Climate Change
Implications for Gastrointestinal Health and Disease

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Abstract: The earth's atmosphere has warmed by about 1°C compared with preindustrial temperature. This is producing changes in the earth's climate and weather which have implications for gastrointestinal health and disease. Climate change will exacerbate current challenges with regard to provision of adequate nutrition and access to clean water. An increase in high rainfall events, flooding and droughts will be associated with an increase in enteric infections and hepatitis. Changes in habitat may result in altered distribution of gastrointestinal illness such as Vibrio cholera. Climate change will force migration between countries, and within countries, and will drive relocation from rural to urban areas, further straining sanitation and clean water provision. The infrastructure required to the delivery of gastrointestinal care is vulnerable to extreme weather events which will become more frequent. The Gastroenterology community needs to join the debate on climate change by organizing, educating, advocating, and supporting our political leaders as they face the enormous challenges posed by global warming.

Key Words: climate change, global warming, gastroenterology, gastrointestinal health, gastrointestinal disease

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PURPOSE

The purpose of this article is to introduce some of the concepts behind the science of global warming and to outline how we, the global Gastroenterology community, might organize to meet the challenge.

The World Is Warming and It's Impacting on Us

There is strong evidence that the world is warming compared with preindustrial levels.[1] There is compelling evidence that the rising temperature of the earth is producing changes in climate which have significant implications for the health of humanity,[2] including gastrointestinal health and disease, for which we as gastroenterologists have a high level of custodial care. As physicians with expertise in gastrointestinal health we need to prepare for the challenges ahead.

Greenhouse Gases

We can state, with a high degree of confidence, that the rise in global temperature is secondary to the accumulation of greenhouse gases (GHG) in the atmosphere and that this is primarily as a result of human activity.[1] Despite rising concern with regard to global warming, release of these gases into the atmosphere continues to increase.[3]

GHG, by virtue of their chemical structure, are able to absorb heat energy from the sun and hold it in the atmosphere. CO_2 can absorb photons from infrared radiation reflected back from the earth and release this energy to other molecules, thus trapping the heat in our atmosphere rather than allowing it to disperse into space. GHG can be naturally occurring such as water vapor, produced by both humans and nature such as ozone, CO_2 and methane, or purely synthetic. GHG differ in their concentrations, origins, duration of time for which they remain in the atmosphere, and their ability to contribute to warming. Global warming potential reflects the ability of a gas to absorb energy over a period of time, usually 100 years, relative to an equivalent amount of CO_2.[4] It allows a comparison of the contribution of different gases impact to atmospheric warming. For example, Nitrous oxide, although released in much smaller volumes than CO_2, is 265 times more potent in absorbing heat energy.

It is important to understand the origins of the gases since strategies to reduce output can be aimed at the source. Methane, for example, is produced by a number of sources including cattle. There were 1.4 billion cattle in the world in 2010.[5] A lactating cow can produce nearly 3 kg of methane each week.[6] Hence the call by environmentalists to move to a more plant based diet.

Different activities produce more or less GHG. Reductions in GHG involve an understanding of these contributions to GHG. Countries vary in their GHG emission profiles but globally the main activities, and percent contribution, are as shown in Figure 1.

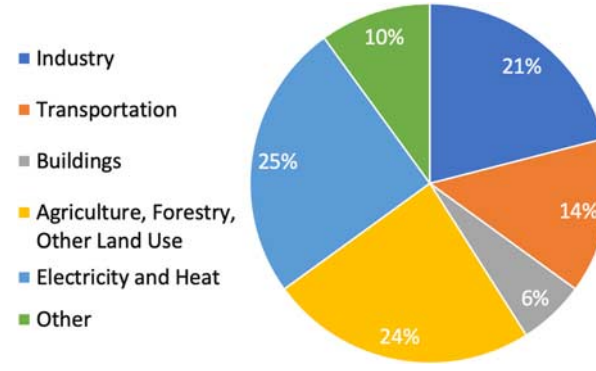

FIGURE 1. Contribution to greenhouse gases emissions by percentage and activity sector.[7]

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Electricity and heat production accounts for 25% of emissions. These are generated by burning of fossil fuels to produce electricity. Agriculture, forestry, and other land use generate a similar amount primarily through the cultivation of crops and livestock. Buildings produce GHG through onsite energy generation and burning of fuels for heat or cooking. Transportation accounts for 14% and includes road, air, rail, and marine transport. Industry produces one fifth of the global emission by burning fossil fuels on site for energy, and by emissions from chemical and metallurgical processing. A variety of other activities account for the remainder.

