2], Matthew Bombyk [3]

[1] Colorado Department of Public Health and Environment - Air Pollution Control Division, United States; anamcilie@gmail.com
[2] Breathe Mongolia – Clean Air Coalition, United States
[3] University of Minnesota, Department of Applied Economics, United States
† Presented at the 6th International Electronic Conference on Atmospheric Sciences, 2023

Abstract: Conducted by the nonprofit organization Breathe Mongolia - Clean Air Coalition, this study investigated ambient air pollution in Ulaanbaatar, focusing on the significant role of coal briquette combustion within ger areas. This combustion not only contributes to outdoor air pollution but also significantly degrades indoor air quality within these traditional dwellings, leading to substantial health concerns. To address this challenge, the study assessed indoor air pollution in gers – traditional Mongolian yurts – that had implemented Cooking, Heating, and Insulation Packages (CHIP), a program offering subsidized electrical heating, cooking, and insulation materials. The study encompassed 28 gers, among which 25 were equipped with CHIP while 3 were not, enabling a comparative analysis. Employing cost-effective technology, carbon monoxide levels were monitored across all 28 gers using Binary System monitors. Fine particulate matter concentrations were measured using AirVisual monitors in 14 of these gers. Data collection occurred during the winter of 2022-2023. To comprehensively assess indoor air quality within gers and ascertain the efficacy of interventions like CHIP in diminishing indoor air pollution, Breathe Mongolia intends to sustain monitoring efforts within ger areas. These initiatives strive to address data gaps and inform strategies aimed at enhancing indoor air quality.

Keywords: air pollution; carbon monoxide; ger area; $PM_{2.5}$;

1. Introduction

Severe winter air quality challenges are prevalent in Mongolia, with Ulaanbaatar, experiencing extreme pollution (Cousins, 2019 and Davy et al., 2011). The primary cause of this pollution, as in other countries, is high particulate matter (PM) levels (Guttikunda et al., 2013 and Hasenkopf et al., 2016). Air pollution's detrimental impact on public health in Ulaanbaatar has been widely acknowledged (Allen et al., 2013). Extensive research studies have been conducted to assess the quality of ambient air in Mongolia (Byambaa et al., 2019; Nirmalkar et al., 2020). These studies have examined the chemical and physical properties of atmospheric particulate matter, uncovering insights into its composition (Davy et al., 2011; Nishikawa et al., 2011; Batmunkh et al., 2013; Amgalan et al., 2016) and physical characteristics (Hasenkopf et al., 2016). Moreover, researchers have worked to identify specific sources of atmospheric pollutants and to analyze the interplay of climatic and socioeconomic factors that impact urban air quality (Davy et al., 2011; Nishikawa et al., 2011; Amgalan et al., 2016; Ganbat et al., 2013; Ganbat and Baik, 2016). In an endeavor to address air pollution challenges in Ulaanbaatar, the nonprofit organization Breathe

Citation: To be added by editorial staff during production.

Academic Editor: First name Last name

Published: date

Mongolia – Clean Coalition actively implemented "Let's Take Action!" project last winter 2022/2023, (Dagvadorj et al., 2022). The central objective of this initiative was to curb the prevalence of smoke-emitting chimneys in the city while simultaneously fostering citizen involvement in acquiring, gathering, and disseminating crucial air quality data. By equipping individuals with the tools to confront air pollution issues head-on, the project aimed to facilitate positive change on a community level, (Ilie et al., 2022; Dagvadorj et al., 2023).

2. Methods

Mongolia is accommodating a population of merely 3.36 million. The administrative structure of Mongolia comprises twenty-one provinces and a principal capital city. Notably, urbanization has surged since the mid-1990s, leading to a significant impact on the capital city, Ulaanbaatar, which now has 1.57 million inhabitants, equivalent to 45.4% of the nation's total populace (NSOM, 2023). The pressing environmental concern within Mongolia's urban areas is ambient air pollution, with Ulaanbaatar being particularly affected due to its substantial population, elevated rate of air pollution emissions, and the interplay of geographical and climatic factors (Cousins, 2019). At its core, the "Let's Take Action!" project directed its efforts towards minimizing the exposure of children to chronic carbon monoxide (CO) and fine particulate matter ($PM_{2.5}$) air pollutants in Ulaanbaatar. This mission was primarily achieved through the implementation of the Cooking, Heating, and Insulation Products (CHIP) package, a comprehensive intervention designed to upgrade traditional gers. This package incorporated enhanced insulation, electric heating systems, and ventilation mechanisms. Notably, Breathe Mongolia assumed half of the financial burden, amounting to $500, for the installation of these critical enhancements, with participating families contributing the remainder. 25 families residing in the Bayanzurkh district were part of this project, and an indoor air quality monitoring network was deployed, as shown in Fig. 1.

