



## Haber-Bosch Process and Production of Fertilizers

**For Prelims:** [Haber-Bosch process](#), [Nitrogen](#), [Ammonia](#), [Lightning](#), [Azotobacter and Rhizobia](#), [Volcanic eruptions](#), [Acid rain](#), [organic farming](#), [biofertilizers](#).

**For Mains:** Importance of the Haber-Bosch process, Implications of Using Fertilizers, Nitrogen cycle.

[Source: TH](#)

### Why in News?

Through the [Haber-Bosch process](#), a hundred million tonnes of [nitrogen](#) are extracted from the atmosphere and transformed into fertiliser, resulting in the addition of 165 million tonnes of reactive nitrogen to the soil.

- In comparison, **natural biological processes** generate an estimated **100-140 million** tonnes of reactive nitrogen annually.

### What is the Haber-Bosch Process?

- **About:**
  - The **Haber-Bosch process** is an **industrial method for synthesizing ammonia** by combining nitrogen from the air with hydrogen, significantly contributing to fertiliser production.
- **Process:**
  - **Experimental Setup:**
    - The reaction occurs in a steel chamber at a pressure of 200 atm, allowing the **nitrogen-hydrogen mixture to circulate** effectively.
    - A specially designed valve withstands high pressure while allowing the  $N_2-H_2$  mixture to flow through.
    - Haber implemented a system to transfer heat from the outgoing hot gases to the incoming cooler gases, optimizing energy efficiency.
  - **Catalyst Development:**
    - Haber **initially experimented with various materials** looking for suitable filament materials as Catalyst to speed up reaction.
    - Among the tested materials was **osmium, which, when placed in the pressure chamber with the  $N_2-H_2$  mixture**, successfully cracked the nitrogen triple bond, **allowing for ammonia production**.
      - **Uranium** was another effective catalyst but both osmium and uranium were too expensive for large-scale applications.
      - The search for a **more cost-effective catalyst led to the identification of specific iron oxides** as viable options.
- **Applications:**
  - **Manufacturing:** As a refrigerant in industrial refrigeration systems and air conditioning.
  - **Household:** An ingredient in household **cleaning products**, including glass and surface

cleaners.

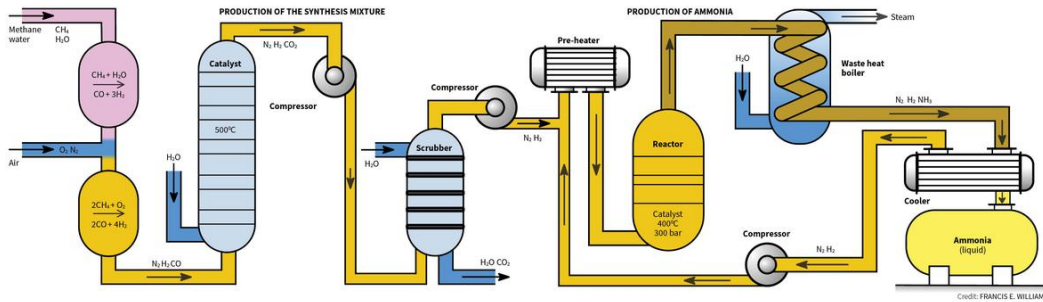
- **Automotive fuel:** An internal combustion **engine powered by ammonia is being explored** as an alternative propulsion technology.
- **Chemicals:** A precursor for various chemicals, including nitric acid and explosives.

#### ▪ **Key Milestones:**

- **In 1913**, the **German chemical company opened its first ammonia factory**, marking a significant milestone in the production of fertilizers.
- **Fritz Haber**, a German chemist, won the **Nobel Prize in Chemistry in 1919** for his work on **ammonia synthesis**.

## How ammonia is made on an industrial scale

Ammonia is made of nitrogen and hydrogen. Under extreme heat, the molecules separate and form a compound, but it is short-lived because of the heat. The German chemist Fritz Haber heated the N<sub>2</sub>-H<sub>2</sub> combination to various temperatures in a platinum cylinder and applied pressure to create ammonia. This graphic demonstrates the Haber-Bosch process



## What is the Nitrogen Cycle?

#### ▪ **About:**

- Plants obtain reactive nitrogen from the soil by **absorbing nitrogen-based minerals like ammonium (NH<sub>4</sub><sup>+</sup>) and nitrate (NO<sub>3</sub><sup>-</sup>)**, dissolved in water.
- Humans and animals rely on plants for **nine essential nitrogen-rich amino acids**, as nitrogen makes up about 2.6% of the human body.
- After being ingested, nitrogen **returns to the soil through excreta and decomposition of dead organisms**, but some nitrogen escapes back into the atmosphere as molecular nitrogen, leaving the cycle incomplete.

