Ethical issues arising in research into health and climate change

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Ethics of Microbiome science, climate change and health

Yonghui MA, Centre for Bioethics, School of Medicine, Xiamen University, China

Brief description of context

Climate change is unarguably a critical existential threat to humanity in the 21st century. As the most abundant organisms on Earth, microorganisms make considerable contributions to and are greatly affected by a changing climate. Microbes include viruses, bacteria, archaea, fungi, algae, and protozoa and are found in all areas of the planet, including terrestrial, urban, atmospheric, subsurface, and aquatic ecosystems. While small, microbes' contributions to the planet's climate are momentous because of their sheer numbers. Microbes are major drivers of global geochemical cycling, critical symbionts of global crops, and important producers and consumers of greenhouse gases.

While the threat of climate change is approaching, conversations about the relationship between it and microorganisms are still rare. We must appreciate the links between human, animal, environmental, and microbial health as an important part of confronting this significant threat. As climate change presents unprecedented challenges to humanity, we need novel ideas, unconventional approaches, and progressive innovations. Building on current knowledge, expanding our understanding of microbes, and implementing sustainable and microbe-based innovations are important actions to help contain climate change and promote human health and well-being worldwide.

Ethical aspects related to microbiome research and microbiome knowledge-derived use have been most extensively considered in human microbiome research and medicine. Considering a broader ethical perspective on microbiome research, (including use and societal impact) is timely, as the basis has been generated to develop new types of microbiome-based products, targeting environmental, plant, animal and human health.

The aim of this article is to construct a framework for microbiome ethics, which not only transcends various sciences disciplines, but also goes beyond existing applied ethics fields such as research ethics, public health ethics, and animal ethics, considering the broad impacts of microbes on climate change, environment, animals, humans, and the future. A microbiome ethics framework helps us plan and act with greater coordination. For example, it recognizes how microbes and antimicrobial-resistant pathogens can be transmitted across species, thereby directing policy attention to antimicrobial use across human, veterinary, and agricultural sectors simultaneously. Applied to problems of climate change and health, a microbiome ethics approach highlights how environmental, animal, and human uses of microbiome-based interventions must be coordinated among many stakeholders and involve complex considerations. Moving toward an ethics of microbiome requires a more nuanced analysis of ecological relationships, including humans' connections to other species as hosts, vectors, domestic companions, and to climate and space.

Climate change and microbes impact each other

While human activity has been a main driver of climate change, microbes are also a major factor. As the most abundant organisms on Earth, microbes both affect, and are affected by a changing climate. Newly evolved microbial activities can lead to positive or negative feedback on climate

change and its effects. The main effect of climate change on microbiota is related to biodiversity changes in different regions of the planet, mainly due to variations in temperature. These alterations are resulting in a worldwide (re)distribution of pathogens, which was not considered a few years ago. They mainly affect different food chain sectors (such as agriculture, livestock and fishing), as well as human health. Hence, the spread of numerous animal and plant pathogens has been observed in recent years from south to north (especially in America, Europe and Asia), leading to the spread of numerous plant and animal diseases, which results in economic and ecological losses. In addition, global warming that accompanies climate change could also be related to emerging antibiotic resistance.

Microbes, health and the environment

Case study: Inequitable microbial exposure in urban housing[1]

Urban populations are growing rapidly, with the United Nations (UN) projecting 68% of the global population living in urban areas by 2050. While living in an urban area reduces overall microbial exposure compared to that in rural environments, exposures to microbes are not equal in urban areas. Lower-income, minority, and immigrant populations disproportionately live in housing with physical problems that can lead to mold exposure from water damage, dangerous aerosols, and exposure to vectors of disease because of building deterioration. Living in low-income neighborhoods and crowded conditions are also associated with higher rates of infectious diseases. Increased exposure to microbes harms these communities' health inequitably. Global warming and altered precipitation patterns will allow pathogens to expand their geographic and temporal range and expand into novel environments in urban areas. Land management and urban planning strategies along with pathogen surveillance and public health policies must be integrated to preserve the health and well-being of all populations.

Though microorganisms contribute to the negative effects of climate change, they can also help mitigate its impacts. Growing evidence suggests that microbial tools can provide effective solutions for both mitigation and ecosystem adaptation to climate change. By understanding and managing soil microbial communities, it is possible to improve soil health, soil water-holding capacity, and promote plant growth in agricultural and natural ecosystems.[2] Based on the new knowledge generated from human microbiome research, the microbiome has increasingly been proposed as a tool and a target in the effort to address antimicrobial resistance, including strategies involving manipulation of the microbiome to deplete antibiotic resistance organisms or to enhance immune responses to vaccines may prove valuable.

