The Global Nitrous Oxide Budget 2024

For Prelims: Nitrogen pollution, UNEP, Nitrogen-based fertiliser, Ammonia, Air pollution, Methemoglobinemia, Stratospheric ozone layer.

For Mains: Sources of Nitrogen Pollution, Major Impacts of Nitrogen Pollution, Major Compounds of Nitrogen and their Effects.

Source: TH

Why in News?

According to a new study by the **Global Carbon Project (GCP)** titled, **"Global Nitrous Oxide Budget (1980-2020)"**, the emissions of nitrous oxide have been rising continuously between 1980 and 2020.

- A study found that in 2021 and 2022, nitrous oxide was released into the air faster than ever before, even though we need to cut **greenhouse gasses** to fight **global warming**.

About GCP Study

- **Global Carbon Project (GCP)** is an **organisation** established in 2001 which conducts studies that seek to quantify global greenhouse gas emissions and their causes.
  - This study by GCP analyses the **impact of human activity on greenhouse gas emissions** and earth systems and **quantifies emissions of carbon dioxide, methane and nitrous oxide (3 major greenhouse gases)** to inform public policy and international action.
- **It involved the examination of global data for all major economic activities that lead to nitrous oxide emissions from 18 anthropogenic and natural sources and 3 absorbent "sinks" of global nitrous oxide.**

Absorbent "Sinks" of Nitrous Oxide:

- **Soils:**
  - Soils act as a significant **sink for N_2O.** Microbial processes in soils can consume and **reduce N_2O emissions.**
  - **Denitrifying bacteria convert N_2O to nitrogen gas (N_2)** under anaerobic conditions, effectively **removing it from the atmosphere**. The balance between nitrification (which produces N_2O) and denitrification determines the net soil sink capacity.
- **Oceans:**
  - Deeper and **subsurface oceans absorb N_2O from the atmosphere,** through dissolution at the air-sea interface. **Marine phytoplankton and other organisms** play a role in consuming dissolved N_2O.
- **Stratosphere:**
  - In the stratosphere, **N_2O reacts with ozone (O_3),** leading to the formation of **nitrogen oxides (NOx)** and ultimately **nitrogen gas (N_2).**

- N_2O stays in the atmosphere for **longer than the average human lifespan (117 years),** making it an effective sink for this greenhouse gas, impacting climate and ozone for a longer time.

What are the Key Findings of the Study?

- **Alarming Rise in Nitrous Oxide (N2O) Emission: N2O emissions from human activities have increased by 40% (3 million metric tons of N2O per year) between 1980 and 2020.**
  - **Top 5 Emitters of N2O** were China (16.7%), India (10.9%), US (5.7%), Brazil (5.3%) and Russia (4.6%).
    - Thus**, India is the 2nd largest emitter** of N2O globally after China.
  - In **Per-Capita terms**, **India has the lowest per capita emission of 0.8 kg N_2O/person** lower than China (1.3), US (1.7), Brazil (2.5) and Russia (3.3).
  - The concentration of atmospheric **N_2O reached 336 parts per billion in 2022,** a 25% rise over pre-industrial levels, more than what was estimated by the **Intergovernmental Panel on Climate Change (IPCC).**
  - The study points out that currently, **no technologies exist that can remove** N_2O **from the atmosphere.**
- **Sources of Nitrous Oxide Emissions:**
  - **Natural Source:**
    - **Natural sources such as oceans, inland water bodies and soil contributed 11.8% of the global emissions of N2O between 2010 and 2019.**
  - **Human-Driven Source (Anthropogenic):**
    - **Agricultural activities** were responsible for **74%** of human-driven nitrous oxide emissions.
      - This was mainly due to the application of **chemical fertilisers** and the **use of animal waste on croplands**.
      - The growing use of **nitrogen fertilisers** in the production of food worldwide is increasing concentrations of N2O.
    - Other significant sources include **industry, combustion, and waste treatment**.
    - The **growing demand for meat and dairy products** has also contributed to an increase in emissions **through the increase in manure production**, which also causes N2O emissions.
- **Rate/Growth of Emissions:**
  - **Emissions from agriculture continue to grow,** while those from other sectors, such as fossil fuels and the chemical industry, are not growing or declining globally.
  - Emissions from **aquaculture are only a tenth of those from the use of chemical fertilisers on land** but are growing rapidly, particularly in China.
- **Emission Pattern in Regions: Among the 18 regions considered in this study, only Europe, Russia, Australasia, Japan and Korea had decreasing nitrous oxide emissions.**
  - Europe had the largest rate of decrease between 1980 and 2020, resulting from reduced fossil fuel and industry emissions.
  - **China** and **South Asia** had the **largest increases** in N2O emissions from 1980 to 2020 at **92%.**

