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Air Quality in Kampala, Uganda: A Review of the Causes of Low Air Quality and its Impacts

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ABSTRACT

Air quality is a critical aspect of environmental health, directly impacting human well-being and ecosystem integrity. Currently, available data indicates that close to 99% of the global population is inhaling air that does not meet the required quality. Uganda is no exception to the global challenge of air pollution. The purpose of this review was to assess the current causes and impact of air pollution with a special focus on Kampala City, Uganda. Thus, the literature review explores the air quality situation in Uganda, examining the causes behind its low quality and the consequential impacts on public health and the environment. Drawing from a wide range of scholarly sources, this paper analyzes the various factors contributing to air pollution in Uganda. These include industrial activities, vehicular emissions, biomass burning and agricultural practices. Additionally, it discusses the health implications of poor air quality, such as respiratory diseases and cardiovascular problems, as well as its environmental consequences, such as ecosystem degradation and climate change. By digesting existing recent research published from 2015 to 2024, this review aims to provide a comprehensive understanding of the air quality challenges faced by Uganda and to highlight potential strategies for mitigation and improvement.

KEYWORDS

Air quality, industrial activities, pollution, environmental health, public health

INTRODUCTION

Air quality is a critical aspect of environmental health, directly impacting human well-being and ecosystem integrity. In recent years, the issue of air quality has garnered increasing attention worldwide due to its significant implications for public health, economic development and environmental sustainability[1]. While much of the focus has been on air pollution in urban centers of developed countries, the issue is equally pressing in developing nations, where anthropogenic activities often outpace environmental regulations and mitigation efforts[2,3]. Currently, available data indicates that close to 99% of the global population is inhaling air that does not meet the required quality[4].

Uganda, a landlocked country in East Africa, is no exception to the global challenge of air pollution. Despite its largely agricultural economy and comparatively low level of industrialization, Uganda faces

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various sources of air pollution, including vehicular emissions, biomass burning, industrial activities and agricultural practices. However, compared to more industrialized nations, comprehensive data and research on air quality in Uganda are relatively limited, hindering a thorough understanding of the extent, causes and impacts of air pollution in the country.

This review paper provides an extensive overview of air pollution in Uganda, focusing on its causes and impacts on public health, ecosystems and socio-economic development. It evaluates existing literature, data and research findings to contribute to a better understanding of air quality challenges in Uganda and inform evidence-based policy interventions and mitigation strategies. The paper examines the current state of air quality in Uganda, including pollutants, sources and spatial distribution patterns. It also analyzes the primary drivers of air pollution, including transportation, energy production, agriculture and waste management. The review also examines the socio-economic and environmental factors shaping Uganda's air quality. The paper critically assesses the impacts of low air quality on human health, including respiratory diseases and cardiovascular disorders. It also examines the environmental consequences of air pollution, including its effects on ecosystems and biodiversity. The review paper concludes by summarizing key findings, identifying knowledge gaps, methodological challenges and policy implications for advancing research and action on air quality in Uganda.

Current state of air quality in Kampala, Uganda: Uganda, like many other developing countries, is struggling with the challenge of air pollution. While comprehensive data on air quality in Uganda is limited, existing studies indicate the presence of various pollutants in the atmosphere, including particulate matter (PM), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2) and carbon monoxide (CO)[5-7]. These pollutants stem from a range of sources, including vehicular emissions, biomass burning for cooking and heating, industrial activities, agricultural practices and waste burning[8].

Studies have revealed spatial variations in air quality across different regions of Uganda, with urban centers experiencing higher levels of pollution compared to rural areas. This discrepancy is largely attributed to the concentration of emission sources in urban centers, such as vehicular traffic, industrial facilities and residential combustion activities. The adoption of low-cost sensors has enabled air quality monitoring in areas where they are installed such as Kampala City. Uganda air reaches an annual average particulate matter ($PM_{2.5}$) concentration of 50 µg/m^3 (STD NMT 10 µg/m^3)[9-11] This implies that throughout the year, Uganda has moderate air pollution levels. Kampala the capital city of Uganda was found to be among the most air-polluted cities in Africa with a high concentration of $PM_{2.5}$[11].

