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Planetary Health: What You Need to Know as a Pediatric Infectious Diseases Doctor

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Planetary Health: What You Need to Know as a Pediatric Infectious Diseases Doctor

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Over the past decades, we have succeeded in improving child survival and well-being, including a reduction in the burden and mortality of infectious diseases, particularly in children under 5 years of age. However, much remains to be done to reduce the 3 million deaths per year from communicable diseases among children and adolescents worldwide, which equates to about one death every 10 seconds.[1] First and foremost, the ongoing changes in natural systems threaten to reverse the health gains achieved over the last century.[2] The United Nations Children's Fund's Children's Climate Risk Index reveals that up to half of the world's 2.2 billion children are at "extremely high risk" of the impacts of climate change, and today's expectations predict only increase in coming decades.[3] More than half of known human infectious diseases may be exacerbated by climate change (Fig. 1).[4] For instance, increasing circulation of mosquitos infected with viruses such as dengue or zika, already observed in European Mediterranean areas, can be expected as a consequence of rising temperatures.[5] A recent scoping review found that 81% of all publications investigating the link between climate change and infectious diseases concluded that climate change exacerbates infectious diseases.[6] Therefore, all pediatric infectious disease specialists are likely to experience, to some degree, the effects of climate change on the diseases that they see in their daily practice. This review aims to give an outline of these effects in the broader context of planetary health. Planetary health reflects the relationship between climate change, environmental factors and human well-being.[7]

As coguardians of children's health, many pediatricians are concerned about the vulnerability of the next generation of children to the effects of planetary health issues. We aim to describe the impact of planetary health on pediatric infectious diseases, considering aspects such as air quality, global warming, biodiversity loss and socioeconomic inequalities. We included respiratory, foodborne, vector-borne and zoonotic diseases. Our aim is to provide healthcare workers involved in the care of children with infectious diseases with a comprehensive summary of the challenges posed by planetary health topics. This enables them to integrate this knowledge into their clinical practice and to contribute to global advocacy efforts.

AIR QUALITY AND RESPIRATORY DISEASES

Climate change is expected to lead to a decrease in temperature variability at high latitudes and an increase at low latitudes.[8] Rising global temperatures contribute to ground-level ozone pollution, a key component of smog. Together with byproducts from fossil fuel combustion, traffic-derived benzene and smoke emissions from wildfires, these air pollutants can contribute to

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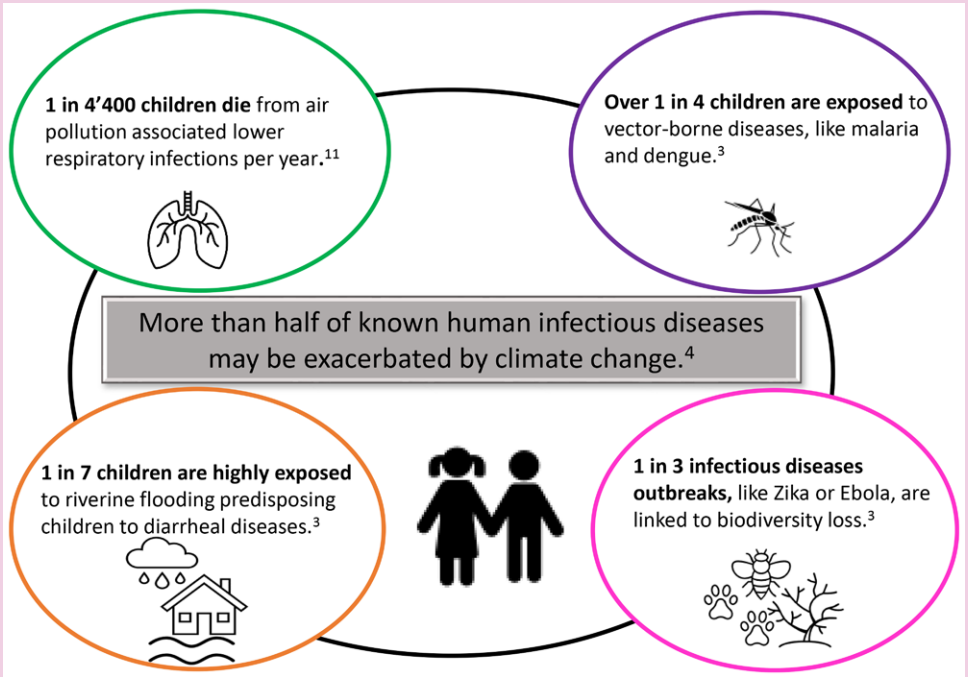