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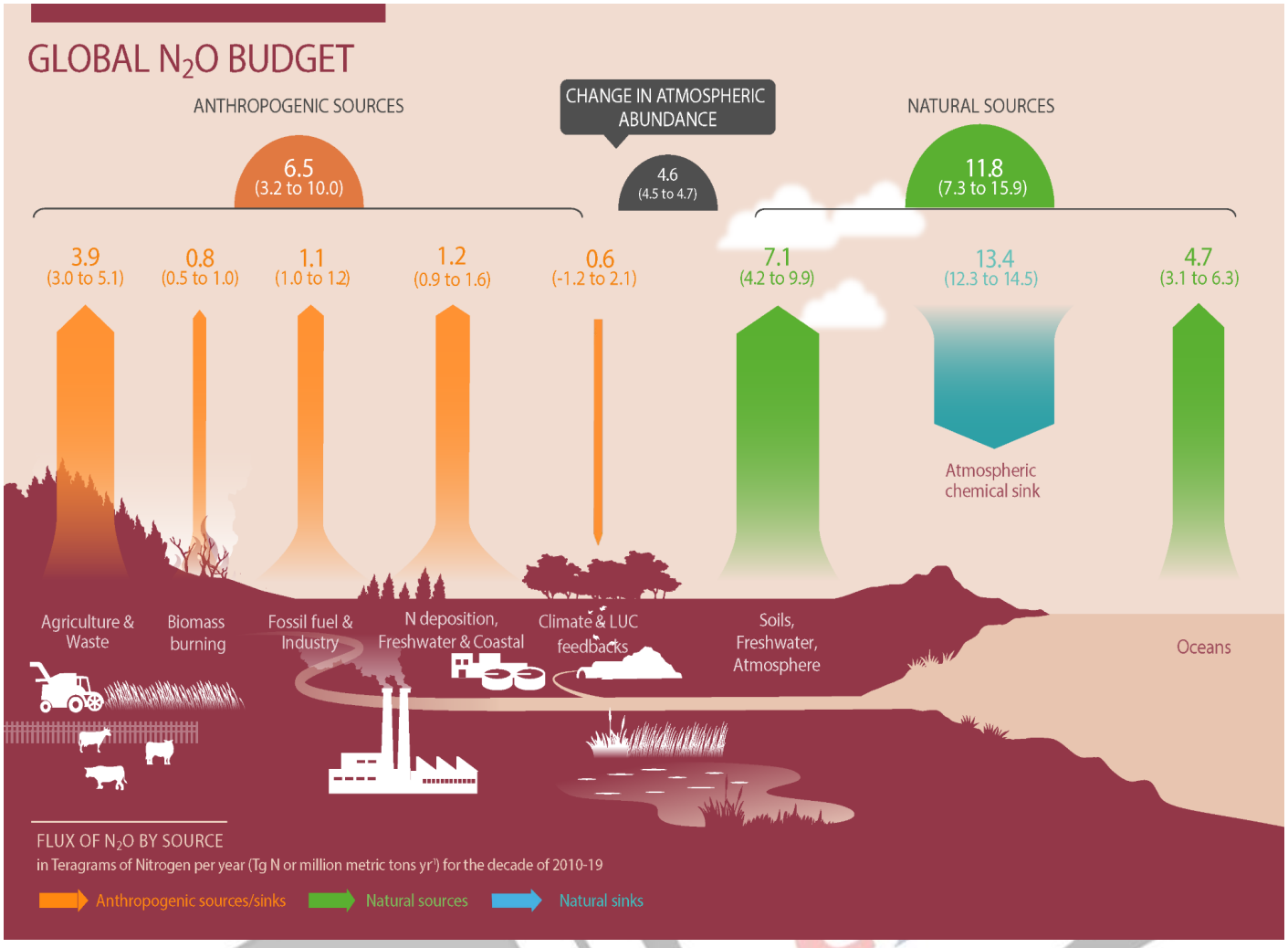

Key Fact about Nitrous Oxide (N_2O)

- Nitrous oxide, commonly known as **laughing gas or happy gas**, is a **colourless, odourless, and non-flammable gas.**
- While nitrous oxide is not flammable, it supports combustion to the same extent as oxygen.
- It leads to a **state of euphoria, explaining its nickname, 'laughing gas.'**
- It is **soluble in water**. Its vapours are heavier than air.
- **Applications:**
    - It is commonly used by **dentists and medical professionals** to sedate patients undergoing minor medical procedures.
    - The gas is also used as a **propellant in food aerosols**.
    - It is used in the **automotive industry** to enhance engine performance.

What are the Implications of Rising Nitrous Oxide Emissions?

