Assessment of Sociodemographic Disparities in Environmental Exposure Might be Erroneous due to Neighborhood Effect Averaging: Implications for Environmental Inequality Research

Junghwan KIM[*1] and Mei-Po KWAN[†2]

[1]University of Illinois at Urbana-Champaign
[2]The Chinese University of Hong Kong

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Summary

This paper examines the neighborhood effect averaging problem (NEAP) in the evaluation of sociodemographic disparities in people's air pollution exposures in Los Angeles using GIScience methods and activity-travel diary data of 3790 individuals. Spatial regression model results indicate that assessments of sociodemographic disparities in people's air pollution exposures are erroneous when people's daily mobility is ignored because of the different manifestations of neighborhood effect averaging for different social/racial groups. Therefore, to avoid erroneous conclusions in environmental inequality research, it would be critical to consider the NEAP in studies of sociodemographic disparities related to mobility-dependent environmental factors.

KEYWORDS: air pollution; environmental inequality; human mobility; Los Angeles; the neighborhood effect averaging problem (NEAP)
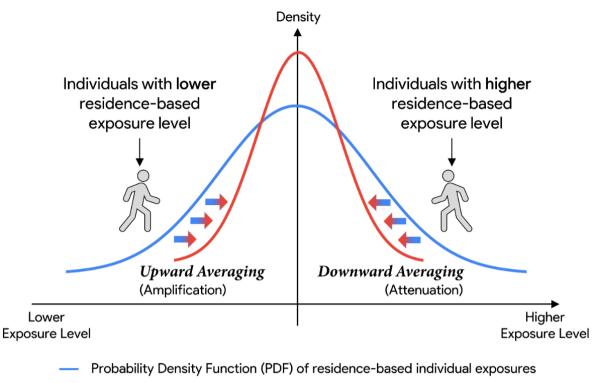
1. Introduction

In recent decades, air pollution exposure is one of the critical environmental factors that have significant negative impacts on people's health. Many studies have investigated sociodemographic disparities in people's air pollution exposure, which may result in disparities in their health outcomes (e.g., Chakraborty, 2009; Clark *et al.,* 2014). For these studies, one of the critical tasks is to accurately assess how and to what extent people are exposed to air pollution (Kwan, 2012). Most previous studies assumed that people are static and remain in their residential neighborhoods and considered a fixed residential administrative unit (e.g., census tracts) as the most important and relevant neighborhood where air pollution affects people (Kwan, 2013). In other words, previous studies have adopted the residence-based exposure assessment.

Although these previous studies have provided a useful ground for future works, we argue that evaluations of the sociodemographic disparities in people's air pollution exposures obtained by residence-based assessments can exacerbate the neighborhood effect averaging problem (NEAP; Kwan, 2018). The NEAP is the methodological problem that mobility-based exposures tend towards the mean level of the participants or population of a study area when compared to their residence-based exposures (**Figure 1**). As a result, the assessment of people's exposure to mobility-dependent environmental factors can be erroneous when people's mobility is ignored. Specifically, the NEAP implies that using residence-based exposure assessments might lead to erroneous evaluations of the sociodemographic disparities in such exposures. Furthermore, given that current public health policies largely rely on residence-based exposure assessments, the NEAP implies that their evaluations of sociodemographic disparities in exposures might be erroneous and lead to inefficient allocations of policy efforts and resources (Caplin *et al*., 2019; Macintyre *et al.,* 2001).

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[*] jk11@illinois.edu
[†] mpk654@gmail.com

Figure 1 A conceptual illustration of how neighborhood effect averaging operates in individual air pollution exposures (Source: Kim and Kwan, 2021b).