FIGURE 1. Planetary health and child health are closely related to intersections on different levels and organ systems through different vectors and mechanisms.

respiratory morbidity in children through a variety of mechanisms. These include bronchial inflammation, hyperreactivity and an increased prevalence of viral respiratory infections.[9,10] The World Health Organization estimates that more than half a million children die each year due to acute lower respiratory tract infections triggered by exposure to air polluted by excessive fossil fuel use.[11] Furthermore, extreme weather events such as floods have been described to promote or aggravate respiratory infections. In addition, studies investigating emergency department visits for acute respiratory infections have identified temperature variability, that is, day-to-day variance in temperature, as a risk factor.[12] Climate change–induced temperature fluctuations are particularly likely in tropical regions, caused by the transition to a substantially drier land surface.[8] Children's susceptibility is amplified by physiological factors such as a higher ventilation rate, smaller airways and a developing immune system.

GLOBAL WARMING AND FOODBORNE AND VECTOR-BORNE DISEASES

Heat waves are associated with an increased risk of emergency department visits for infectious diseases in young children.[13] Prolonged elevated ambient temperatures create favorable conditions for the proliferation of bacteria and an increase in bacterial diarrhea incidence.[14] A recent modeling study identified shigellosis, cryptosporidiosis and typhoid as the infectious diseases with the most increased temperature-attributable excess deaths, predominantly in sub-Saharan Africa and South Asia.[15] On the other hand, excessive heat can increase the mortality rates for some pathogens. As global warming continues, *Aedes aegypti*, the mosquito host for yellow fever and dengue fever viruses, may disappear from some regions where water temperature rises beyond its threshold for larval development. Also, rising temperature may limit the proliferation of foodborne disease–related *Campylobacter spp*. because warmer temperature supports other bacteria to out-compete *Campylobacter spp*. and ultraviolet light prohibits its survival.[16] As warmer temperatures cause increased evaporation from land and oceans, this can lead to changes in the size and frequency of precipitation events, which, in turn, may affect the occurrence and intensity of river flooding. Flooding events contribute to the contamination of crops and water sources, predisposing children to diarrhea and cholera, particularly in areas with unsafe drinking water sources.[17] Around 1 in 7 children globally are currently exposed to riverine flooding.[3] On the other hand, periodic droughts can also threaten agricultural practices. Over one-third of children globally are currently exposed to water scarcity. Climate change increases the frequency and severity of droughts, and demand and competition for water increases.[3] The repercussions of climate change–associated impaired crop yields can lead to malnutrition, which itself is a risk factor for infectious disease–related morbidity and mortality.[18] In addition, the maturation of the young immune system is influenced by multiple extrinsic factors, many of which are affected by climate change, such as poor sanitation and increased ultraviolet radiation exposure. This can potentially increase the susceptibility to infectious diseases but also to atopic or autoimmune conditions later in life.[19] At the same time, changes in the transmission season and geographical spread of vectors such as *Anopheles* and *Aedes* are leading to the spread of malaria and dengue into higher altitudes and latitudes. At present, 600 million children—over 1 in 4 globally—are frequently exposed to vector-borne diseases, and this number is probably increasing.[3] For example, the direct impact of climate change on tick-borne diseases has been demonstrated globally, with Lyme disease predicted to increase by 10%-20% in the coming decades.[20] Cases of autochthonous tick-borne encephalitis are increasing in Europe, which is due to an expansion of the geographical range of ticks in the extreme altitudes of Central Europe, and the extreme latitudes of Scandinavia.[21] While most children with tick-borne encephalitis recover without severe sequelae, residual problems such as cognitive deficits have been reported.

