Disruption in Emissions and Uptake of Methane

For Prelims: Climate Change, Methane Cycle, Amazon Rainforest, Wetland, Methanotrophic Microorganisms, Landfills, Livestock, Methane Hydrate, Global Warming Potential, Global Warming, Tropospheric Ozone, Aerobic Digestion, Mangroves, Salt Marshes.

For Mains: Impact of climate change on Methane cycle and vice-versa, Steps to balance Methane cycle.

Source: DTE

Why in News?

Recently, new research warned that **climate change** could disrupt the **Methane Cycle** (methane emissions and uptake) in the **Amazon rainforest**, leading to significant **global consequences.**

- The methane cycle refers to the series of **processes** that control the **production, consumption, and release** of methane (CH4) in the environment.

What are the Key Highlights of the Research on Methane?

- **Floodplain Ecosystems**: **Floodplains** (waterlogged areas) in the Amazon contribute up to **29% of global wetland methane emissions**. Climate changes increase the risk of methane-producing **microbes.**
- **Upland Forests**: **Upland forests** in the Amazon function as **methane sinks.**
    - The study found that **methane uptake** in upland forest soils **dropped by 70%** under warmer, drier conditions, signalling a reduction in their capacity to mitigate methane emissions.
- **Methane Cycling:** The research also delved into the role of **methanotrophic microorganisms**, which consume methane.
    - Isotope analysis showed that both **aerobic and anaerobic** methane-consuming microbes were active in **floodplains**, highlighting the complex interactions in **methane cycling** in the Amazon.

What is a Methane Cycle?

- There are many **sources** like **wetlands** that release **methane (CH4)** into the atmosphere. There are also **sinks** or ways that methane is **trapped or destroyed.**
- The methane cycle **begins in the soil** where methane gas is created by **microbes.**
- Soil methane is **consumed by methanotrophs**, microorganisms that feed on methane.
- **Methanogens** make more methane that methanotrophs consume.
    - Methanotrophs live in **drier oxygen-rich upper layers of soil** because they need **oxygen** to function.
    - Their **food bubbles r**ise to the surface, releasing **methane into the atmosphere.**
    - This methane joins methane from other sources, such as **landfills, livestock** and exploitation of **fossil fuels.**

- The main mechanism for **removal** of methane from the earth's atmosphere is **oxidation** within the **troposphere** by the **hydroxyl radical (OH)**.
    - Hydroxyl radicals are a form of **sink** because they **scrub the atmosphere clean of pollutant** molecules and break them down. For this reason **OH is known as the 'cleanser of the atmosphere'.**
    - After reacting with OH, **atmospheric methane is converted to CO2** by a long series of chemical reactions.
- Some of the methane present in the troposphere passes into the **stratosphere** where a **similar process removes it** from the atmosphere..

