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INVITED COMMENTARY

Planetary Health and Population Health: the Anthropocene Requires Different Thinking and Approaches in Serving Public Health

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The health of humans has been at the forefront and priority of effort of all past, current and future civilizations, but we are now in an age where planetary health is becoming as important as human health because of overuse of the planet's resources in the Anthropocene, the resulting health impacts of which we are now witnessing. We therefore need to think outside our usual approaches in epidemiology and pursue a paradigm shift towards the boundaries of our sciences and collective wisdom. We need to better understand the seriousness of the risk to human well-being and how we might prepare for it and even attempt to prevent or ameliorate the worst scenarios among the populations who will be impacted the most.

Earlier civilizations have cared for the health of the planet, such as the indigenous populations all over the world and the remnants of their cultures till today, whether American Indians in both South and North America, Maori in New Zealand, or Nomadic Bedouin in the Deserts of Arabia and Nomadic Saami in the Arctic region. They all consider the earth, nature, and its bounties a privilege to be cherished and respected because of the interdependence with the environment for their survival. As if they had sustainability in their genetic code and culture transmitted through the generations, they have ensured that they are part of the eco-system and are a positive force to live and let animals, plants and all other creations live.

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Though there were mass extinctions because of natural environmental disasters throughout the long history of Earth, we are at a pivotal era in which humans are a cause of the decline in the planet in what is known as the Anthropocene. The more visible indicators of the start of Anthropocene and the end of the Holocene is the start of the "Great Acceleration" as reported by Steffen et al. 2015, in which the authors demonstrate since the year 1950 there was an exponential increase in population, wealth, energy and water use, and overconsumption of resources that is driven by the 36 wealthiest countries that are part of the Organization for Economic Cooperation and Development (OECD). This has driven a similar exponential increase in CO_2, NO, methane, ocean acidification, and the associated increase in surface temperature and the decline in stratospheric ozone that was not limited to these countries but rather impacted the globe as a whole [1]. These changes are undermining the ecosystem of the earth, and eventually undermining our very own existence as a species in an Earth-System that will no longer sustain us if we continue on this path.

Therefore, there is a need for a paradigm shift in how we deal with human health in the context of planetary health in the Anthropocene. That is why *Health-Earth* was created as an international network of epidemiologists focusing attention on the gap in research and education regarding planetary health in the Anthropocene and its impact on population health in the long term [2]. This issue of Current Environmental Health Reports is dedicated to this topic and includes contributions from founding members of the network.

The manuscripts tackle the need for new approaches and methods in epidemiology to address this major public health risk that is real and threatening our long-term existence.

The paper by Butler [3] provides provocative theoretical frameworks to challenge the discipline of epidemiology to

come up with a new approach he names *Planetary Epidemiology*. The common approach taken by epidemiology is focused on individual cause and effect with human well-being as the focus of these associations. The confounders are other known risk factors for human health. However, the resources of the earth, how human activity impacts them and how, in turn, the lack of such resources impact the health of humans is under-recognized. The models he provides are initial simple theories and equations about how these relationships might be considered and quantified, opening the door for further methodological and statistical development to make them feasible in practice. The main challenge will be how to collect the data for these variables and how to get unified acceptance for the standards for these variables in these equations. The fact that he has put forth six clear and well-articulated principles helps advance this area for future scientists to build on them. He focuses on how there is competition between humans and the rest of creation for the same gradually dwindling and finite resources of the earth. He makes the case that human ingenuity cannot by itself sustain resources unless there is cooperation rather than competition and wars, and that there is disparity in the impacts from the declines in these resources. Without such cooperation and an effort to sustain Earth for all, the decline in population health will impact nations that are rich, such as the heat waves in Russia and Europe, as well as nations that are poor, such as the rise in the food prices and famines despite global prosperity and affluence.