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BIODIVERSITY LOSS AND ZOONOTIC DISEASES

Together with climate change, the collapse of biodiversity is increasingly driving the emergence and spread of infectious diseases. Disrupted ecosystems have a particularly large impact on infectious diseases that arise at the human-animal interface, such as zoonotic diseases. In recent years, it has become apparent that some animals are more likely to act as zoonotic hosts and these animals often breed in human-dominated landscapes, directly leading to an increased risk of potential transmission contacts and spillover.[22] For example, the white-footed mouse, which is considered the most competent reservoir for *Borrelia burgdorferi* (and also the most likely to transmit the pathogen to a tick), thrives in impoverished ecosystems.[23] The ongoing loss of biodiversity and the need to mitigate the effects of climate change have led the European Commission to set ambitious targets for the protection and restoration of nature by 2030. The European Biodiversity Strategy commits to plant an additional 3 billion trees.[24] However, it is worth noting that the net effect on human disease risks remains unpredictable, as reforestation may also have the negative effect of increasing tick abundance, because forests are the preferred habitat of *Ixodes ricinus*, the principal vector of tick-borne diseases in Europe.[25] Overall, the interplay between climate change, biodiversity loss and zoonotic diseases is highly complex and not yet fully understood. From today's perspective, it is unlikely that a zoonotic disease will disappear completely due to biodiversity loss because most pathogens either rely on multiple nonhuman hosts or their hosts can relocate to geographically favorable regions.[26] Amid the predominant focus on vector-borne diseases in climate change research, diseases transmitted from wildlife to humans are likely to be significantly underestimated, particularly in remote regions.[6] Rodents, bats and primates have been identified as hosts for up to 75% of zoonotic viruses described to date.[27] For example, a decline in wildlife biodiversity has been linked to an increased risk of hantavirus spillover transmission from rodents to humans.[28] A projected global decline in local vertebrate diversity of 18% by 2100 raises significant concerns about a further increase in zoonotic diseases.[29]

SOCIOECONOMIC DISPARITIES AND PLANETARY HEALTH CHALLENGES

Climate change disproportionately affects those who are least responsible for harming the health of our planet, putting them at the highest risk of experiencing both direct and indirect health consequences. This is particularly evident in the case of children (Fig. 1).[3] Child and adolescent morbidity and mortality from infectious diseases are disproportionately high in sub-Saharan Africa and South Asia,[1] regions that also bear the greatest burden of climate change impacts.[3] Socioeconomic and ethnic disparities may lead to increased vulnerability to infectious diseases while potentially also limiting the ability to mitigate the effects of climate change. However, research on climate change and infectious diseases has fallen short in terms of social inclusivity and geographic balance, particularly in areas most affected by climate change.[6] This lack of research efforts has resulted in a significant knowledge gap, leaving critical aspects of the interaction between planetary health and infectious diseases in affected regions unexplored.

The intersection of planetary health and socioeconomic disparities is evident in the energy consumption dilemma. While energy consumption is recognized as a major contributor to the global environmental crisis, it is also a major component of human well-being. A recent modeling analysis suggests that achieving both climate change goals and a decent standard of living will require an unprecedented reduction in global economic inequality.[30] However, achieving these ambitious goals may require substantial technological advances, with potential risks to planetary health. Alternative proposals suggest prioritizing energy use for basic needs and ensuring that targeted efficient technologies are available to low-income groups worldwide, thereby addressing both environmental and socioeconomic concerns.[31] Incorporating aspects of race, ethnicity and socioeconomic status in health studies, as well as assessing and reporting on these factors, can contribute to a nuanced interpretation of results. Finally, all physicians, not only pediatricians, should be aware that early life experiences not only can impact health during childhood but also may transition into health issues in adulthood. Addressing disparities in children is, therefore, not only a concern for pediatricians but for all physicians.

PROMOTING PLANETARY HEALTH FROM A PEDIATRIC INFECTIOUS DISEASE PERSPECTIVE

As members of the newly launched European Society for Paediatric Infectious Diseases (ESPID) Committee for Sustainability and Green Practices, we recognize the urgency of incorporating planetary health into pediatric infectious disease care. This includes not only patient care but also community outreach and education on the link between planetary health and pediatric infectious diseases. Collaborative opportunities can arise through partnerships between healthcare workers and local communities, schools, public health organizations, environmental agencies and policymakers. For infectious diseases specifically, partnering with infection prevention specialists offers significant potential to reduce climate change by, for example, the targeted application of infection prevention measures and increased use of recyclable materials.