Per capita CO_2 emissions vary markedly by country. In 2014, for example, Bangladesh produced 0.406 metric tons per capita; Morocco, 1.8; UK, 6.5; and USA, 16.5.[8] Wealthier countries produce more GHG as a result of greater activities in all areas.

Since the onset of the industrial revolution we have put 900 billion tonnes of GHG into the atmosphere and are adding over 53 billion tonnes of CO_2 equivalent per year at present.[9] This is close to 1 billion tonnes per week and it is affecting atmospheric GHG levels.

Historical concentrations of CO_2 can be measured from air trapped in ice deposits. Since 1958 direct continuous measurements have been available. The data indicate that the concentration of CO_2 in the atmosphere is higher than at any time in the 800,000 years for which we have data.[10] CO_2 concentrations began to rise in 1850, close to the start of the industrial revolution, and accelerated markedly after 1950.

TEMPERATURE CHANGE

Global mean surface temperature has risen by about 1°C. Two thirds of the warming has occurred since 1975.[11] Climate models using datasets from Representative Concentration Pathways (RCP) have produced consistent results. Currently we are on track to experience a 1.5°C rise in global mean temperature between 2030 and 2052.[12]

Response to Global Warming

In 1988 the United Nations and the World Meteorological Association founded the Intergovernmental Panel on Climate Change (IPCC).[13] The mandate of the IPCC is to assess the state of the scientific literature on all aspects of climate change, its impacts and society's options for responding to it. Three working groups issue regular reports as evidence warrants. The reports are very comprehensive. The IPCC report, Global Warming of 1.5°C,[12] for example, references over 6000 papers and involved more than 90 authors from 40 countries. These reports are difficult to read in entirety, but they include a section on information for policymakers which is reasonably succinct. Physicians who are interested in the science of global warming will find a comprehensive repository of data related to the issue.

In 2016 the Paris Agreement came into force. The objective was to limit warming to <2°C. Central to the strategy was the concept of Nationally Determined Contributions (NDCs).[14] The plan was that participating countries would develop targets for their contribution to GHG emissions. The agreement was a remarkable achievement. Unfortunately, implementation of the agreement required a degree of trust, equity, and cooperation between countries which has not been forthcoming. Although there are some signs of change, the effort has not been adequate, emissions continue to rise.

TABLE 1. Greenhouse Gases by Type, Amount as Percent of Total Global Emissions, Life Span in the Atmosphere, Origin, and Global Warming Potential (GWP) at 100 Years

Gases	Amount (%)	Life Span (y)	Origin	GWP 100
Carbon dioxide	76	Indefinite	Fossil fuels, deforestation, cement	1
Methane	16	12	Agriculture, cattle, waste management, biomass burning, wetlands, rice paddies	28
Nitrous oxide	6	100	Fertilizer use, fossil fuel use	265
Fluorinated	2	100-50,000	Mostly not naturally occurring. Coolants	>15,000

The target of holding warming to <2°C represents, in large part, a political compromise rather than a decision based on science. Significant climate impacts are already being seen with a rise of less than half of what was considered safe.

At present warming is continuing at about 0.2°C per decade. Even if we stopped producing GHG now, given the life span data of global warming potential of GHGs (Table 1), the effects will continue for thousands of years. Projections may also need to be revised as there are several critical ecosystems whose collapse could acutely accelerate global warming.[15] The permafrost of the Canadian Arctic has the potential to release, even at low temperature rise, as much as 100 billion tonnes of GHG. Additional GHG will lead to further warming with subsequent increased permafrost emissions and a positive feedback loop. There are several other systems whose collapse may trigger catastrophic cascades including loss of the Arctic, Antarctic and Greenland ice sheets, the Amazon rainforest, and the Gulf Stream circulation. In addition to the potential contributions of these defined ecosystems, additional events such as the massive bushfires seen recently in Australia, will significantly increase GHG concentrations.

Climate change is a major health issue.[2] Gastrointestinal health is vulnerable to climate change in a number of ways including effects on food, water, changes in disease patterns from habitat change, migration, and infrastructure damage (Table 2).

Developing world countries will be severely affected by climate change. Their health systems already struggle with demand, they have less ability to respond to infrastructure and other challenges. Climate change is a threat amplifier, the negative impacts of climate change will be most pronounced in the countries least able to cope.