Continuing from such theoretical concepts by Butler, the paper by Jaakkola and colleagues [4] provides an example of a population that is impacted by the decline in the health of the planet who are indigenous and lived in harmony with the harsh ecosystem of the Arctic by herding reindeer for centuries: the Saami in Northern Finland and other Scandinavian countries. To be able to identify a subpopulation that is at the forefront of climate change health impacts is challenging because of the widespread and variable trends of climate change globally and the variability among and between populations. Therefore, the Saami population in the arctic zone in Northern Europe present a unique opportunity to study climate impacts on a population similar to the example of the canaries in coal mines, warning the rest of the population about the future risks from the decline in planetary health. The dependence of the Saami on environmental resources makes them more vulnerable than other populations to the impacts of climate change. The paper by Jaakkola and colleagues provides the first comprehensive review focusing on this issue and why this population is vulnerable. Their dependence on reindeer herding as a major livelihood and the rapid economic development and the search and drilling for natural resources in the Arctic because of receding snow from global warming is a major risk. There is clear absence of data to help demonstrate this impact because of confounders. Although they are not a large population compared to many other populations likely impacted by climate change in Africa, Asia, the Middle East, and other areas, the impact on this well-defined homogenous population can be more easily measured and the small numbers are an advantage for population studies. Jaakkola and colleagues provide a holistic approach and framework to study the overall well-being of the Saami and demonstrate the primary, secondary and tertiary impacts of warming global climate on their lifestyle and livelihood. Grazing for reindeer is undermined by forestry and competing land use as well as climate change, leading to a decline in the natural diet for reindeer (lichen). Other vegetation is competing with lichen because of warming weather and the warmer temperatures create crust ice rather than soft snow and reindeer cannot dig through it to reach lichen. This is leading to a change in the lifestyle of the herders and some are moving to urban areas for better-paying positions, while others are suffering stress and mental illnesses because of the scarcity and unpredictability of the impacts of climate change on their future and livelihood. In addition, chronic diseases such as diabetes are becoming common due to lack of physical activity and abandoning traditional diets. The authors emphasize the need for a holistic approach to assess the impact of climate change on this vulnerable population that goes beyond the traditional epidemiological methods. Pasture is impacted by a climate that is impacting grazing of reindeer that is, in turn, impacting the lifestyle and well-being of the Saami people through "climigration" and mental illness, becoming urbanized and physically less active, turning away from traditional food of reindeer meat, fish and berries to a Western high-energy diet leading to chronic diseases. This is a demonstration of why we need different holistic approaches to determine the health of the populations in the era of the Anthropocene.

In another contrasting and different target population impacted by the Anthropocene and planetary health, the manuscript by Svendsen et al. [5] brings attention to disaster epidemiology in the context of extreme weather impacting the city of Charleston, South Carolina in the USA as a vulnerable metropolitan urban area. As an example of increased precipitation, sea level rise, high winds, and extreme events in the form of hurricanes, all causing flooding more frequently than before, Charleston is highly vulnerable to these events and the authors detail the recent history of such events for this city and how future flood predictions are going to be even more serious. This is leading to public health emergencies by increasing infectious diseases, food poisoning, and major economic losses. The extreme events are going to increase in frequency and severity and they can lead to death, injury, and disease in a very short period. Just this last September, Hurricane Florence hit North Carolina and South Carolina and caused one of the worst floods in the history of the East Coast, resulting in damage to the livelihood of farmers, spread of infectious diseases, and a major outbreak of mosquitos that are three times the size

of normal mosquitos which carry diseases such as the West Nile virus [6]. As a result of flooding, a hog farm manure pit filled with feces and urine overflowed into the flood water causing serious risk of disease transmission. The damage is estimated to reach $22 billion dollars. The death toll reached 35, and 10,000 people were displaced into shelters and whole towns were submerged in flood water. Although there are tools for research and practice-based epidemiology in disaster situations, the authors argue that there is lack of awareness of the public health community for preparation, response and recovery for such weather-related disasters. Further, healthcare facilities should not rely on outdated flood hazard maps in preparation for such disasters. Climate change health vulnerability assessments should reflect the response to such extreme weather disasters and their increased frequency and the type of public health problems they bring. All these factors are increasing the vulnerability of public health from weather-related natural disasters and new approaches in epidemiology and public health in dealing with such disasters are needed.