At the ESPID 2023 and ESPID 2024 conferences, our committee implemented several sustainability initiatives, such as donating surplus meals, eliminating single-use plastics and introducing meatless meals. We began measuring the event's carbon footprint and introduced the ESPID Sustainability Travel Grant, encouraging delegates to opt for travel alternatives to air. In 2024, more than 210 delegates chose to arrive at the meeting in an alternative way other than air travel. We also offered public transport discounts to travel to the venue. In addition, we transitioned the abstract allocation meeting, which was traditionally a face-to-face event prior to the conference, to a virtual format to reduce unnecessary travel.

Children, with their developing immune and respiratory systems and unique physiological characteristics, are particularly vulnerable to infections from environmental changes. Recommendations for patient care may include advising vulnerable individuals to limit outdoor activity or wear protective masks when air quality is poor. Physicians can also guide parents and caregivers to adopt active transportation methods, such as walking or cycling, instead of relying on motor vehicles. Similarly, they can encourage a predominantly plant-based diet.[32] In Western countries, healthcare systems are responsible for 4%–8% of national greenhouse gas emissions. The COVID-19 pandemic highlighted the substantial amount of medical waste generated. Heating, water and electricity, together with transport and the production chain of pharmaceuticals and chemical products, are the major contributors to healthcare-associated CO_2 emission.[33] A feasible short-term approach to this issue is reducing the energy consumption of healthcare buildings, for example, by implementing intelligent lighting systems and turning off devices when not in use. Given the financial pressures faced by many hospitals in Europe, green initiatives are often overlooked. Therefore, it is crucial to install green teams in hospitals to identify and implement sustainable practices.

Finally, active involvement in research projects focusing on the intersection of planetary health and pediatric infectious diseases yields data-driven evidence for informed policy recommendations. This reinforces the

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pediatrician's role as a crucial advocate for a healthier and more sustainable future.