In a study by Atuyambe *et al.*[12], the daily time series of $PM_{2.5}$ values presented in Fig. 1 demonstrates that December, January and February had the greatest concentrations above 80 µg/m^3. It is also discovered that in each year, the lowest $PM_{2.5}$ values were recorded in April and May. The highest recorded $PM_{2.5}$ concentration occurred in February, 2021, during the dry season, (Fig. 1). The overall annual mean of $PM_{2.5}$ concentration between 2018-2021 was 38.8 µg/m^3 with a standard deviation of 18.6 in the range of 1.2-162.9. There was an increase in the average annual $PM_{2.5}$ concentration levels from 2019 to 2021.

As of 11 July, 2024, the particulate matter ($PM_{2.5}$) concentration in Kampala (47 µg/m^3) was 9.4 times the WHO annual air quality guideline value (15 µg/m^3). Particulate matter (PM), one of the major health-damaging air pollutants classified by the World Health Organisation (WHO) and the United States Environmental Protection Agency (EPA), forms in the atmosphere as a result of chemical reactions between different pollutants. It contains tiny liquid or solid droplets that, depending on their size, can be inhaled and cause serious health effects[13]. Fine particulate matter ($PM_{2.5}$) is harmful to humans because of its small size and diameter, which allow it to easily penetrate the lower respiratory tract[14].

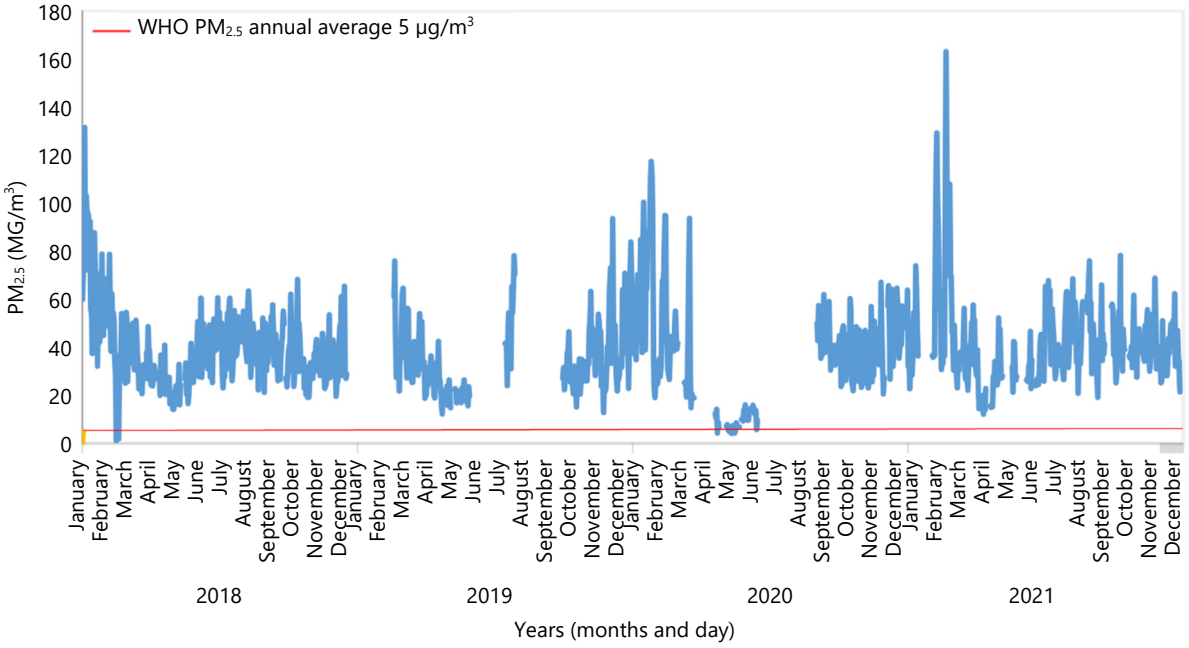

Fig. 1: Time series patterns of $PM_{2.5}$ based on BAMs 1022 at Makerere University School of Public Health 2018-2021[12]

