Nano Coated Fertilisers

For Prelims: Nano Fertilisers, Nutrient Use Efficiency, Carbon Nanotubes (CNTs), Fullerenes, Fullerols, Precision Agriculture, Nitrogen Metabolism, Photosynthesis, Biofortification, Soil Contamination, Nitrogen Fixation, Rhizobium, Azotobacter, Ecotoxicity, Phosphate Rock.

For Mains: Use of nanotechnology in agriculture, Advantages and challenges associated with nanotechnology.

Source: PIB

Why in News?

Recently, Indian scientists have developed **nano coated muriate of potash** (nano fertilisers) which can enhance the **nutrient use efficiency (NUE)** of fertilisers.

- The coating made of **nanoclay-reinforced binary carbohydrates** can reduce the recommended **fertiliser dose** and maintain **enhanced crop production**.
- It is **mechanically stable, biodegradable and hydrophobic** which can **enhance NUE** by their **slow release in soil.**
- NUE is the **efficiency of a plant** in using **applied or fixed nitrogen** for biomass production.

What are Key Facts About Nano Fertilisers?

- **About Nanofertilisers:** Fertilisers coated with **nanomaterials** (particles in the nanoscale range of 1-100 nanometer) are called **Nanofertilisers.**
  - These nanomaterials enable **controlled release** of nutrients into the soil, optimising **nutrient availability** to plants over a longer period.
- **Nanomaterial Components:**
  - **Inorganic Materials:** Common inorganic nanomaterials used for nanofertilizers include:
    - **Metal Oxides: Zinc oxide (ZnO), titanium dioxide (TiO2)**, magnesium oxide (MgO), and silver oxide (AgO).
    - **Silica Nanoparticles:** These provide **high surface area**, **biocompatibility, and non-toxicity,** enhancing crop quality and supporting sustainable agriculture, especially under stress like **salinity**.
    - **Hydroxyapatite Nanohybrids:** They help in delivering **calcium and phosphorus** to plants.
  - **Organic Materials:** Common organic nanomaterials used for nanofertilizers include:
    - **Chitosan:** It is a **biodegradable**, natural material which helps in delivering nutrients efficiently.
    - **Carbon-based Nanomaterials:** Organic nanomaterials such as **carbon nanotubes (CNTs), fullerenes, and fullerols** increase the rate of **germination, the chlorophyll content, and the protein** content.
- **Types of Nanofertilizers:** Nanofertilisers can be classified based on the method of preparation.
  - **Nanoscale Coating Fertilisers:** These fertilisers have **nutrients coated** in nanoparticles

for slow and controlled release.
    - **Nanoscale Additive Fertilisers:** Nutrients are added to **nano-sized adsorbents**, keeping them stable and gradually available to plants.
    - **Nanoporous Materials:** Fertilisers in **nanoporous** materials release nutrients slowly, ensuring plants **absorb them fully.**
- **Applications in Agriculture:**
    - **Precision Agriculture:** Nanotechnology is used in **precision agriculture** to optimise **water and fertiliser use**, reducing waste and energy consumption.
        - In Precision agriculture, inputs are utilised in **precise amounts** to get **increased average yields**, compared to traditional cultivation techniques.
    - **Soil and Plant Health:** Nanofertilisers boost **seed germination, nitrogen metabolism, photosynthesis**, protein and carbohydrate production, and stress tolerance, leading to healthier crops.
    - **Long-Term Soil Fertility:** Nanofertilisers release slowly, helping maintain or improve soil fertility for sustainable crop production.

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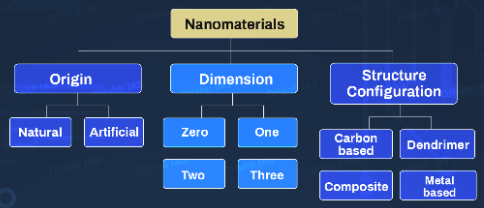
Nanotechnology and Nanomaterials

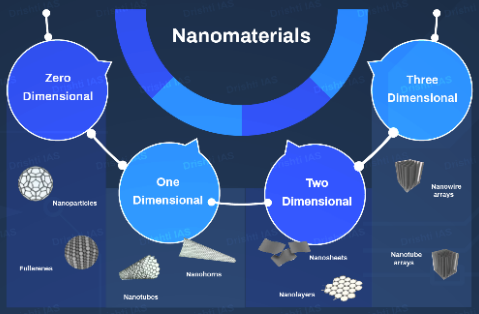
Nanotechnology is the branch of science and engineering focused on manipulating matter at the atomic and molecular scale (dimensions ≤ 100 nanometers).

Nanomaterials

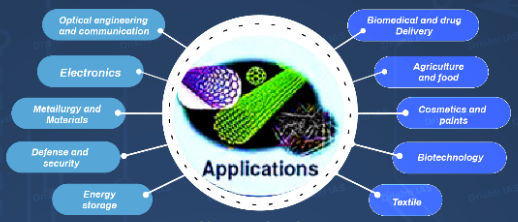
Materials with at least one dimension ≤ 100 nm

- Classification:





- Properties:
  - **Mechanical Strength:** Higher durability and lightweight – ideal for aerospace and automotive
  - **Quantum Confinement:** Alters electronic properties at nanoscale – enhances semiconductor performance and display technologies
  - **Increased Surface Area:** Enhanced catalytic properties – ideal for chemical reactions and environmental cleanup
  - **Magnetic Properties:** Exhibits superparamagnetism – useful in data storage



Nanotechnology

Nanotechnology in India – Evolution

Chintamani Nagesa Ramachandra Rao is regarded as the father of Indian nanotechnology.