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REFERENCES

1. Azzopardi PS, Kerr JA, Francis KL, et al. The unfinished agenda of communicable diseases among children and adolescents before the COVID-19 pandemic, 1990–2019: a systematic analysis of the global burden of disease study 2019. *Lancet*. 2023;402:313–335.
2. Whitmee S, Haines A, Beyrer C, et al. Safeguarding human health in the anthropocene epoch: report of the Rockefeller Foundation-Lancet Commission on Planetary Health. *Lancet*. 2015;386:1973–2028.
3. UNICEF. *The Climate Crisis Is a Child Rights Crisis*. New York; 2021. Available at: https://www.unicef.org/media/105531/file/UNICEF_climatecrisis_child_rights_crisis-summary.pdf. Accessed February 4, 2024.
4. Mora C, McKenzie T, Gaw IM, et al. Over half of known human pathogenic diseases can be aggravated by climate change. *Nat Clim Chang*. 2022;12:869–875.
5. Lühken R, Brattig N, Becker N. Introduction of invasive mosquito species into Europe and prospects for arbovirus transmission and vector control in an era of globalization. *Infect Dis Poverty*. 2023;12:1–15.
6. Van de Vuurst P, Escobar LE. Climate change and infectious disease: a review of evidence and research trends. *Infect Dis Poverty*. 2023;12:1–10.
7. Horton R, Lo S. Planetary health: a new science for exceptional action. *Lancet*. 2015;386:1921–1922.
8. Olonscheck D, Schurer AP, Lücke L, et al. Large-scale emergence of regional changes in year-to-year temperature variability by the end of the 21st century. *Nat Commun*. 2021;12:2–11.
9. Nenna R, Evangelisti M, Frassanito A, et al. Respiratory syncytial virus bronchiolitis, weather conditions and air pollution in an Italian urban area: an observational study. *Environ Res*. 2017;158:188–193.
10. Zhang R, Meng Y, Song H, et al. The modification effect of temperature on the relationship between air pollutants and daily incidence of influenza in Ningbo, China. *Respir Res*. 2021;22:1–9.
11. The World Health Organization. *Air Pollution and Child Health: Prescribing Clean Air*. Geneva: WHO; 2018. Available at: https://www.who.int/publications/i/item/WHO-CED-PHE-18-01
12. Di Cicco ME, Ferrante G, Amato D, et al. Climate change and childhood respiratory health: a call to action for paediatricians. *Int J Environ Res Public Health*. 2020;17:5344–5312.
13. Sheffield PE, Herrera MT, Kinnee EJ, et al. Not so little differences: variation in hot weather risk to young children in New York City. *Public Health*. 2018;161:119–126.
14. Carlton EJ, Woster AP, DeWitt P, et al. A systematic review and meta-analysis of ambient temperature and diarrhoeal diseases. *Int J Epidemiol*. 2016;45:117–130.
15. Chua PLC, Huber V, Ng CFS, et al. Global projections of temperature-attributable mortality due to enteric infections: a modelling study. *Lancet Planet Health*. 2021;5:e436–e445.
16. Wu X, Lu Y, Zhou S, et al. Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environ Int*. 2016;86:14–23.
17. Zhang N, Song D, Zhang J, et al. The impact of the 2016 flood event in Anhui Province, China on infectious diarrhea disease: an interrupted time-series study. *Environ Int*. 2019;127:801–809.
18. Hassan M, Saif K, Ijaz MS, et al. Mean temperature and drought projections in Central Africa: a population-based study of food insecurity, childhood malnutrition and mortality, and infectious disease. *Int J Environ Res Public Health*. 2023;20:2697.
19. Swaminathan A, Lucas RM, Harley D, et al. Will global climate change alter fundamental human immune reactivity: implications for child health? *Children (Basel)*. 2014;1:403–423.
20. Deshpande G, Beetch JE, Heller JG, et al. Assessing the influence of climate change and environmental factors on the top tick-borne diseases in the United States: a systematic review. *Microorganisms*. 2023;12:50.
21. Medlock JM, Hansford KM, Bormane A, et al. Driving forces for changes in geographical distribution of Ixodes ricinus ticks in Europe. *Parasites and Vectors*. 2013;6:1–11.
22. Keesing F, Ostfeld RS. Impacts of biodiversity and biodiversity loss on zoonotic diseases. *Proc Natl Acad Sci USA*. 2021;118:1–8.
23. Hummell GF, Li AY, Kent CM, et al. Zoonotic implications of white-footed mice habitat selection and territoriality in fragmented landscapes. *J Vector Ecol*. 2023;48:89–102.
24. Mammola S, Riccardi N, Prié V, et al. Towards a taxonomically unbiased European Union biodiversity strategy for 2030: popularity drives EU conservation. *Proc R Soc B Biol Sci*. 2020;287:2166.
25. Köhler CF, Holding ML, Sprong H, et al. Biodiversity in the Lyme-light: ecological restoration and tick-borne diseases in Europe. *Trends Parasitol*. 2023;39:373–385.
26. Brisson D, Brinkley C, Humphrey PT, et al. It takes a community to raise the prevalence of a zoonotic pathogen. *Interdiscip Perspect Infect Dis*. 2011;2011:741406.
27. Johnson CK, Hitchens PL, Pandit PS, et al. Global shifts in mammalian population trends reveal key predictors of virus spillover risk. *Proc R Soc B Biol Sci*. 2020;287:2736.
28. Khalil H, Hörnfeldt B, Evander M, et al. Dynamics and drivers of hantavirus prevalence in rodent populations. *Vector Borne Zoonotic Dis*. 2014;14:537–551.
29. Strona G, Bradshaw CJA. Coextinctions dominate future vertebrate losses from climate and land use change. *Sci Adv*. 2022;8:eabn4345.
30. Millward-Hopkins J, Oswald Y. Reducing global inequality to secure human wellbeing and climate safety: a modelling study. *Lancet Planet Health*. 2023;7:e147–e154.
31. Carley S, Konisky D. The justice and equity implications of the clean energy transition. *Nat Energy*. 2020;5:569–577.
32. Willett W, Rockström J, Loken B, et al. Food in the anthropocene: the EAT–Lancet Commission on Healthy Diets From Sustainable Food Systems. *Lancet*. 2019;393:447–492.
33. Pichler PP, Jaccard IS, Weisz U, et al. International comparison of health care carbon footprints. *Environ Res Lett*. 2019;14:064004.

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