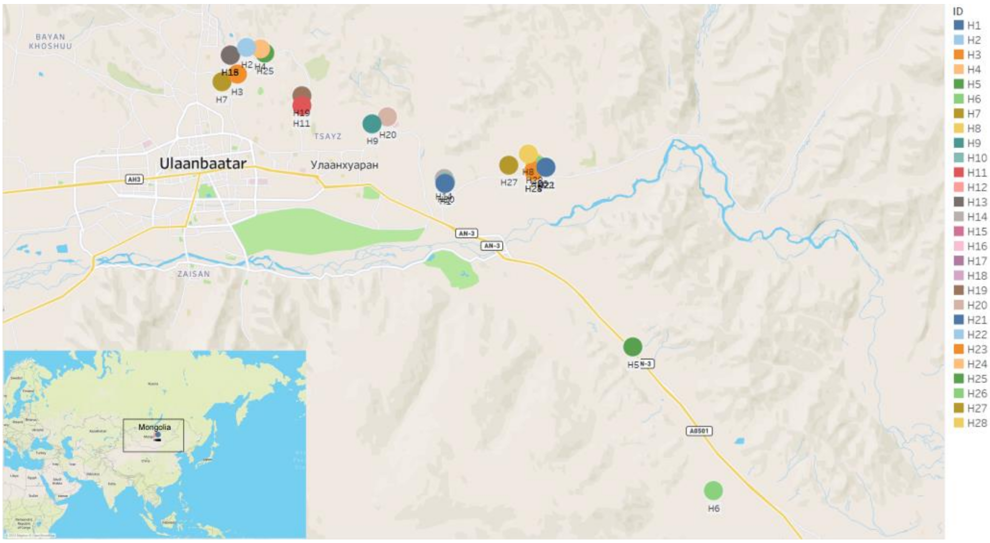

Figure 1. Indoor air quality monitoring network in Ulaanbaatar, Mongolia.

The study involved 28 gers, 25 of which had CHIP installed while three without it, serving as basis for comparison. Using cost-effective technology, carbon monoxide levels were measured using the electrochemical MQ-7 gas sensor of the Binary System monitors in all 28 gers, and fine particulate matter was measured using AirVisual monitors in 14 of them. The data was collected during the winter of 2022-2023.

3. Results

Understanding the spatial distribution of carbon monoxide (CO) and fine particulate matter, specifically $PM_{2.5}$ (Particulate Matter 2.5 micrometers in diameter or smaller), is crucial for assessing air quality and its potential impacts on public health and the environment. This article presents the results of a comprehensive study that analyzed CO and $PM_{2.5}$ concentrations across Bayanzurkh district, during the winter of 2022-2023. The focus lies on highlighting the areas with both minimal and elevated CO and $PM_{2.5}$ concentrations, shedding light on the air quality patterns prevalent during this period. The study utilized data collected from air quality monitors strategically positioned in each household. These monitors continuously measured CO and $PM_{2.5}$ concentrations in parts per million (ppm) and micrograms per cubic meter (ug/m^3), respectively.

