The fundamentals: understanding the climate change crisis

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This is the first of a series of nine commentaries, each of which is designed to stand alone but when read as a whole provide a broad overview of the status of the intersection between digestive health and climate change. The nine commentaries encapsulate a 9-webinar open-access climate course hosted by the World Gastroenterology Organisation March–June 2023.[1]

CLIMATE CHANGE FUNDAMENTALS

The atmosphere is a thin layer of gaseous material which surrounds the earth, mostly within 10 km of the earth surface. Shortwave energy from the sun passes through it and heats the oceans and the surface of the earth, which thus emit infrared radiation. Much of this infrared radiation escapes into space, but some is trapped, increasing the kinetic energy of greenhouse gas (GHG) molecules that include carbon dioxide (CO_2), methane, nitrous oxide, fluorinated gases and lower atmospheric ozone.

GHG differ in their potency regarding atmospheric heating.[2] Some gases, such as methane, are much more powerful than CO_2 but have different half-lives in the atmosphere. To allow quantification and comparisons, the energy-trapping potency of the different GHG is expressed in 'carbon dioxide equivalents' (CO_2e). A metric tonne (t) of CO_2 is 1000 kg, equivalent to over 500 000 L of CO_2, or roughly the volume of a detached suburban house in the UK. To put a few numbers in perspective, the annual carbon footprint, the amount of CO_2 for which the lifestyles of an individual are responsible each year, varies from over 14 t CO_2e per person per year in the USA to <0.1 t per person per year in the Democratic Republic of the Congo.[3] A return flight from London to New York generates about 1 t of CO_2e per passenger. The average petrol car releases about 0.184 kg CO_2e/km.[4] There is no question that human activity has led to increased emissions of GHG through industrial processes, agricultural activity and the burning of fossil fuels. At the same time, we have damaged the systems that would normally sequester CO_2 from the atmosphere. For example, when forests are burned to provide land for animal feed or grazing, their ability to sequester CO_2 is lost. Meanwhile, CO_2 released by burning worsens global heating, as does the fact that carbon monoxide increases the half-life of atmospheric methane. As ruminants, the grazing cattle add yet more methane.

The net result is that atmospheric GHG concentrations are rising steeply, thereby driving an accelerating atmospheric energy imbalance and progressive heating of the atmosphere by the surface of the earth below it. However, the earth's surface is not uniform, with parts consisting of water and some raised as mountains. The tilt of the earth and its rotation around the sun mean that not all parts of the earth receive the same amount of solar radiation. Marked differences in temperature between places, such as between the poles and the tropics, and the changing seasons, result in differences in air pressure and winds. Rotation of the earth also means that temperature of an area will be higher by day and lower by night. Warmer air and water tend to expand and rise, and colder air and water to sink. Energy is used to

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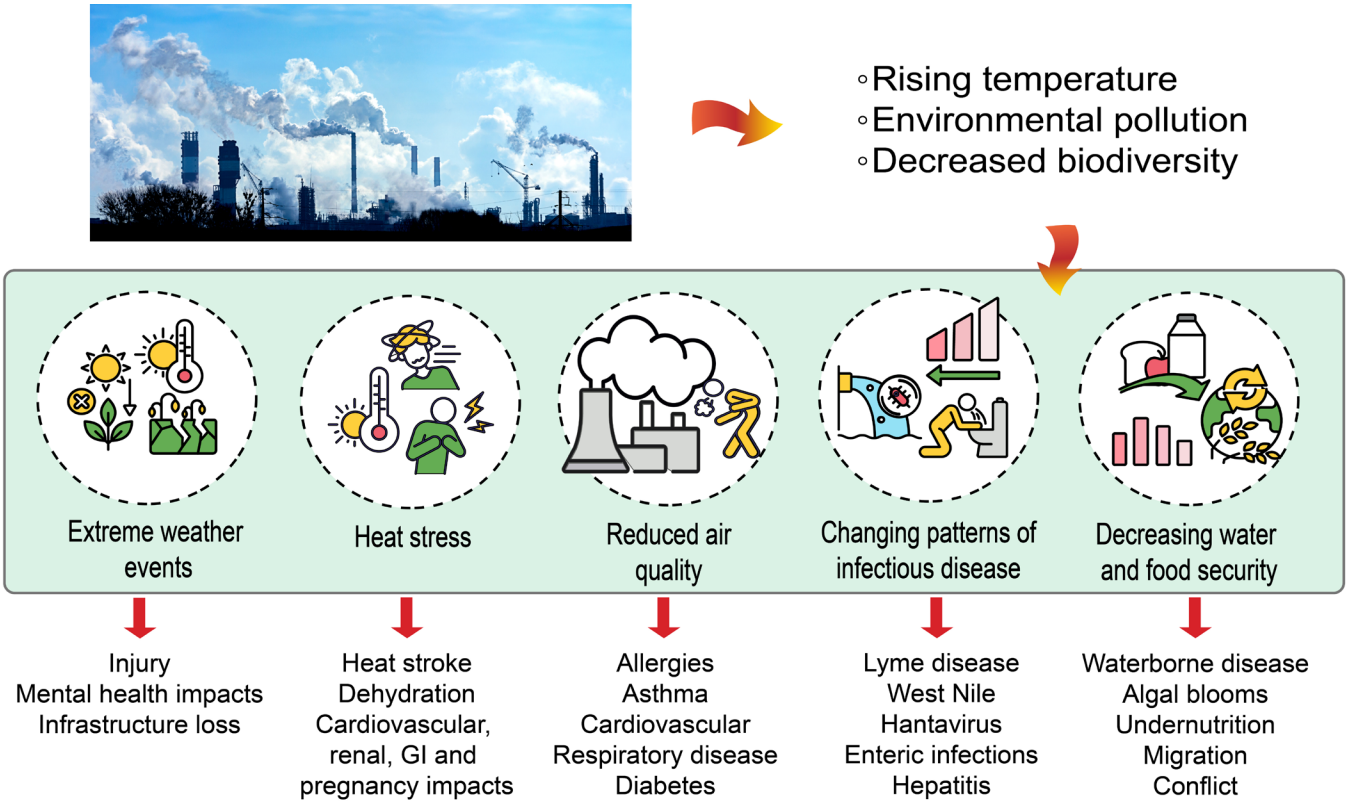