Causes of air pollution

Transportation: Uganda has a booming demand for motorization which has been propelled by the increasing spending capacity of its middle-class population. Hence, this has made the transportation sector become the major contributor to air pollution in the country. Transportation is responsible for emitting significant amounts of air pollutants such as NO_2, CO and particulate matter. In a study conducted by Ghaffarpasand *et al.*[11], they reported that the COVID-19 pandemic lockdown reduced the movements of motor vehicles thus resulting in a significant reduction in the concentrations of $PM_{2.5}$, indicating that transport was playing a vital role in the air pollution of Kampala City. The main air pollutant from the transportation industry is particulate matter ($PM_{2.5}$) that is produced by idling cars[12]. Other than emitting during idling, the other motor vehicle conditions that elevate the level of pollution are; rapid growth of motor vehicle ownership, coupled with outdated vehicle fleets and inadequate emission control measures. Poorly maintained vehicles, inefficient fuel combustion and traffic congestion further contribute to elevated pollutant levels along major roadways and urban centers.

Energy production and consumption: Uganda's household energy usage is dominated by the usage of biomass in the forms of wood and charcoal. In energy usage, air pollution arises from the combustion of fuels. These combustions produce pollutants such as particulate matter, SO_2, NO_2, CO and ozone[14-16]. Therefore, reliance on biomass fuels, such as wood, charcoal and crop residues, for cooking and heating purposes is leading to air pollution in Uganda. Traditional cooking stoves and open fires produce high levels of particulate matter and other harmful pollutants, contributing to indoor and outdoor air pollution and posing significant health risks, particularly for women and children. Moreover, the limited access to clean and efficient energy technologies perpetuates reliance on biomass fuels, perpetuating the cycle of air pollution and associated health impacts. There is sufficient literature to support the relationship between the energy sector and air pollution in Uganda for example households that used charcoal for cooking[17,18]. These and more indicate the increase in pollution where such biomass is used for household purposes. For example, in Mbarara, the 24 hrs ($PM_{2.5}$) mean concentration was higher than the WHO's recommended limit. The same was true for the concentration of CO[17]. The main emphasis in research has been put mainly on investigating charcoal as a source of indoor air pollution, however, other forms of biomass fuel are yet to get similar attention.

Industrial activities: Uganda's industrialization sector is growing however, these industrial activities also contribute to air pollution through emissions of particulate matter, sulfur dioxide and other pollutants. Industries such as manufacturing, mining and food processing release pollutants into the atmosphere through combustion processes, material handling and waste disposal practices. Inadequate regulatory oversight, outdated technologies and limited pollution control measures exacerbate the environmental impacts of industrial emissions on air quality and public health.

Several studies have highlighted industrialization as one of the contributors to air pollution in Uganda. These studies include; Atuyambe *et al*.[12], Toe *et al*.[19] and Clarke *et al*.[20] all point to industrialization as one of the causes of air pollution. However, there are fewer studies done to correlate industrialization and air pollution.

Agricultural practices: Uganda is predominantly an agriculture-dependent economy with a focus on cash crops and subsistence levels. Agricultural produce 26.9% of the total greenhouse gas emissions[20]. Activities, including livestock farming, crop burning and the use of agrochemicals, all lead to air pollution by releasing ammonia, methane and other agricultural-related pollutants. Livestock farming, in particular, is a significant source of methane emissions, a potent greenhouse gas and contributor to air quality degradation. Additionally, the burning of crop residues and agricultural waste releases particulate matter and other pollutants into the atmosphere, further exacerbating air quality concerns, especially during the dry season. While agricultural practices do play a part in air pollution, there is not enough literature related to the subject.

Waste management: Inadequate waste management practices, including open burning of waste and improper disposal of solid waste in landfills, contribute to air pollution in both urban and rural areas. Open burning of waste releases harmful pollutants such as particulate matter, carbon monoxide and dioxins into the air, posing risks to public health and the environment. Furthermore, uncontrolled landfill sites emit methane and other gases as organic waste decomposes, exacerbating greenhouse gas emissions and air quality degradation[21-23].

Impacts of air pollution

Public health: It is estimated that 8.34 million deaths of people annually are caused by air pollution[24,25]. Environmental factors such as dust, pollution, infections and smoking have been identified as potential contributors to systemic autoimmunity prior to the onset of symptoms[26]. Studies have also shown that environmental contaminants contribute to diabetes by triggering blood vessel rupture and insulin resistance[27]. In 2022, the World Health Organization reported that 43% of the deaths of patients from stroke and ischaemic heart disease were triggered by air pollution. Exposure to high levels of pollutants is linked to respiratory diseases, cardiovascular disorders and other health conditions. Air pollution has been associated with causing acute respiratory infections. Lung infections were earlier reported in children exposed to highly polluted air environments[10].

