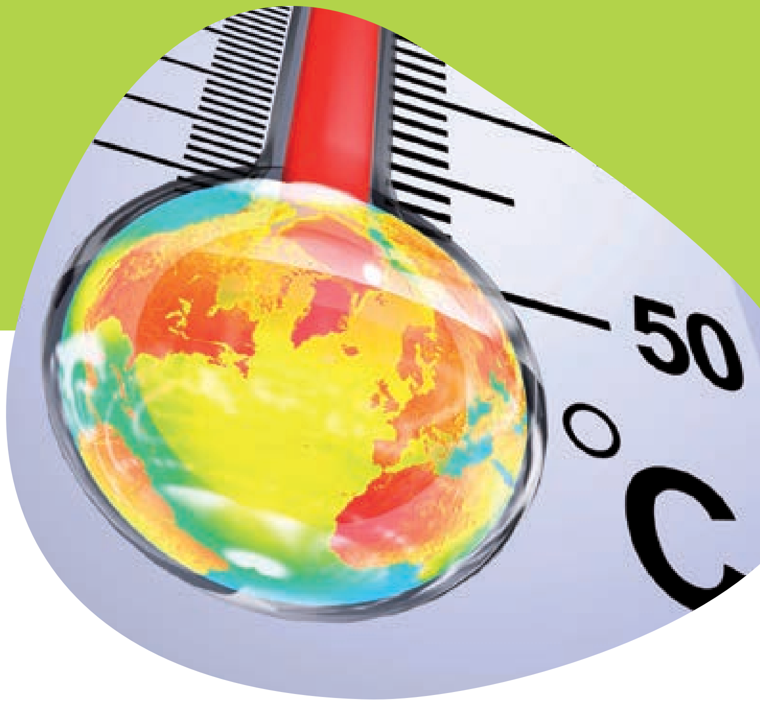
BRIEFING

Microbiology and Climate Change



- **Micro-organisms play crucial roles in climate change as users and producers of greenhouse gases.**
- **Climate change is increasing risks to public health and agriculture from microbial diseases.**
- **Managing and harnessing microbial processes could help us mitigate and adapt to climate change.**

MICROBES AS CLIMATE ENGINEERS

Microbial processes in oceans, soils and other environments are important drivers of global cycles of carbon, nitrogen and other nutrients, which are vital for life on earth. These processes both use and produce key greenhouse gases (GHGs), including carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). However, human activities, including those which stimulate microbial emissions, are accelerating climate change by altering the balance of these natural cycles through enhanced GHG emissions.

CARBON CYCLING

Ocean and soil ecosystems, significantly through microbial processes, together act as a sink for approximately 50% of anthropogenic carbon emissions.

Microbial activity in the oceans: Photosynthetic marine algae and cyanobacteria are responsible for almost half of global photosynthesis, drawing tens of billions of tonnes of CO_2 from the atmosphere each year. Conversely, respiration and decomposition of organic matter by other marine microbes ultimately releases much of this carbon again, the remainder being stored in the deep sea.

Increasing levels of atmospheric CO_2 are being dissolved in the oceans causing them to become more acidic. There is concern that higher ocean acidity combined with higher temperatures could impact marine microbial populations important for carbon cycling and marine food chains.

Microbial activity in the soil: Plant photosynthesis dominates terrestrial CO_2 uptake. However, some soil micro-organisms assimilate CO_2 themselves, while others indirectly contribute to uptake by aiding plant growth and helping store carbon in soils. The majority of this carbon is released again by respiration and decomposition of organic matter, with micro-organisms estimated to be responsible for about half of these natural CO_2 emissions.

Soils store an estimated 1,500–2,400 billion tonnes of organic carbon. Consequently, soil degradation and erosion due to activities such as agriculture is a major concern because this can enhance microbial decomposition of organic matter, thereby increasing CO_2 emissions.