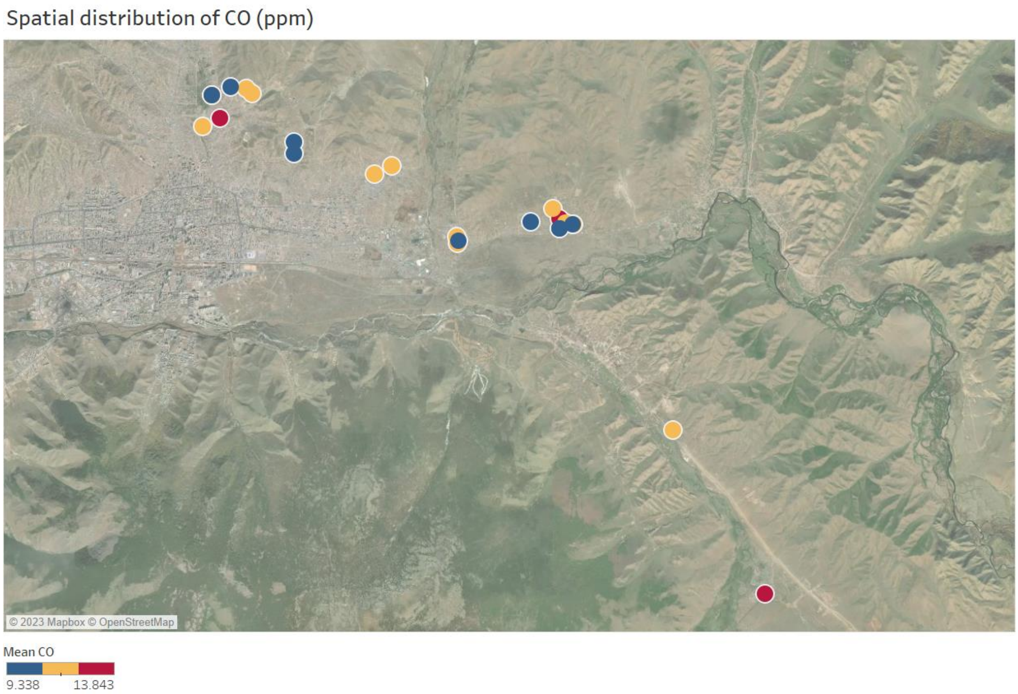

Figure. 2 Carbon monoxide concentrations of winter 2022-2023.

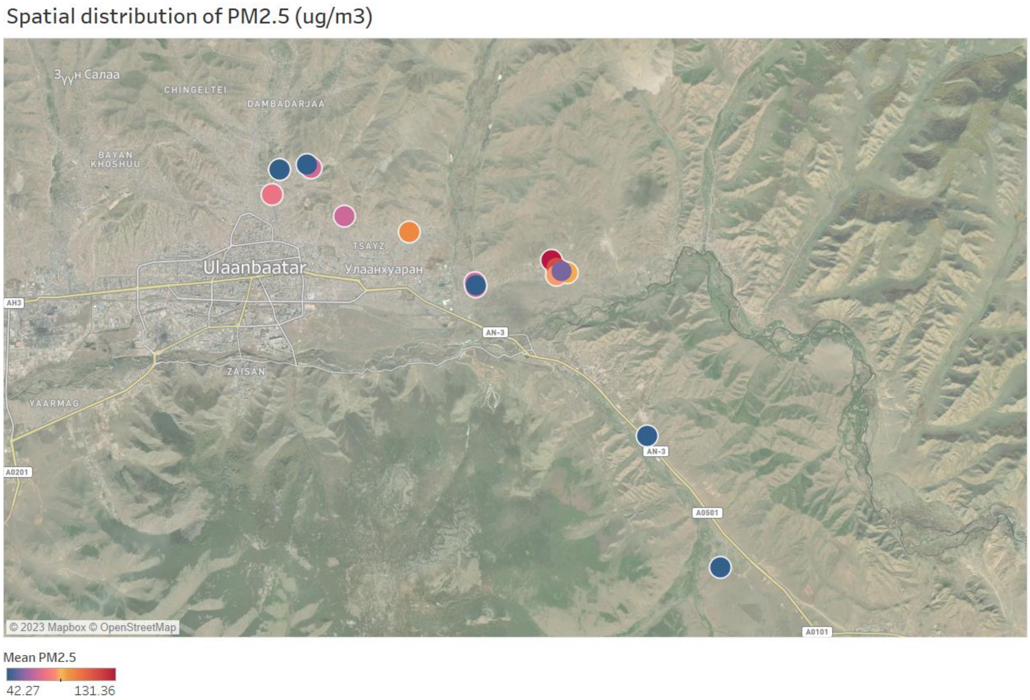

Figure. 3 Fine particulate matter $PM_{2.5}$ concentrations of winter 2022-2023.

The findings are visually represented through a spatial distribution plot, a map that vividly illustrates the varying levels of CO and $PM_{2.5}$ concentrations across the study area. The map employs a color gradient scheme, where lighter colors such as blue indicate lower concentrations, while red color signify higher concentrations. The spatial distribution plots, as shown in figure 2 and 3, highlight distinct patterns in CO and $PM_{2.5}$ concentrations during the winter of 2022-2023. Low concentration areas, regions colored in lighter shades correspond to areas where CO and $PM_{2.5}$ concentrations were relatively low, measuring around 9.338 ppm and 42.47 ug/m^3 respectively. These areas with cleaner air quality can be used as examples for making cities more sustainable and finding better ways to control pollution. Moderate to unhealthy concentrations, moderate concentrations of $PM_{2.5}$, ranging between 50 and 100 ug/m^3, are depicted using intermediate colors on the map. These areas signify that air quality might pose potential health concerns to sensitive populations, necessitating attention and strategies for improvement.