Furthermore, air pollution has been linked to the cause of the development of cardiovascular disease among the patients. Exposure to particulate matter of $PM_{2.5}$ had a higher probability of causing the disease[28]. In Uganda, exposure to particulate air of $PM_{2.5}$ was found to contribute to a significant increase in heart disease among HIV-positive adolescents[29]. The most vulnerable groups of people whose health is easily affected by air pollution include children, the elderly and individuals with pre-existing health conditions.

Ecosystems and biodiversity: Air pollution by ground-level ozone affects vegetation by reducing photosynthetic activity, which reduces the vegetation's physiological processes and increases the plant's susceptibility to diseases. High levels of ground-level ozone can accelerate species loss, which negatively alters ecosystem interactions[30].

Air pollution also poses risks to ecosystems and biodiversity in Uganda, with pollutants such as nitrogen oxides and sulfur dioxide contributing to acid rain, which might likely lead to searing of the vegetation soil acidification and nutrient imbalances[31]. Acid rain can adversely affect soil quality, water bodies and vegetation, leading to reduced agricultural productivity, loss of biodiversity and ecosystem degradation. Moreover, air pollution can impair the reproductive success of plants and animals, disrupt ecological processes and alter species composition and distribution patterns. However, there are little or no statistics on the exact impact of air pollution on the biodiversity and ecosystem in Uganda.

Socio-economic development: Globally, the impacts of air pollution carry an economic impact be it in terms of costs per death or treatment of ill-health. Premature deaths count as the utmost ill consequence of air pollution with the related deaths anticipated to increase[32]. The economic costs of air pollution in Uganda are significant, encompassing healthcare expenditures, productivity losses, environmental remediation costs and impacts on tourism and agricultural sectors. It is projected that the global economy will spend $5 trillion in combating air pollution-related atrocities[33]. Poor air quality undermines socio-economic development efforts by reducing labor productivity, increasing healthcare expenditures and deterring investment in affected regions. Moreover, air pollution exacerbates poverty and inequality by disproportionately affecting low-income communities and exacerbating social disparities in access to clean air, healthcare and other essential services. While the social implications of air pollution in Uganda have been identified to a certain degree, the economic impacts have not been studied extensively and thus a gap in the literature.

CONCLUSION

There is substantial evidence indicating the accelerating levels of air pollution in areas where the activities predominantly support air pollution. These include areas where the source of energy is biomass and areas with high vehicular activities. Consequently, available research provides evidence of health-related issues influenced by air pollution majorly affecting children, the elderly population and those with underlying medical conditions. Thus, there is a need to develop and implement policies to curb air pollution in Uganda's Cities.

SIGNIFICANCE STATEMENT

There is sufficient research on the contribution of the energy and transport sectors toward air pollution and these studies have shown that the sector contributes more to the low air quality in cities. Thus, there is a need to develop and implement policies to curb air pollution in Uganda's Cities. Furthermore, sensitization of the public about the dangers of the usage of biomass-based fuels in household cooking is highly required to curb the evil of air pollution and its health impacts. More studies on the impacts of low-quality air on the ecosystem and the economy are also suggested.

REFERENCES

1. Obaroh, I., T. Yahaya and U. Ibrahim, 2016. Bacteriological assessment of soil contaminated with cement dust. Front. Environ. Microbiol., 2: 12-17.
2. Obaroh, I.O., U. Abubakar, M.A. Haruna and M.C. Elinge, 2015. Evaluation of some heavy metals concentration in River Argungu. J. Fish. Aquat. Sci., 10: 581-586.
3. Alum, E.U., 2023. Highlights of heavy metals: Molecular toxicity mechanisms, exposure dynamics, and environmental presence. IAA J. Appl. Sci., 10: 8-19.
4. Das, R.C., T. Chatterjee and E. Ivaldi, 2021. Sustainability of urbanization, non-agricultural output and air pollution in the world's top 20 polluting countries. Data, Vol. 6. 10.3390/data6060065.
5. Kirenga, B.J., Q. Meng, F. van Gemert, H. Aanyu-Tukamuhebwa and N. Chavannes *et al*., 2015. The state of ambient air quality in two Ugandan cities: A pilot cross-sectional spatial assessment. Int. J. Environ. Res. Public Health, 12: 8075-8091.