Figure 1 The relationship between climate change, climate hazards, adverse health outcomes and vulnerability. Adapted from Goverment of Canada.[23]

evaporate water, and this is released again when the evaporated water condenses as rain and snow. Such processes mean that energy is transported around the globe, and we perceive the movement of the atmosphere with changes in temperature, wind and rainfall, as *weather*. Weather is what we experience over the short term and is generated when energy is added to the atmosphere. If more energy is added because of global heating, the weather becomes more extreme. Global heating is a long-term shift in average weather conditions and is characterised by a shift of weather to the more extreme—higher temperatures, greater rainfall events, more drought, storms of greater intensity.

Another relevant concept is the Global Mean Surface Temperature (GMST), which reflects the average temperature of the whole planetary sea surface and of the air over land. Current global heating of 1.2°C thus refers to a rise in GMST of 1.2°C above pre-industrial (1850) levels. This reflects an enormous energy gain that is equivalent to 25 billion Hiroshima atomic bombs in the last 50 years alone.[5] Importantly, this heating is not uniform: some areas, such as the oceans are warming at a lower rate while others, like the Arctic, are heating four times faster than the surface average, further disrupting weather patterns. The earth's ice stocks are melting ever faster,[6] and the Arctic may be free of sea ice by the summer of 2030.[7] Together with thermal expansion, land ice melt is driving accelerating sea level rise, which is leading to coastal erosion and intrusion of sea water into freshwater supplies and which may threaten the habitat of over half a billion people within the next 75 years alone.[8]

IMPACT OF CLIMATE CHANGE ON HEALTH WARRANTS A CALL TO ACTION

The 2009 Lancet Commission described climate change as the 'greatest global health threat of the 21st century'.[9] This threat is now grave and immediate for us all (figure 1). Altered, unstable and extreme weather patterns impede crop growth and the ability to work outside. Extreme temperatures can kill directly, and worsen air quality. Patterns of vector-borne and waterborne disease change, and water safety, security and quality are impacted. Vulnerability to these hazards is increased by socioeconomic status, age, forced migration, underlying health needs and other factors. These vulnerability factors drive migration and conflict, and will increasingly impact us all, as global food and supply chains, and economies, are affected.

We are now all becoming familiar with the reality of these impacts. The last 5 years alone have seen annual or seasonal temperature records broken (and often repeatedly) on every continent and in nearly every country. In 2021, worsening wildfires released the greatest amount of carbon into the atmosphere ever recorded.[10] The last 3 years have seen severe or record-breaking floods in South Africa, Spain, Florida (with its highest ever storm surge), Indonesia (with its 'once in a century' flood), Nigeria (with over half a million displaced), Pakistan (with one-third of its land mass underwater in 2022) and more.

The degree of heating has come far faster than anticipated,[11] and is predicted to strike even faster and harder in the future,[12] even if we cease GHG emissions at once and draw down and sequester atmospheric CO_2.[13] Unfortunately, matters may worsen fast, given that we have triggered multiple interacting positive feedback loops. As snow and ice

melt, there is less to reflect light back into space, and heating accelerates.[14] Wildfires release more CO_2 and carbon monoxide, which extends the atmospheric half-life of methane, which is 83 times as powerful a GHG as CO_2 in its first 20 years. Methane is also being released as its frozen hydrates melt, carbonate rocks cook and warming wetlands ferment.[15–17] Furthermore, drying rainforests are now net CO_2 emitters.[18]

The speed of change in weather systems will be accelerated as 'tipping points' are reached, such as the sudden accelerations in sea level rise from collapsing ice sheets.[19] In 2022, a late season warm air mass over the Greenland ice sheet saw unprecedented rises in temperature and rate of ice loss.[20] Global weather patterns, too, can suddenly and catastrophically 'flip': the major currents which transfer global heat through the oceans are already being massively disrupted, and will likely decline or collapse in coming decades.[21] The Northern jet stream is moving north as the Arctic warms four times faster than the global average. The result will be worsening droughts in the Iberian Peninsula, but more severe winter flooding in Northern Europe.

But such impacts do not occur in isolation, and their correlation amplifies human impacts and economic harm. The 2022 heatwave cost Italy's farming sector US$6.5 billion and floods in Pakistan US$40 billion. Barge transport on the Rhine was impacted in 2022 (the river was only 36 cm deep at Kaub), while low water levels had similar impacts on the Panama Canal in 2023, adding a surcharge of up to US$500 to every container and (by August) limiting shipping movement itself.

Despite our lived experience and the worsening threat, humanity has failed to act. Global GHG emissions rose by 1.5% in 2022,[22] reaching nearly 60 billion t/year when accounting for deforestation and land-use change. Meanwhile, the world's negotiators (in 2022) removed having a target to peak emissions, with the consequence being a rise rather than a decrease in emissions. It now seems that securing our demise is the new target, given the message from the Intergovernmental Panel on Climate Change in the same year: "… any further delay risks our missing a brief and rapidly closing window to secure a livable future".[13] The threat is no longer to the health of distant generations, but to our own survival, and that of our children.

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