Studies by Morin [7] and Morse [8] both discuss weather, seasonal climate forecasting and early warning systems that would help predict infectious disease outbreaks resulting from climate change, thereby helping decision makers allocate resources and control such outbreaks. These forecasting approaches are similar to understanding patterns of flooding and preparing for them but at a global scale. The approaches are in demand and provide decision makers with advantages in a time of warming climates, leading to spread of disease-carrying vectors into new areas beyond the tropics. They argue that the traditional epidemiological approach depending on early clinical cases through surveillance after the outbreak begins will not be optimal for the future decades of a warming planet. Although all weather conditions are needed for such forecasting, precipitation is the most important for impacting the life cycle of vectors of infectious diseases. The authors provide the argument that such warning systems will create a paradigm shift from surveillance epidemiological methods to forecasting data that might be months ahead of the actual predicted outbreaks and therefore giving much longer preparation for public health officials to deal with them and even prevent them. The main challenge for such forecasting is the quality and accessibility of health data. Additionally, major confounders of outbreaks that forecasting would not take into consideration are travel and tourism, herd immunity and socioeconomic status. Forecasting systems can be adapted and include such confounders in the forecasting, but other challenges of operationalizing such a system and the need of cooperation between countries will require time after the system is built. Morin and colleagues provide a good example of how such forecasting is being implemented by the European Center for Disease Control to address Vibrio cholera outbreaks from the Baltic Sea, a sea that is decreasing in salinity and increasing in warmth making it appropriate for outbreaks of this and other pathogens. Morse in his paper focuses on the tropics and rain prediction months ahead of time to prepare for outbreaks of vector-borne diseases using the seasonal scale ensemble prediction system to model ocean and atmospheric conditions. These models can be run out for 7 months by typically running 50 models with different scenarios to predict if the season will be drier or wetter during a certain month in the near future but not the exact day that it will rain. The prediction is enough to model the vector-borne disease models based on such information and the forecast has a geographical resolution of 80 km. But similar to Morin and colleagues, Morse cautions about the challenges of using such models, especially given limited weather data availability, challenges in interpretation of results to decision makers and the other confounding factors that can play a role in spread of diseases (by vectors such as mosquitos) including land use, and migration of humans and animals carrying the disease. He also provides an example of the system being applied regarding malaria in Botswana, as well as similar applications in Brazil regarding dengue, and Bangladesh regarding cholera. Both papers suggest there is a need for new methods and approaches in dealing with global warming and the challenges of vector-borne diseases and a need for cooperation between countries.

In this issue, we provide a glimpse of what directions public health and environmental epidemiology need to take locally and globally to address climate change, not because this the only concern in the Anthropocene, but because this is an area for which we do not have enough data, methods and literature. Other areas of sustainability and agricultural practice, population growth and poverty, security and transportation and their relation to health is understudied. These proposed methods go beyond reusing or expanding statistical methods and focus on the need for data and cooperation of countries. It also depends on cross-disciplinary collaboration of environmental and weather data and science with epidemiology to address vector-borne diseases, re-educating public health and health care professionals and administrators about epidemiology tools in extreme weather-related public health disasters, studying vulnerable indigenous populations holistically in terms of the impact of climate change on their livelihood beyond traditional public health, and developing a new discipline of planetary epidemiology.

As section editor and a founding member of Health-Earth, I planned this issue in consultation with the authors to elaborate on the areas they have been working on to raise awareness about the challenges the discipline of public health and epidemiology in planetary health is facing and some examples of approaches that can overcome such challenges. That is how

this issue became dedicated to the area of the Anthropocene and planetary health and their impact and relevance on human health. The quality of data required for this future area is a common challenge across all the themes, and the need for cooperation by governments and unconventional collaborators is a must for the success of this new field. Retraining and re-education of epidemiologist is critical for dealing with this major public health risk of the twenty-first century. This was also one of the recommendations of the International Network for Epidemiology in Policy and the International Society for Environmental Epidemiology joint policy brief regarding the role of epidemiology in climate change [9]. We have a responsibility towards fellow humans and the planet we share to fulfill the health needs of society as our major target, but cannot neglect the health of the rest of the planet and how to study human health as part of such planetary system in a holistic way.

Compliance with Ethical Standards

Conflict of Interest Wael K. Al-Delaimy declares that he has no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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