TABLE 2. Gastrointestinal Health Consequences of Climate Change

Global warming and Gastrointestinal Health
Food security: increase in malnutrition and starvation
Water security: increase in the number of people experiencing water shortages
Increased high rainfall events, flooding, and drought with increased risk of gastrointestinal infections and hepatitis
Change in disease patterns
Migration: increased migration to cities and between countries
Infrastructure loss from increased severity of storms

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WATER AND FOOD SECURITY

Access to adequate amounts, and varieties, of food is essential to nutrition and adequate nutrition is essential for health. The effects of rising temperature on food production will vary by geographic location and crop type. Some areas, such as those in high latitudes, may actually experience increased crop yields but overall as temperature rises, yields will fall. Drought, especially in the Mediterranean basin and West Africa will increase. The IPCC report concluded that "increasing global temperature poses large risks to food security globally and regionally, especially in low latitude areas."[16] More than 815 million people were undernourished in 2016. Global warming will not lead to net enhanced crop yields globally. Many millions more will be at risk of starvation or malnutrition as temperatures rise.

The oceans cover over 70% of the earth's surface and have thus far buffered the rise in atmospheric temperature and CO_2 levels by absorbing heat and GHGs. The oceans are now at the warmest ever recorded in human history.[17] Warm water expands and this combined with increased ice cap runoff has led to a rise in ocean level. Changing water temperature contributes to ecosystem loss such as that of reefs, and migration of fish to marine environments which have not adapted so quickly to temperature changes, with resultant loss of aquatic food sources.

Changing water level is physically threatening low-lying areas such as the islands of the South Pacific, leading to a loss of coastal arable land, and contamination of groundwater. Global mean water level rose by 11 to 16 cm in the 20th century and, even with immediate reductions, in GHG emissions a rise of 50 cm is likely this century.[18] Under low-emission projections, 190 million people currently occupy land below the high tide lines for 2100. The rate of water level change is variable. In some areas, such as Fiji, rising by 7 mm a year.[19]

The IPCC estimates that 80% of the world's population already suffers from serious threats to its water security.[20] The IPCC also estimates that over the next decades, changes in population (growth, density, migration to cities) will have a greater effect than climate change but climate change will exacerbate this. On the basis of some studies, an additional 8% of the global population will experience a severe reduction in water resources at 1.7°C of warming.[20]

Access to adequate amounts of clean water is essential to human health. Contaminated water is a potent source of infection from bacteria, protozoa, viruses and helminths and a major cause of diarrheal illness with resultant morbidity and mortality, especially in children in developing countries. Water quality will be affected by several phenomena, especially floods, high effluvial events, and droughts.

In 2014 the IPCC issued its fifth assessment report (AR5) and concluded that there was low confidence, due to limited evidence, that anthropogenic (human driven) climate change has affected the frequency and magnitude of floods.[21] However both droughts and flood damage are projected to increase in certain areas in the same report.

HIGH AND LOW RAINFALL EVENTS

Water treatment and sewage systems are designed with limited tolerance for extreme events. They can be overwhelmed with subsequent appearance of pathogens even in treated water. There is concern that the frequency of heavy rainfall events will increase in many areas.[22] Concerns with regard to outbreaks of gastrointestinal illness associated with high effluvial events are appearing from both developed and developing countries.[23,24]

Flooding destroys infrastructure and contaminates water supplies and is a risk for both enteric and hepatic disease such as hepatitis A and E. The recent floods in Djakarta have led to a recommendation from the Indonesian government that the entire capital should be moved to higher grounds in Kalimantan.

Drought is also associated with an increased risk of infections. A decrease in water supply concentrates pathogens, reduces river, and sanitation system flow. Droughts have been associated with increased incidence of amebiasis, salmonella, shigellosis, typhoid, cholera, and leptospirosis.[25]

CHANGES IN DISEASE PATTERNS DUE TO HABITAT AND ENVIRONMENTAL CHANGES

As temperature increase alters habitats, there will be changes in the distribution of some gastrointestinal diseases. For example, the Baltic sea is an increasingly fertile ground for the emergence of cholera.[26] The Vibrio organism thrives in warm water of reduced salinity. Warming temperatures in the Baltic combined with increased freshwater runoff are combining to produce favorable conditions. Concerns have also been raised with regard to the pattern of Schistosomiasis in Africa[27] and ciguatera poisoning in French Polynesia.[28]