It is important for the scientific community to recognize microbes as invaluable partners in the fight against climate change and the promotion of human wellbeing. Microbiome research is relevant and important for many of the topics prioritized: Food quality, productive and sustainable agriculture, forestry, food safety and food security, circular bio-based economies, reducing waste, upgrading residues/side-streams, protecting soil, improving nutrition, green and healthy-eating, reducing AMR, drug discovery, stopping biodiversity loss and ensuring water quality. Notably, most of these are central tenants of the UN Sustainable Development Goals[3].

Ethical issues with commentary: Towards a comprehensive framework of microbiome ethics

Microbiome ethics relates to several recognized fields of ethics, including research ethics, environmental ethics and animal ethics. Animal welfare at large is supported by bioethics, and by microbiome ethics, as improved microbiomes may reduce animal suffering. Biodiversity and conservation biology are a focus of environmental ethics, but also of microbiome ethics, as e.g., soil/plant microbiome improvements can reduce the need for chemical pesticides or fertilizers.

[1] This case is partly derived from a report "Microbes and climate change—Science, People & Impacts", American Society for Microbiology & American Academy of Microbiology.
[2] Kumari, A., Dash, M., Singh, S.K. et al. Soil microbes: a natural solution for mitigating the impact of climate change. Environ Monit Assess 195, 1436 (2023).
[3] Lange et al, Microbiome ethics, guiding principles for microbiome research, use and knowledge management, Environmental Microbiome, 2022, 17(50)

Microbiome-derived interventions to improve a distorted gut microbiome are thus relevant to microbiome ethics. Furthermore, ethical examinations on human microbiome preventive and therapeutic uses (e.g., faecal microbiome transplants) are already widely explored[4]. Another emerging topic of ethical relevance is where anthropogenic-incurred wildlife biodiversity loss has reached a stage, where microbiome-targeted interventions provide the only solution[5].

The key concepts in microbiome ethics is an ethics of interconnection and interdependence. Increasing volume of evidence between climate change and health, including the health of human, animal, and environment, heightens the importance of time in our moral deliberations and highlights intergenerational justice. Microbiome ethics recognize the fact that climate change, health of people is connected to the health of animals and our shared environment, so its core idea is the ethics of interconnectedness and interdependence. Though scholars distinguish these two concept, as Beever and Morar note, interconnectedness is conceptually proximal to, but distinct from, interdependence, although the two are often conflated[6]. A microbiome ethics would advance efforts to enact microbiome-based strategies and health policies that recognize the connections, conceptually and practically, between individual and community, freedom and public benefit. Collective interconnection, such as the shared impacts of climate change and widespread antimicrobial resistance, raises questions about interdependence—how we distribute or share responsibility when we rely on each other to coordinate action because of our shared fate[7]. Issues in microbiome ethics includes: How do we ensure that future, potentially disruptive, microbiome knowledge-based and microbiome-derived treatments in the health and food system and beyond are being developed globally, for the benefit of all, supporting environmental, dietary, and ethnic diversity? While we have developed a system of informed consent for use of organs, tissues, and other bio-samples, the handling of microbiomes remains largely unregulated (?). Do we have the ideal system in place for microbial strains isolated from human individuals (or their faeces)? Are we in gear with regard to establishing a similar system, ensuring that respect for human integrity also cover its microbiota? Timely and responsible action should ensure that microbiome studies are integrated in all these areas, and that microbiome ethics, identifying issues and dilemmas, becomes an integrated part of sustainability assessment.

Conclusions

This paper raises important questions relevant to the intersection of microbiome research, climate change, human health, and innovations. It is urgent and essential to develop a new framework for microbiome ethics which acknowledge the interconnectedness and interdependence between domains of climate change, the health of human, animal, and environment, and calls for coordination among many stakeholders and involve complex considerations. We have the consciousness and much of the knowledge and technology needed to avoid the most dangerous scenarios of anthropogenic climate change. Incorporating microbial sciences into climate change initiatives will help provide a better understanding of and ability to mitigate climate change's future impacts. Policies should be informed by microbiome ethics and enacted in ways that facilitate public-private partnerships between diverse scientists, commercial entities, regulatory and policy makers, and other stakeholders to translate research discoveries into scalable microbial innovations. It's also important to highlight and prioritize addressing inequities in microbial threats of vulnerable communities at greater risk of infectious disease exposure, altered microbiota, and food insecurity caused by climate change.

[4] Ma Y, et al. Ethical issues in fecal microbiota in practice, American Journal of Bioethics. 2017 May;17(5):34-45.
[5] Reardon S. Faecal transplants could help preserve vulnerable species. Nature. 2018;558:173–4
[6] Beever J, Morar N. Interconnectedness and interdependence: challenges for public health ethics. Am J Bioeth. 2017;17(9):19-21
[7] Meagher KM. Can One Health Policy Help Us Expand an Ethics of Interconnection and Interdependence? AMA J Ethics. 2024 Feb 1;26(2):E162-170. doi: 10.1001/amajethics.2024.162. PMID: 38306206.