NITROGEN CYCLING

Nitrogen-fixing soil bacteria play an important role in converting nitrogen gas into biologically available nitrogen that can be used by plants. Soil nitrifying micro-organisms convert ammonia to nitrate, releasing N_2O as a by-product

MICROBIAL CLIMATE FEEDBACKS

Scientists are investigating how micro-organisms that use and produce GHGs will respond to climate change. Climate change may cause feedbacks whereby microbial processes use or produce more GHGs, thereby further affecting climate change. Scientists have collected soils from different environments and latitudes and found that, when subjected to the range of temperature increases predicted by climate models, microbial respiration and CO_2 release can increase significantly.

Specifically, there is concern about global warming thawing leading to enhanced microbial activity in carbon-rich permafrost, which is estimated to currently store 1,700 billion tonnes of organic carbon. This could potentially lead to the release of massive quantities of CO_2 and CH_4. It is unclear if the activity of other micro-organisms, which for example oxidise CH_4, would also increase sufficiently to help mitigate these emissions.

into the atmosphere. The nitrate is then broken down by denitrifying bacteria releasing both nitrogen gas and more N_2O.

The global warming potential of N_2O over 100 years is about 300 times that of CO_2. A major driver of increases in N_2O emissions globally is human activities including the widespread, often inefficient use of ammonia- and nitrate-based fertilisers in agriculture, which is enhancing the activity of nitrifying and denitrifying micro-organisms.

METHANE CYCLING

Micro-organisms called methanogens, which live in wetlands, oceans, and the guts of ruminants and termites, account for about 75% of natural CH_4 emissions. CH_4 has a global warming potential about 34 times that of CO_2. Human activities account for an estimated 50–60% of all CH_4 emissions, the predominant source being activities that enhance methanogen emissions, including landfill, livestock farming and rice cultivation.

DISEASE RISKS FROM CLIMATE CHANGE

Climate change is likely to significantly affect the reproduction, transmission and geographic distribution of pathogens of humans, other animals and plants. Researchers are currently investigating these threats, and the potential to mitigate them.

Water-borne diseases: Increased risk of flooding and challenges to sanitation facilities by heavy rainfall events are predicted to increase the incidence and transmission of water-borne diseases such as cholera and cryptosporidium. Climate change will also likely affect access to safe water in some regions, which would compromise hygiene and sanitation.

Vector-borne diseases: Certain disease vectors, including some mosquito species, thrive in floodwaters. Higher temperatures can increase the rate of reproduction of these vectors, the frequency of bites and the length of their breeding season. These combined factors may increase the incidence and geographic distribution of vector-borne diseases such as dengue and West Nile virus. It has been estimated that a temperature rise of 2–3 °C could increase the global population vulnerable to malaria by several hundred million.

There is evidence that the northern European climate is becoming more favourable for some human and livestock disease vectors. For example, modelling has linked climate change to the spread of bluetongue disease, a midge-borne disease of livestock, into northern Europe.

Plant diseases: Changes in climate may also promote the growth and dispersal of many crop pathogens, threatening food security. Some key plant fungal pathogens are estimated to be spreading towards the poles at an average rate of about 8 km per year, which poses new disease control and surveillance challenges for agriculture, particularly in the northern hemisphere.

MICROBIAL MITIGATION AND ADAPTATION

Managing and harnessing microbial processes could help us to mitigate and adapt to climate change.

Agriculture and food: Developing cultivation methods and biotechnologies to better harness soil micro-organisms that benefit crop growth (e.g. biofertilisers) could reduce reliance on fossil fuels, help reduce GHG emissions from agricultural soils, and improve crop resilience to climate-related stresses such as drought.

Methane emissions from ruminant livestock, which account for about 25% of anthropogenic emissions, could be reduced through the use of feed additives or vaccines, and reducing meat consumption.

Globally, it is estimated that more than 30% of all food produced is lost to spoilage and wastage along the food supply chain. Reducing food spoilage by microbes could substantially reduce nitrous oxide emissions associated with agricultural production.

Biofuels and energy: Biofuels can be efficiently produced through microbial anaerobic digestion of waste products from agriculture and other human activities.

Photosynthetic micro-organisms, such as cyanobacteria and algae, could be engineered to produce clean fuels such as biological hydrogen.

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Contact: Policy Officer, Microbiology Society, Charles Darwin House, 12 Roger Street, London WC1N 2JU, UK. Tel. +44 (0)20 7685 2400; email policy@microbiologysociety.org.

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