However, only a few studies to date have provided an in-depth examination of the NEAP for studies that evaluate sociodemographic disparities in people's exposure to air pollution. To fill this gap, this research (Kim & Kwan, 2021b) seeks to examine the NEAP in the evaluation of sociodemographic disparities in people's exposure to air pollution (outdoor ground-level ozone) by employing GIScience methods (e.g., co-kriging estimation) and a one-day activity-travel diary dataset of 3790 people (2640 weekday-participants and 1150 weekend-participants) collected in Los Angeles, California. This study focuses on the Los Angeles MSA because of its infamously severe air pollution levels for decades (Houston *et al.*, 2004). Specifically, this study asks the following two research questions. **RQ1**. How does the NEAP affect the evaluation of sociodemographic disparities in people's air pollution exposures? **RQ2.** Which social groups with high residence-based exposures do not experience neighborhood effect averaging?

2. Methods

First, 24 hourly (0-23h) ground-level ozone concentration surfaces are created for one weekday and one weekend day at a 1 square km resolution by utilizing co-kriging estimation. Second, each participant's daily exposure to ground-level ozone is estimated based on the two approaches: the residence-based approach and the mobility-based approach. Specifically, we use each participant's daily activity-travel diary data (collected in the U.S. National Household Travel Survey) to create his/her daily space-time paths that are used to evaluate his/her mobility-based exposure. Third, for each participant group (i.e., weekday and weekend), two regression analyses are conducted to examine the association between individual exposure levels (i.e., residence- and mobility-based estimates) and sociodemographic characteristics. By comparing the direction, size, and statistical significance of the coefficients estimated in two models, this study examines how sociodemographic disparities in people's air pollution exposures are inaccurately evaluated when human daily mobility is overlooked (**RQ1**). Lastly, to identify the sociodemographic characteristics of the doubly disadvantaged people, a spatial autologistic regression model is used (**RQ2**). The doubly

disadvantaged group consists of people whose residence-based exposure level is relatively high (among the study participants) as well as whose mobility-based exposure level is higher than the residence-based exposure level.

3. Results

First, focusing on weekday participants, the spatial regression model results indicate that using residence-based exposure assessments (1) overestimates the disparity in exposures between African-American and White people and low- and middle-income people and (2) underestimates the disparity in air pollution exposures between workers and non-workers. This is because of the different manifestations of neighborhood effect averaging of each group (Kim and Kwan, 2021a; Kwan, 2018; Ma *et al.*, 2020). Therefore, the results imply that ignoring human daily mobility can exacerbate the NEAP when examining the sociodemographic disparities in air pollution exposures. Moreover, focusing on weekend participants, the spatial regression model results reveal that there is no significant association. This is because there is a smaller regional variation in ozone concentrations and participants have a lower level of daily mobility during the weekend when compared to the weekday.

Second, 560 participants have a relatively high residence-based exposure level (top 20%). Among them, 194 (35%) are doubly disadvantaged in air pollution exposures. The results of a spatial autologistic regression model indicate that, for those who live in high air pollution neighborhoods, non-workers (e.g., unemployed, homemakers, retired, and students) have significantly higher odds of being doubly disadvantaged (i.e., lower odds of experiencing downward averaging) in ozone exposures than workers. Most non-workers are doubly disadvantaged people because they tend to spend most of their time in their residential neighborhoods as the spatial entrapment hypothesis suggests (Kwan, 1999; McLafferty and Preston, 1996).

4. Conclusion

This study concludes that ignoring human daily mobility can aggravate the NEAP in the evaluation of sociodemographic disparities in air pollution exposures. One important policy implication of our results is that public health policymakers should consider human daily mobility to take the NEAP into account when evaluating sociodemographic disparities in exposures (Kestens *et al.*, 2017; Shareck *et al.*, 2014). Furthermore, policymakers should pay special attention to the doubly disadvantaged group to fully mitigate sociodemographic disparities in people's air pollution exposures.

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Biographies

Junghwan KIM is Ph.D. candidate in the Department of Geography and Geographic Information Science at the University of Illinois at Urbana-Champaign. His research interests include human mobility, travel behavior, environmental health, the application of GIScience methods, and geoprivacy.

Dr. Mei-Po KWAN is Choh-Ming Li Professor of Geography and Resource Management and Director of the Institute of Space and Earth Information Science at the Chinese University of Hong Kong. Her research interests include environmental health, human mobility, sustainable cities, urban, transport, and social issues in cities, and GIScience.