#### ▪ **Natural Availability of Nitrogen:**

- **Lightning:** **Lightning** bolts **possess enough energy to break the N<sub>2</sub> bond**, combining nitrogen with oxygen to form nitrogen oxides (NO and NO<sub>2</sub>).
  - These **oxides mix with water vapour**, forming **nitric and nitrous acids**, which fall as **acid rain**, providing reactive nitrogen to the soil.
- **Biological Fixation:** Some bacteria, like **Azotobacter and Rhizobia**, can **convert atmospheric nitrogen into reactive nitrogen**.
  - These bacteria often have **symbiotic relationships with plants such as legumes or aquatic ferns** like Azolla, which enhance nitrogen availability in the soil, making them valuable for agriculture.
- **Process of Nitrogen Replenishment:**
  - While **legumes can fix nitrogen naturally**, most **staple crops like rice, wheat, corn, potatoes, cassava, bananas, and other fruits and vegetables depend on soil nitrogen for growth**.
  - As **human populations grow**, the **depletion of nitrogen in agricultural soils accelerates**, requiring the use of fertilizers to restore soil fertility.
- **Historical Fertilization Methods:**
  - Farmers historically cultivated legumes to naturally replenish nitrogen in the soil or applied ammonia-based fertilizers to increase crop yields.
  - They also **utilized ammonium-rich minerals from volcanic eruptions** and naturally occurring nitrates found in caves and rocks to enhance soil fertility.

## What is the Impact of Industrial Production of Fertilizers?

#### ▪ **Pros:**

- The Haber-Bosch process enabled the **mass production of synthetic fertilizers**, significantly **boosting global food supply** during the 20th century, contributing to increased life expectancy.
  - An **estimated one-third of the world's population relies on food produced** using **nitrogen fertilizers**.
    - **Without the industrial production of ammonia** from nitrogen and hydrogen, it would have been **impossible to meet the growing global demand for food**.
- **Cons:**
- Synthetic nitrogen fertilizers, although critical for food production, **have adverse environmental impacts**.
  - Excess nitrogen application leads to **plant over-nourishment, boosting bacterial activity and accelerating nitrogen release** into the atmosphere.
  - This **contributes to environmental degradation**, including **acid rain**, land corrosion, and surface water deoxygenation through runoff, causing excessive weed growth in water bodies.

## Way Forward

- **Promote Sustainable Fertilizer Use:** Encourage the **adoption of precision agriculture and controlled-release fertilizers** to reduce nitrogen waste, minimize environmental damage, and enhance the efficiency of fertilizer usage in farming.
- **Invest in Alternative Technologies:** Develop and **promote eco-friendly alternatives to synthetic fertilizers**, such as **organic farming practices, nitrogen-fixing crops, and biofertilizers**, to mitigate the environmental impacts of chemical fertilizers.
- **Strengthen Policy Frameworks:** Governments should implement **regulations to control fertilizer overuse** and incentivize sustainable farming practices, ensuring food security while protecting ecosystems and public health.
- **Enhance Global Cooperation:** Foster international collaboration to **address food distribution disparities, improve access to agricultural innovations**, and support capacity-building initiatives for regions facing food insecurity, ensuring equitable solutions to global food challenges.

### Drishti Mains Question:

Critically examine the impact of synthetic fertilizers on agriculture and the environment. Discuss sustainable alternatives to mitigate these challenges.

## UPSC Civil Services Examination, Previous Year Question (PYQ)

### Prelims:

**Q. With reference to chemical fertilizers in India, consider the following statements: (2020)**

1. At present, the retail price of chemical fertilizers is market-driven and not administered by the Government.
2. Ammonia, which is an input of urea, is produced from natural gas.
3. Sulphur, which is a raw material for phosphoric acid fertilizer, is a by-product of oil refineries.

**Which of the statements given above is/are correct?**

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

**Ans: (b)**

**Mains:**

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

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