- **9th Five-Year Plan (1998-2002):** Introduced nanomaterials into India's strategic science goals
- **10th FYP (2002-07):** Launched National Nanoscience and Nanotechnology Initiative (NSTI)
  - **Nano Science and Technology Mission (NSTM) (2007)** pushed nanotechnology into mission-mode R&D
- **12th FYP (2012-17):** Phase-II of NSTM
- **Institute of Nano Science and Technology (INST):** Estd. 2013

Challenges	Way Forward
• Safety & toxicity • Efficient mass-production • Inadequate regulatory frameworks • High production expenses • IPR related legal complexities	• Prioritising R&D and fostering international collaboration • Rigorous testing of nanomaterials to assess their potential toxicity • Develop comprehensive regulatory frameworks + ethical guidelines

What are the Advantages of Nanofertilisers?

- **Enhanced Nutrient Efficiency:** Nanofertilisers can **minimise nutrient loss** due to **leaching and runoff**, and reduce their **fast degradation and volatility**. This improves **soil fertility** and ensures that plants receive nutrients more efficiently.
- **Improved Crop Productivity:** The slow and controlled release of nutrients can lead to **increased crop yield** over time, as plants can access nutrients when needed, resulting in better growth and development.
- **High Surface Area and Penetration Ability:** Nanofertilizers possess a high **surface area-to-volume ratio**, allowing for better nutrient uptake by plant roots. This property also facilitates the **penetration of nutrients** deeper into the soil.
- **Biofortification:** Nanofertilisers can be used to enhance the **nutritional content** of crops by supplying **essential micronutrients**, such as **iron, zinc, and iodine**, through **nano-based biofortification**.
- **Environmental Benefits:** Nanofertilisers can reduce **environmental hazards** caused by traditional fertilisers, such as **runoff and soil contamination**, promoting eco-friendly farming practices.
- **Cost Efficiency:** Nanofertilisers can minimise costs in the long run by **reducing** the need for **frequent applications**. E.g., While **conventional urea** has an efficiency of **about 25%,** the efficiency of **liquid nano urea** can be as high as **85-90%.**
    - Recent advances in manufacturing processes have made them affordable for **small-scale farmers** and **plant breeders**.
- **Compatibility with Biofertilizers:** Nanofertilisers can complement **biofertilisers** by supporting the activities of beneficial **microorganisms** in the soil. For example, enhanced **nitrogen fixation** by **Rhizobium** and **Azotobacter**.
    - **Nano-composite fertilisers** boost **rhizosphere bacteria**, encouraging **secondary metabolites** that enhance plant growth by promoting **root surface colonisation.**

What Challenges are Involved in Use of Nanofertilisers?

- **Impact on Environmental:** Nanofertilisers may have potential **ecotoxicity** risks to the **soil, water, and non-target organisms**.
    - Ecotoxicity studies how **chemicals, physical agents, or biological stressors harm organisms** and the environment.
- **Toxicity to Humans:** Nanoparticles can **penetrate biological systems** more easily than larger particles, which raises potential risks to both **human health and the environment.**
- **Impact on Soil Microorganisms:** Metal or metal oxide nanoparticles may **disrupt soil ecosystems**, potentially harming beneficial microbes essential for nutrient cycling and soil fertility.
- **Lack of Legislation and Regulation:** Currently, there is **no adequate legislation** or risk management system in place to regulate the use of nanofertilizers which raises concerns about the **safety and effectiveness** of nanofertilizers.
    - The use of nanomaterials in agriculture raises concerns regarding **regulations** and **safety standards** for both human health and environmental protection.
- **Bioaccumulation:** The long-term **persistence** of nanofertilizers in plant systems may lead to **build-up** of nanoparticles in the food chain.
- **Decline in Yield:** A study has found that there was a **21.6% decrease in wheat yield and a 13% decrease in rice yields** with the use of nano urea in India.

Way Forward

- **Supporting Small-Scale Farmers:** Processing abundant **phosphate rock resources** can make **phosphates nanofertilisres** more affordable and effective for small-scale farmers.
- **Enhance Farmers' Reach:** Enhance reach of the nano fertiliser in both **micro and macro nutrients** through **Krishi Vigyan Kendras (KVKs)**, farmer education campaigns etc.
- **Standardisation and Regulation:** For nanofertilizers to be widely adopted, there must be **clear**

regulations and standards governing their production, application, and safety.

- **Invest in Fundamental Research:** Continued **research** is needed to understand how nanoparticles interact with plants, focusing on **nano-toxicity and safety.**
- **Optimise Nanomaterials: Biodegradable nanomaterials**, such as those derived from **plant-based sources or microorganisms**, can reduce potential toxicity and environmental hazards.

Drishti Mains Question:

Nanotechnology holds immense potential for enhancing agricultural productivity, but its adoption raises several concerns regarding safety and environmental sustainability. Critically examine.

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)

Q.There is some concern regarding the nanoparticles of some chemical elements that are used by the industry in the manufacture of various products. Why?(2014)

1. They can accumulate in the environment, and contaminate water and soil.
2. They can enter the food chains.
3. They can trigger the production of free radicals.

Select the correct answer using the code given below:

(a) 1 and 2 only

(b) 3 only

(c) 1 and 3 only

(d) 1, 2 and 3

Ans: (d)

Mains

Q. What do you understand about nanotechnology and how is it helping in the health sector? (2020)

Q. How can biotechnology help to improve the living standards of farmers? (2019)

Q. Why is there so much activity in the field of biotechnology in our country? How has this activity benefitted the field of biopharma. (2018)