6. Omolo, A., C. Angiro, W.A. Wagaye, E. Olomo, J. Okino and T. Omara, 2021. Aviation noise and air pollution: Results of a study at Entebbe International Airport, Uganda. Open Access Lib. J., Vol. 8. 10.4236/oalib.1107454.
7. Pál, L., S. Lovas, M. McKee, J. Diószegi, N. Kovács and S. Szűcs, 2024. Exposure to volatile organic compounds in offices and in residential and educational buildings in the European Union between 2010 and 2023: A systematic review and health risk assessment. Sci. Total Environ., Vol. 945. 10.1016/j.scitotenv.2024.173965.
8. Odekanle, E.L., F.W. Olubiyo, O.O. Sonibare, O.M. Ogunlaja, C.O. Aremu, J.O. Ojediran and B.S. Fakinle, 2022. Health impact assessment of volatile organic compounds (VOCs) emission from the combustion of agricultural wastes. Cogent Eng., Vol. 9. 10.1080/23311916.2022.2143049.
9. Galiwango, R., E. Bainomugisha, F. Kivunike, D.P. Kateete and D. Jjingo, 2023. Air pollution and mobility patterns in two Ugandan cities during COVID-19 mobility restrictions suggest the validity of air quality data as a measure for human mobility. Environ. Sci. Pollut. Res., 30: 34856-34871.
10. Onyango, S., B. Parks, S. Anguma and Q. Meng, 2019. Spatio-temporal variation in the concentration of inhalable particulate matter (PM_{10}) in Uganda. Int. J. Environ. Res. Public Health, Vol. 16. 10.3390/ijerph16101752.
11. Ghaffarpasand, O., D. Okure, P. Green, S. Sayyahi and P. Adong *et al*., 2024. The impact of urban mobility on air pollution in Kampala, an exemplar Sub-Saharan African City. Atmos. Pollut. Res., Vol. 15. 10.1016/j.apr.2024.102057.
12. Atuyambe, L.M., S. Etajak, F. Walyawula, S. Kasasa and A. Nyabigambo *et al*., 2024. Air quality and attributable mortality among city dwellers in Kampala, Uganda: Results from 4 years of continuous $PM_{2.5}$ concentration monitoring using BAM 1022 reference instrument. J. Exposure Sci. Environ. Epidemiol., 10.1038/s41370-024-00684-9.
13. Manisalidis, I., E. Stavropoulou, A. Stavropoulos and E. Bezirtzoglou, 2020. Environmental and health impacts of air pollution: A review. Front. Public Health, Vol. 8. 10.3389/fpubh.2020.00014.
14. Zhang, L., Y. Yang, Y. Li, Z. Qian and W. Xiao *et al*., 2019. Short-term and long-term effects of $PM_{2.5}$ on acute nasopharyngitis in 10 communities of Guangdong, China. Sci. Total Environ., 688: 136-142.
15. Bamwesigye, D., P. Kupec, G. Chekuimo, J. Pavlis, O. Asamoah, S.A. Darkwah and P. Hlaváčková, 2020. Charcoal and wood biomass utilization in Uganda: The socioeconomic and environmental dynamics and implications. Sustainability, Vol. 12. 10.3390/su12208337.
16. Epuitai, J., K.E. Woolley, S.E. Bartington and G.N. Thomas, 2022. Association between wood and other biomass fuels and risk of low birthweight in Uganda: A cross-sectional analysis of 2016 Uganda demographic and health survey data. Int. J. Environ. Res. Public Health, Vol. 19. 10.3390/ijerph19074377.
17. Kansiime, W.K., R.K. Mugambe, E. Atusingwize, S.T. Wafula and V. Nsereko *et al*., 2022. Use of biomass fuels predicts indoor particulate matter and carbon monoxide concentrations; evidence from an informal urban settlement in Fort Portal City, Uganda. BMC Public Health, Vol. 22. 10.1186/s12889-022-14015-w.
18. Nakora, N., D. Byamugisha and G. Birungi, 2020. Indoor air quality in Rural Southwestern Uganda: Particulate matter, heavy metals and carbon monoxide in kitchens using charcoal fuel in Mbarara Municipality. SN Appl. Sci., Vol. 2. 10.1007/s42452-020-03800-0.
19. Toe, S., M. Nagy, Z. Albar, J. Yu and A. Sattar *et al*., 2022. Ambient air pollution is associated with vascular disease in Ugandan HIV-positive adolescents. AIDS, 36: 863-870.
20. Clarke, K., K. Ash, E.S. Coker, T. Sabo-Attwood and E. Bainomugisha, 2022. A social vulnerability index for air pollution and its spatially varying relationship to $PM_{2.5}$ in Uganda. Atmosphere, Vol. 13. 10.3390/atmos13081169.
21. Jakhar, R., L. Samek and K. Styszko, 2023. A comprehensive study of the impact of waste fires on the environment and health. Sustainability, Vol. 15. 10.3390/su151914241.
22. Ferronato, N. and V. Torretta, 2019. Waste mismanagement in developing countries: A review of global issues. Int. J. Environ. Res. Public Health, Vol. 16. 10.3390/ijerph16061060.