- **Intensified Global Warming: N_2O is around 300 times more effective than carbon dioxide (CO_2) at trapping heat over 100 years. This magnifies its impact on global warming and its rapid growth adds considerably to atmospheric heat.**

- **Threat to Ozone Layer:** N_2O breaks down in the stratosphere, **releasing nitrogen oxides that damage the ozone layer,** which shields us from harmful **ultraviolet (UV) radiation.**

    - This increased UV radiation can lead to a rise in skin cancer, cataracts, and harm to ecosystems reliant on UV protection.
- **Challenge to Food Security: Agricultural sector, particularly the use of nitrogen-based fertilisers, is a major contributor to N_2O emissions and the growing demand for food will likely lead to a further increase in N_2O emissions, creating a conflict between food security and climate goals.**

- **Challenge to Paris Climate Agreement:** The increasing level of N_2O emissions will pose a challenge in achieving the goals of the Paris Climate Agreement **(keeping global warming below 2°C compared to pre-industrial times).**

What are the Proposed Solutions to Mitigate Nitrous Oxide Emissions?

- **Innovative Agricultural Practices:**
    - **Precision Agriculture:** Utilising technologies like **soil sensors** to **optimise fertiliser application** reduces unnecessary nitrogen input, thereby minimising N_2O formation.
        - A study by Journal Nature found that **precision agriculture techniques can decrease N_2O emissions by up to 50%.**
    - **Nitrification Inhibitors:** These additives **slow the conversion of ammonium in fertilisers to nitrate**, a readily available form for N_2O-producing microbes.
    - **Cover Cropping**: Planting cover crops during fallow periods helps retain soil moisture and nitrogen, reducing the risk of N_2O release.
    - **Using Anti-Methanogenic Feed:** Using Anti-methanogenic feed like '**Harit Dhara' (HD)**, or developing similar **anti-nitrogen feed** for cattle will help to reduce methane and nitrogen emissions.
        - Additionally, adopting a **cyclic method** to **generate fuel gas from cattle dung**, instead of allowing nitrogen emissions from anaerobic degradation, can also minimise N_2O formation.
    - **Using Nano-Fertilisers:**
        - Nano fertilisers can deliver nutrients directly and slowly to plant roots, **minimising excess nitrogen** and **reducing nitrous oxide emissions**. They enhance nutrient absorption, potentially requiring less fertiliser overall. By delivering nutrients slowly and directly to plant roots, they can minimise the surplus nitrogen available for conversion
- **Effective Policy Measures:**
    - **Emission Trading Schemes**: Implementing a **cap-and-trade system for N_2O emissions** can incentivise industries and farmers to adopt cleaner practices.
        - The successful implementation of such schemes in the **European Union** for other greenhouse gasses offers valuable lessons.
    - **Targeted Subsidies:** Governments can provide financial support for farmers transitioning to sustainable practices that minimize N_2O emissions.
        - **China's successful reduction in N_2O emissions** since the mid-2010s has been partly attributed to **targeted subsidies for improved fertiliser management.**
    - **Research and Development:** Increased funding for research on N_2O mitigation strategies, including **improved fertilisers and waste management techniques,** is crucial for long-term progress.
- **Addressing Emissions from Other Sources:**
    - **Industrial Processes:** Implementing **stricter regulations and promoting cleaner technologies** can minimise N_2O emissions from industrial sources such as **nylon** production and **nitric acid** manufacturing can curb rising nitrous oxide emissions.
    - **Combustion:** As per the IPCC Climate Change 2021 report, **optimizing combustion processes in vehicles and power plants** can help reduce N_2O emissions as a by-product.
    - **Waste Management:** As per the **World Bank** report, technological advancements in waste-to-energy conversion and the effective **treatment of wastewater and agricultural waste** can significantly decrease N_2O emissions from these sources.

Drishti Mains Question:

What are the reasons for the rise in global nitrous oxide emissions? Discuss the environmental and policy implications of this trend, and suggest measures to mitigate nitrous oxide emissions.

UPSC Civil Services Examination, Previous Year Question:

Q. Which of the following add/adds nitrogen to the soil? (2013)

1. Excretion of urea by animals
2. Burning of coal by man
3. Death of vegetation

Select the correct answer using the codes given below:

(a) 1 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Ans: (c)

Q. Which one of the following sets of elements was primarily responsible for the origin of life on the Earth? (2012)

(a) Hydrogen, Oxygen, Sodium
(b) Carbon, Hydrogen, Nitrogen
(c) Oxygen, Calcium, Phosphorus
(d) Carbon, Hydrogen, Potassium

Ans: (b)

Q. Which feature of some species of blue-green algae helps promote them as bio-fertilizers? (2010)

(a) They convert atmospheric methane into ammonia which the crop plants can absorb readily

(b) They induce the crop plants to produce the enzymes which help convert atmospheric nitrogen to nitrates

(c) They have the mechanism to convert atmospheric nitrogen into a form that the crop plants can absorb readily

(d) They induce the roots of the crop plants to absorb the soil nitrates in larger quantities

Ans: (c)

Mains:

Q. Sikkim is the first ‘Organic State’ in India. What are the ecological and economical benefits of Organic State? **(2018)**