Probabilistic Assessment of Air Pollution Exposure and Health Risks Among Malaysian Urban Schoolchildren

Ernie Syazween Junaidi[1*], Juliana Jalaludin[1], Mohd Talib Latif[2], Nor Ashikin Sopian[3], Noor Fatihah Mohamad Fandi[4]

[1]Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[2]Department of Earth Sciences and Environment, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[3]Faculty of Industrial Sciences and Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300 Kuantan, Pahang, Malaysia
[4]Department of Biomedical Science, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, Jalan Sultan Ahmad Shah, Bandar Indera Mahkota, 25200 Kuantan, Pahang, Malaysia

Abstract

Urban air pollution, driven by rapid urbanization and industrialization, poses significant health risks globally, particularly for schoolchildren. Children's exposure is intensified during school hours, especially during physical activities near heavy traffic. This study assessed the incremental lifetime cancer risk (ILCR) and hazard quotient (HQ) for schoolchildren in urbanized areas of Malaysia using Monte Carlo Simulation and sensitivity analysis. Air pollutant data from year 2018 to 2020 across nine continuous monitoring stations, collected by the Department of Environment, were analyzed for BTEX (benzene, toluene, ethylbenzene, xylene), ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and particulate matter (PM_{10} and $PM_{2.5}$). Data analysis was conducted using R Studio (Ver. 4.4.1) and Crystal Ball software (Ver 11.1.2.4.850). Results revealed the highest pollution levels in Northern, Central, and Southern regions of Malaysia, which are known for economic hubs with dense populations and high traffic. Benzene at ST1 (Seberang Jaya, Penang) in 2019 had the highest ILCR with mean 1.05E-05 (95^{th}:1.36E-05), exceeding the acceptable limit (1.00E-06). Ethylbenzene at ST4 (Shah Alam, Selangor) in 2018 also surpassed the threshold with 1.26E-06 (95^{th}: 1.63E-06). HQ values for all pollutants remained below one, indicating a lower non-cancer risk. Sensitivity analysis identified pollutant concentrations and exposure duration as key factors influencing ILCR and HQ. These results highlight the potential long-term health implications of sustained exposure among schoolchildren and emphasizing the need for targeted interventions such as anti-idling policies near schools to minimize children's exposure and reduce associated health risks.

Keywords: Ambient air pollution; Children; Probabilistic risk assessment; Incremental lifetime cancer risk; Hazard quotient.