23. Siddiqua, A., J.N. Hahladakis and W.A.K.A. Al-Attiya, 2022. An overview of the environmental pollution and health effects associated with waste landfilling and open dumping. Environ. Sci. Pollut. Res., 29: 58514-58536.
24. Lelieveld, J., A. Haines, R. Burnett, C. Tonne, K. Klingmüller, T. Münzel and A. Pozzer, 2023. Air pollution deaths attributable to fossil fuels: Observational and modelling study. BMJ, Vol. 383. 10.1136/bmj-2023-077784.
25. Kirenga, B.J., R. Nantanda, C. de Jong, L. Mugenyi and Q. Meng *et al*., 2018. Lung function of children at three sites of varying ambient air pollution levels in Uganda: A cross sectional comparative study. Int. J. Environ. Res. Public Health, Vol. 15. 10.3390/ijerph15122653.
26. Alum, E.U. and O.P.C. Ugwu, 2023. Nutritional strategies for rheumatoid arthritis: Exploring pathways to better management. INOSR Sci. Res., 10: 18-26.
27. Yahaya, T., I. Obaroh and E.O. Oladele, 2017. The roles of environmental pollutants in the pathogenesis and prevalence of diabetes: A review. J. Appl. Sci. Environ. Manage., 21: 5-8.
28. Hayes, R.B., C. Lim, Y. Zhang, K. Cromar and Y. Shao *et al*., 2020. $PM_{2.5}$ air pollution and cause-specific cardiovascular disease mortality. Int. J. Epidemiol., 49: 25-35.
29. Hamanaka, R.B. and G.M. Mutlu, 2018. Particulate matter air pollution: Effects on the cardiovascular system. Front. Endocrinol., Vol. 9. 10.3389/fendo.2018.00680.
30. Nowroz, F., M. Hasanuzzaman, A. Siddika, K. Parvin, P.G. Caparros, K. Nahar and P.V.V. Prasad, 2023. Elevated tropospheric ozone and crop production: Potential negative effects and plant defense mechanisms. Front. Plant Sci., Vol. 14. 10.3389/fpls.2023.1244515.
31. Twinomuhangi, R., A.M. Kato and A.M. Sebbit, 2022. The Energy and Climate Change Nexus in Uganda: Policy Challenges and Opportunities for Climate Compatible Development. In: The Nature, Causes, Effects and Mitigation of Climate Change on the Environment, Harris, S. (Ed.), IntechOpen, London, United Kingdom, ISBN: 978-1-83968-611-5, pp: 1-20.
32. Wang, X., B.J. Dewancker, D. Tian and S. Zhuang, 2024. Exploring the burden of PM2.5-related deaths and economic health losses in Beijing. Toxics, Vol. 12. 10.3390/toxics12060377.
33. George, T.E., K. Karatu and A. Edward, 2020. An evaluation of the environmental impact assessment practice in Uganda: Challenges and opportunities for achieving sustainable development. Heliyon, Vol. 6. 10.1016/j.heliyon.2020.e04758.