High concentration hotspots, the map also identifies locations colored in red, indicating $PM_{2.5}$ concentrations exceeding 100 ug/m^3. These high-concentration hotspots demand immediate action to mitigate pollution sources, safeguard public health, and enhance overall air quality. Although the households utilized the CHIP package, their results displayed varying concentrations that exceeded Mongolia's standard limits. This variation suggests that each household exhibited a distinct pollution pattern, necessitating individualized intervention approaches. In fact, Ulaanbaatar, recognized as one of the world's most polluted cities, faces a critical issue with elevated inhalable $PM_{2.5}$ concentrations, particularly attributed to its ger areas (Guttikunda et al., 2013; Cousins, 2019). Consequently, the urban atmosphere experiences significantly elevated levels of particulate matter. Air quality monitoring sites in Ulaanbaatar exhibit pronounced seasonal variations, with the highest concentrations occurring during cold seasons due to increased pollutant emissions associated with fuel consumption and specific weather conditions like temperature inversion. In winter, $PM_{2.5}$ concentrations considerably exceed the national limit while in warmer non-heating periods, they tend to remain near or below this threshold (Ganbat et al., 2020). Some studies underscore coal burning in Ulaanbaatar's ger area as the primary contributor to its pollution crisis (Guttikunda et al., 2013, and Lodoysamba and Pemberton-Pigott, 2011). Over the last decade, a range of efforts has targeted emissions from various sources, with a notable focus on mitigating coal combustion within ger areas. Despite all, it's important to note that PM concentrations still exceed both the WHO guideline values and national standards.

4. Discussion and Conclusions

Having accurate and current insights into source apportionment is of paramount importance for decision-makers aiming to design effective strategies for managing ambient and indoor air quality. Guttikunda's work in 2008 was the first study focusing on the sources of particulate matter emissions in Ulaanbaatar. Within this contextual framework, another study indicated a prevalence of locally generated sources over long-range transport (Nishikawa et al., 2011). The study identified power plants as the predominant contributors to emissions contributing to particulate matter, accounting for 36%, followed by household stoves at 25% and heat-only boilers at 17%. Notably, the primary sources of air pollution within the city's immediate vicinity were stoves and heat-only boilers which exhibited the most pronounced influence at street level (Guttikunda, 2013).

Additionally, it's crucial to take into account that Mongolia's Central Northern and Northwestern Mountain regions face extremely cold and dry winters, with temperatures plummeting to -45°C due to the Siberian high-pressure system's influence (Wesche and Treiber, 2012). This climatic pattern leads to weak surface winds, hindering air mixing and fostering clear skies that trigger temperature inversions, thereby contributing to severe winter air pollution (Ganbat and Baik, 2016). In Mongolian cities, the central environmental concern revolves around ambient air pollution, with Ulaanbaatar being particularly affected due to its high population density, significant emission rates of pollutants, and the interplay of geographic and climatic elements (Cousins, 2019). Our study emphasizes that over the past decade, despite numerous initiatives aimed at reducing emissions from various sources, with a particular focus on mitigating coal combustion in ger areas, air pollutant concentrations persistently exceed both WHO guideline values and national standards. The spatial distribution plots of CO and $PM_{2.5}$ concentrations during the winter of 2022-2023 provide a clear visual representation of indoor air pollution patterns in the Bayanzurkh district. This information is invaluable for policymakers, urban planners, researchers, and the public at large. By identifying areas with varying levels of CO and $PM_{2.5}$ concentrations, the study empowers decision-makers to formulate targeted interventions to improve air quality and prioritize public health during future winter seasons.

Author Contributions: *Conceptualization*: Enkhuun Byambadorj, Azjargal Tsogtsaikhan, Ana M.C. Ilie, Amarjargal Dagvadorj and Mathew Bombyk; *Methodology:* Ana M.C. Ilie, Amarjargal Dagvadorj, Enkhuun Byambadorj, Azjargal Tsogtsaikhan, Ariundelger Ariunsaikhan, Mathew Bombyk; *Investigation:* Amarjargal Dagvadorj, Ariundelger Ariunsaikhan, Oyun-Erdene Nyamsambuu; *Validation:* Ana M.C. Ilie, and Amarjargal Dagvadorj; *Formal analysis:* Ana M.C. Ilie; *Data curation:* Ana M.C. Ilie; *Writing—original draft preparation:* Ana M.C. Ilie; *Visualization:* Ana M.C. Ilie; *Project administration:* Enkhuun Byambadorj, Azjargal Tsogtsaikhan, and Amarjargal Dagvadorj; *Resources and funding acquisition*: Enkhuun Byambadorj, Amarjargal Dagvadorj and Azjargal Tsogtsaikhan.

Funding: This research was funded by AstraZeneca.

Data Availability Statement: Derived data supporting the findings of this study are available from the corresponding author on request. Python scripts for data processing, analysis and visualization available at https://github.com/anamcilie/Air-Quality-Data-Analysis-Mongolia ; data visualization available at https://public.tableau.com/app/profile/ana.ilie4688

Acknowledgments: We extend our gratitude to all participating families for their valuable support in contributing to this research; Breathe Mongolia volunteers; UNICEF Mongolia; Public Lab Mongolia; People in Need Mongolia; Magic Mongolia by Lantuun Dohio; local government agencies; Binary systems LLC.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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