MIGRATION

Human migration occurs for many reasons. It can be voluntary or forced by circumstances, can be within countries, or between countries. It occurs in a social and economic context.[29] For example, the islanders of the South Pacific may not have the resources to mitigate the effects of rising sea levels and may have to move; the residents of Miami have different options. In 1990 the IPCC noted that the greatest single impact of climate change may be on human migration. There may be 200 million climate migrants by 2050, but there is considerable uncertainty about this.[29] Many of these climate migrants will have minimal resources. Provision of gastrointestinal care and disease prevention will be difficult. Climate migration will occur against a background of migration from rural areas to cities which is already under way. Cities are growing at twice the rate of the general population making provision of sanitation and clean water very challenging. Nearly half the world's population lives in cities and one third of the urban population lives in slums.[30] Climate change will exacerbate the problems with which many countries are already struggling.

INFRASTRUCTURE AND SERVICES IN GASTROENTEROLOGY

Infrastructure is critical to the delivery of gastrointestinal care, especially in those countries which have diagnostic and therapeutic endoscopy. Gastroenterology procedures require buildings, electricity, and clean water. Severe storms can destroy infrastructure and cause health care disruption. Although the evidence linking global warming to the frequency of tropical cyclones (hurricanes and typhoons) is not convincing most studies report an increase in the occurrence of very severe storms, in particular for the North Atlantic, North Indian, and South Indian ocean basins. These intense storms are hugely destructive and can cripple health care systems, bringing the practice of

diagnostic and therapeutic gastroenterology to a halt as was seen in New Orleans in 2005.

What Can Be Done?

The World Gastroenterology Organisation believes that Gastroenterologists have a clear responsibility to address the challenge which a changing climate poses to humanity and the world. To do nothing, is not acceptable. There are few benefits to a warming climate. On the contrary, global warming will exacerbate current inequities and make delivery of health care even more challenging.

If we accept that climate change is occurring and that it has implications for gastrointestinal health, then it would seem logical that national Gastroenterology organizations formulate their plans with regard to the issue. We need national gastrointestinal societies to get involved, and to develop and support local leaders with an interest in the topic. Local medical leaders with an interest in the topic could then use their knowledge and understanding of the issues to educate colleagues in their areas and also to advocate for change from national leaders who have a responsibility for managing the issues.

Global projections of the impact of climate change lack granularity and need to be translated to a local level. Therefore the next step could be for neighboring national societies to connect so that learning and resources could be pooled. The rationale for that being that the IPCC produces data projections for the world as a whole but also for 26 defined climatic zones. These zones traverse country boundaries. Climate does not respect borders. The zones are: Alaska/NW Canada, Canada/Greenland/Iceland, Western North America, Central North America, Eastern North America, Central America/Mexico, Amazon, North East Brazil, West Coast South America, Southeast South America, Northern Europe, Central Europe, Southern Europe/Mediterranean, Sahara, West Africa, East Africa, South Africa, North Asia, West Asia, Central Asia, Tibetan Plateau, East Asia, South Asia, Southeast Asia, Northern Australia, and Southern Australia/New Zealand. The "Blue Continent" of Pacific nations should be included.

These areas may, or may not, share a common culture, have similar economies and be at different stages with regard to their approach to climate change, but they do have a similar climate data set and will be facing similar changes. Physicians from Canada, Greenland, and Iceland might, for example, have a discussion on challenges facing countries with an Arctic environment. That discussion would likely be quite different to one which brought the countries of South East Asia together.

We can educate ourselves, colleagues, and others to become literate with regard to the science of climate change and the health implications. We can examine and change our behavior and make personal choices that have our climate and environment at their heart.[31] We can advocate for attention to be paid to this issue on behalf of our populations.

We can support and advise our political leaders. Politicians and others face an enormous challenge in moving their constituencies to accept the radical changes which will be needed to reduce GHG emissions and move to a greener economy. Developing world countries may argue that they should not be denied their chance at prosperity and hesitate to limit their usage of the fossil fuels which have grown the developed world economies. Developed world countries may balk at reducing their consumption and lifestyles.

There is an urgent need to move to solutions, but first we need to organize, educate, and advocate. As a Gastroenterology community we are coming late to the debate, but not one hopes, too late to contribute to the resolution.

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