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Innovative Stacking Method for Enhanced Data Fusion in Pollutant Population Risk Evaluation

摘要

近年来，空气污染，尤其是颗粒物 (PM) 污染，日益成为全球公共卫生领域的重大问题。PM10 和 PM2.5 是关注的重点，由于它们对健康具有重大影响，因此在研究中至关重要。PM2.5 的粒径相对较小，因此更容易进入血液循环，对人体健康造成不利影响，因此风险更高。因此，以高精度和时空分辨率评估 PM2.5 和 PM10 暴露至关重要，这是评估健康影响的基础数据。机器学习方法是实现这一目标的有力候选方法。在本研究中，我们开发了多种机器学习方法，通过对化学迁移模型的结果进行降尺度处理，以高时空分辨率估算 PM 的分布，并比较了这些方法的性能。一项重要发现是，就计算性能和运行效率而言，Stacking 方法在预测准确度和精确度方面与深度学习方法相当甚至更胜一筹。此外，Stacking 方法显著缩短了计算时间。该研究利用堆叠模型对污染物数据进行降尺度处理，成功生成了详细的污染分布图，便于将 PM2.5 和 PM10 污染物分布与人口分布图进行比较分析，最终绘制出一幅全面的环境污染人口风险图。这一观察结果强调了人口规模对污染水平的深远影响，表明人类居住密度与空气质量恶化之间存在直接关联。此外，该研究还探讨了不同人口统计学特征（例如年龄和性别）与其 PM 暴露水平之间的关系。研究发现，老年人口尤其容易受到污染的影响，这表明风险状况存在人口统计学偏差。此外，研究还强调了不同地理环境（包括城市、农村和工业区）中污染物暴露水平的显著差异，并考虑了土地利用模式。这些差异揭示了不同土地利用和城市规划对环境的影响。总而言之，本研究的结果对于制定有效的环境和健康政策具有重要意义。通过加强对颗粒物污染、人口分布和人口统计特征之间关系的理解，这项研究为政策制定者制定有针对性的策略以减轻空气污染对公众健康的影响（特别是在人口稠密和高风险地区）提供了重要见解。

关键词

颗粒物（PM）污染、机器学习技术、叠加方法、人群健康风险分析

Abstract

Air pollution, with a particular emphasis on particulate matter (PM) pollution, has increasingly become a critical global public health concern in recent years. The primary focus of this concern lies in PM10 and PM2.5, which are crucial in research due to their significant health impact. PM2.5, with its relatively smaller particle size, poses a greater risk as it is more likely to penetrate the blood circulation and adversely affect human health. Consequently, it is imperative to assess PM2.5 and PM10 exposure with high accuracy and spatial-temporal resolutions, which is the fundamental data for evaluating health effects. Machine learning methods are promising candidates for this purpose. In this study, we developed various machine learning methods to estimate the distribution of PM with high spatial and temporal resolutions by downscaling results from chemical transport models and compared the performance of the methods. A key finding is that the Stacking method, when considered for computational performance and operational efficiency, aligns with or surpasses deep learning methods regarding prediction accuracy and precision. Moreover, the Stacking method significantly reduced computational time. Utilizing the Stacking model for downscaling pollutant data, the study successfully generated detailed pollution distribution maps, which facilitate comparative and analytical assessment of PM2.5 and PM10 pollutant distributions alongside population distribution maps, ultimately leading to a comprehensive population risk map due to environmental pollution. This observation underscores the profound impact of population size on pollution levels, demonstrating a direct correlation between human habitation density and air quality deterioration. Furthermore, the study investigated the relationship between different demographic characteristics, e.g., age and gender, and their respective PM exposure levels. It was found that the elderly population is particularly vulnerable to pollution, indicating a demographic skew in the risk profile. Additionally, the research highlights significant variations in pollutant exposure levels across different geographical settings, including urban, rural, and industrial areas, with a consideration of land usage patterns. These disparities shed light on the environmental impacts influenced by varying land use and urban

planning. In conclusion, the findings of this study are invaluable in informing the development of effective environmental and health policies. By enhancing understanding of the relationship between particulate matter pollution, population distribution, and demographic characteristics, this research offers critical insights for policymakers to devise targeted strategies to mitigate air pollution's impact on public health, especially in densely populated and high-risk areas.

Keywords

Particulate Matter (PM) Pollution, Machine Learning Techniques, Stacking Method, Population Health Risk Analysis

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