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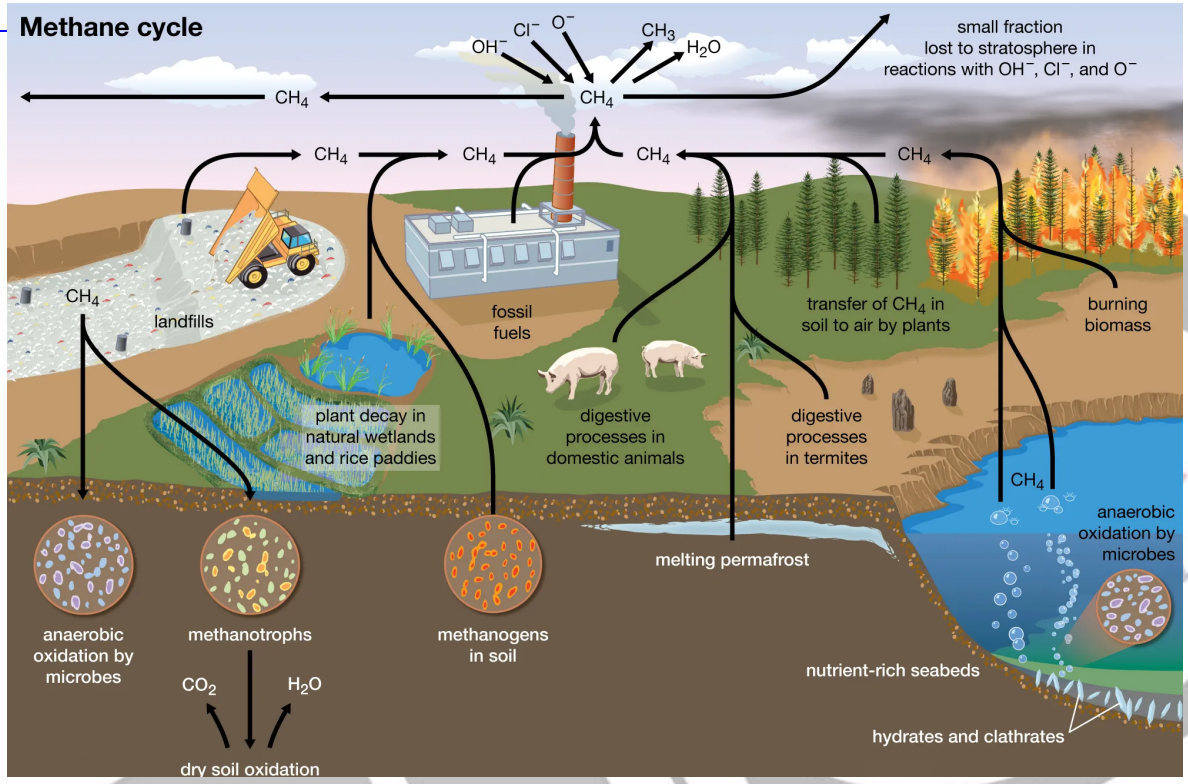

How Global Warming Can Impact Methane Cycle?

- **Imbalance in Sources and Sinks:** In an **ideal world**, methane sources would be **balanced** with methane sinks, as with CO2, however, global atmospheric **methane concentrations are rising** as a result of human activities.
    - Scientists are worried because as the **planet warms**, even more methane will be released from soils or other places adding to the global warming problem.
- **Methane Clathrates:** Methane crystals form in **cold, oxygen-poor undersea sediments**. Clathrates are also trapped in **permafrost**, the permanently frozen soil in the **arctic and subarctic latitudes.**
    - Clathrate ice, also called **methane hydrate**, is **solid and white**, similar to water ice. However, this ice consists of **water molecules** that are **frozen around molecules of methane.**
- **Role of Clathrate Deposits:** Clathrate deposits were **once sinks** where methane was isolated.
    - However, as the planet warms, some of these deep, cold sediments are melting, sending methane bubbling to the surface.
    - Because **CH4 is a greenhouse gas,** it traps heat in the atmosphere and warms the planet more.

How Disruption in the Methane Cycle Can Have Global Consequences?

- **Contributor to Global Warming:** Methane is the second most significant **greenhouse gas** driving climate change, following **carbon dioxide (CO_2).**

    - Due to its high **global warming potential** (28 times greater than carbon dioxide over a 100-year period), even small amounts of methane can significantly contribute to **global warming.**
- **Halts Checking Global Warming Efforts:** According to data from the **United States National Oceanic and Atmospheric Administration**, even as carbon dioxide emissions decelerated during the **Covid-19 lockdowns** of 2020, atmospheric **methane shot up.**
- **Health Impacts:** Methane is a key precursor gas of the harmful **air pollutant**, **tropospheric ozone.**
    - Ozone is responsible for about **1 million premature respiratory deaths** globally.
    - Globally, increased methane emissions are responsible for **half of the observed rise in tropospheric ozone levels.**
- **Effects on Air Quality:** Increased methane emissions **deplete hydroxyl radicals (OH)**, which act as a **natural detergent** for atmospheric pollutants. This reduction allows other air pollutants to persist longer, worsening air quality.
- **Agriculture Impacts:** Methane contributes to **staple crop losses of up to 15% annually** by increasing atmospheric temperatures and producing tropospheric ozone.
- **Economic Impacts:** Methane's impacts on **climate change and public health** contributes to a yearly loss of roughly **400 million hours of work globally** due to extreme heat.
- **Biodiversity Threats**: Methane-induced climate change disrupts ecosystems, causing **shifts in species distributions**, **loss of biodiversity**, and destabilisation of ecological interactions, impacting plant and animal health.

How Can We Balance the Methane Cycle?

- **Enhanced Landfill Design**: **Lining systems and gas collection wells** in landfills can be used to **capture methane for energy** use rather than allowing it to escape into the atmosphere.
- **Livestock Management:** Additives such as **seaweed or specific enzymes** have been shown to lower methane emissions from **ruminants** which can help **mitigate emissions** from livestock.
- **Aerobic Treatment Methods**: Technologies such as **aerobic digestion** can effectively eliminate **organic matter** from wastewater without producing methane.
- **Rice Cultivation Practices:** Implementing **alternative wetting and drying practices** in rice cultivation can minimise methane emissions by reducing the time fields are flooded.
- **Soil Health Management**: Enhancing **soil health** through the use of **organic fertilisers** and **crop rotation** can reduce methane emissions by promoting **aerobic conditions** in the soil, which are less conducive to methane production.
- **Pest Management**: Research into environmentally friendly **pest management** strategies could help regulate **termite populations** in areas where their emissions are significant.
- **Coastal Ecosystem Restoration**: Protecting and restoring coastal ecosystems, such as **mangroves and salt marshes**, can enhance their ability to absorb carbon and mitigate methane emissions from sediments.
- **Safe Extraction Practices**: If **methane hydrates** are to be extracted for energy, developing safe extraction technologies that minimise methane leakage is crucial.
- **Reducing Fossil Fuel Use**: Transitioning to **renewable energy sources** can reduce overall methane emissions associated with fossil fuel extraction and consumption.

Drishti Mains Question:

Discuss the significance of the methane cycle in the context of climate change. What are the major sources and sinks of methane?

UPSC Civil Services Examination, Previous Year Questions (PYQs)

Prelims

Q. Which of the following statements is/are correct about the deposits of 'methane hydrate'? (2019)

1. Global warming might trigger the release of methane gas from these deposits.
2. Large deposits of ‘methane hydrate’ are found in Arctic Tundra and under the sea floor.
3. Methane in the atmosphere oxidises to carbon dioxide after a decade or two.

Select the correct answer using the code given below.

(a) 1 and 2 only

(b) 2 and 3 only

(c) 1 and 3 only

(d) 1, 2 and 3

Ans: (d)

Q. Consider the following: (2019)

1. Carbon monoxide
2. Methane
3. Ozone
4. Sulphur dioxide

Which of the above are released into atmosphere due to the burning of crop/biomass residue?

(a) 1 and 2 only

(b) 2, 3 and 4 only

(c) 1 and 4 only

(d) 1, 2, 3 and 4

Ans: (d)

Q. Due to their extensive rice cultivation, some regions may be contributing to global warming. To what possible reason/reasons is this attributable? (2010)

1. The anaerobic conditions associated with rice cultivation cause the emission of methane.
2. When nitrogen based fertilisers are used, nitrous oxide is emitted from the cultivated soil.

Which of the statements given above is/are correct?

(a) 1 only

(b) 2 only

(c) Both 1 and 2

(d) Neither 1 nor 2

Ans: (c)

Mains

Q. How do the melting of the Arctic ice and glaciers of the Antarctic differently affect the weather patterns and human activities on the Earth? Explain. **(2021)**

Q. ‘Climate change’ is a global problem. How will India be affected by climate change? How Himalayan

and coastal states of India be affected by climate change? (2017)