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TRAINING REPORT

DIAMMONIUM PHOSPHATE PLANT AND CASE STUDY ON NANO DAP IFFCO PARADEEP UNIT

TRAINING PERIOD

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Submitted By-

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CERTIFICATE

This is to certify that Subham Samantaray, a 2nd-year B.Tech student in Chemical Engineering from National Institute of Technology (NIT), Rourkela, has successfully completed his industrial training at IFFCO, Paradeep Unit during the prescribed period under the guidance and supervision of our technical team.

During the training, Subham actively participated in various technical sessions and plant visits, acquiring practical knowledge and firsthand exposure to large-scale fertilizer production processes, particularly in the DAP (Diammonium Phosphate) Plant.

His dedication, discipline, and initiative-taking approach toward learning industrial practices have been commendable. The technical report submitted is a comprehensive reflection of the theoretical understanding and practical insights he has developed during his training tenure.

We appreciate his professional attitude, enthusiasm, and commitment to learning and wish him continued success in his future academic and professional endeavours.

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ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to all those who supported and guided me throughout the course of this technical report on the **manufacturing process of Diammonium Phosphate (DAP) at IFFCO Paradeep and a brief case study on Nano DAP.**

Primarily, I am deeply thankful to the **Indian Farmers Fertiliser Cooperative Limited (IFFCO), Paradeep Unit,** for granting me the invaluable opportunity to undergo industrial training and gain practical insight into the large-scale production of DAP fertilizer. This exposure has enriched my understanding of plant operations and process engineering.

I extend my sincere appreciation to **Mr. K.P. Nanda**, Training Head, and **Mr. Asish Mohapatra**, Training Officer, for their continuous guidance, support, and encouragement during the entire training period. Their mentorship played a pivotal role in shaping this project into a meaningful learning experience.

I would also like to acknowledge **Mr. Barik**, Librarian, for providing access to technical manuals and documentation that were crucial to the preparation of this report.

This report stands as a testament to the collective efforts, cooperation, and mentorship of everyone involved. I am sincerely grateful for their contributions.

ABOUT IFFCO PARADEEP

Indian Farmers Fertiliser Cooperative Limited (IFFCO) is a **multi-state cooperative society** founded in **1967** with the vision of empowering Indian farmers through access to quality fertilizers. It has since grown into one of the largest fertilizer cooperatives in the world, with a massive network of member societies, farmers, and a robust infrastructure of manufacturing and marketing.

IFFCO Paradeep Unit, located in the coastal city of **Paradeep** in Odisha, was acquired in **2005** and transformed into a world-class phosphatic fertilizer manufacturing facility. The unit is strategically located near Paradeep port, enabling easy import of raw materials such as **rock phosphate, sulphur, and ammonia.**

The Paradeep facility is equipped with:

- **Phosphoric Acid Plant (PAP):** One of the world's largest, with a capacity of **2650 TPD with an annual production of 0.875 MTPA**.

- **Sulphuric Acid Plants (SAP): Three trains** with a combined capacity of **9000 TPD** with an annual production capacity of **2.97 MTA**.
- **DAP/NPK Plants:** Three production trains, each capable of producing **2090 TPD DAP with an annual production capacity of 1.92MTPA and 2310 TPD of NPK-1/NPK-2.**
- **Power Plant:** Two units of **55 MW** each, providing reliable captive power supply.
- **Offsite Facilities:** Storage tanks, ammonia refrigeration units, cooling towers, water treatment, and effluent treatment plants.

Key features and initiatives at IFFCO Paradeep:

- **Revamp & Modernization:** Since takeover, IFFCO has invested heavily in upgrading plant systems, safety features, and pollution control measures.
- **Environmental Stewardship:** Initiatives include recovery of fluorine compounds, **phospho-gypsum** utilization in cement and agriculture, tree plantation, and zero liquid discharge practices.
- **Township:** A full-fledged township for employees with modern housing, schools, healthcare, and recreational amenities.

Apart from Paradeep, IFFCO operates several other manufacturing units across India:

- **Kalol Unit (Gujarat):** Produces urea using natural gas as feedstock, with a focus on energy efficiency.

- **Phulpur Units I & II (Uttar Pradesh):** Major producers of ammonia and urea, with state-of-the-art reforming and synthesis technologies.
- **Aonla Unit (Uttar Pradesh):** One of the largest urea production units, known for its modern control systems and high operational reliability.
- **Kandla Unit (Gujarat):** A bulk import and blending terminal for DAP and NPK fertilizers.

Each of these plants complements IFFCO's commitment to serving Indian agriculture, ensuring consistent supply, technological advancement, and environmental care throughout its operations. Annual requirements of the raw materials at the rated capacity of the complex are as follows:-

Sl.no	Raw Materials	Annual Requirements	Source
1	*Rock Phosphate*	*270,000*	*Jordon , Peru , Morocco, Egypt , Vietnam*
2	*Sulphur*	*780,000*	*Middle East*
3	*Ammonia*	*400,000*	*Middle East*
4	*Sulphuric Acid*	*As per need*	*Japan , Korea, Australia, Germany*
5	*MOP*	*112,000*	*Canada ,Peru*

FIRE AND SAFETY

Fire and safety are of paramount importance at **IFFCO Paradeep**, where large volumes of hazardous chemicals such as ammonia, phosphoric acid, and sulphuric acid are regularly handled. The organization ensures a robust safety culture through dedicated training, regular audits, and emergency preparedness.

IFFCO Paradeep utilizes multiple fire extinguishing systems based on the type of fire hazard:

- **ABC Dry Chemical Extinguishers** are used for Class A, B, and C fires, making them suitable for general plant use.
- **Carbon Dioxide (CO_2) Extinguishers** are in control rooms and electrical areas to handle Class C fires.
- **Clean Agent Extinguishers** protect sensitive equipment such as DCS panels and laboratories.
- **Class D Extinguishers or dry sand** are used for reactive metal fires like those involving magnesium or sodium.

Fires are classified into:

- **Class A:** Solid combustibles (wood, paper)
- **Class B:** Flammable liquids (oil, solvents)
- **Class C:** Energized electrical equipment.
- **Class D:** Combustible metals and reactive chemicals

IFFCO Paradeep complies with international safety standards such as **ISO 14001 and OHSAS 18001**. The plant integrates advanced gas detection systems, fire hydrants, sprinkler networks, and foam-based suppression systems in high-risk zones. Fire control panels provide centralized monitoring.

GENERAL SAFETY RULES :

• Employee must report all accidents immediately to their supervisor.

• Any defective or unsafe equipment must be reported to a supervisor so that it may be repaired promptly.

• Access to fire extinguisher or other firefighting equipment must not be blocked. Machine guards must be in position before startup and during normal operation of equipment.

• Equipment must not be operated in unsafe condition.

• Electrical repairing must only be made by authorised personnel.

• Personnel must not operate any equipment unless they have been authorized to do.

• If any other employee or visitor is seen performing unsafe act ,stop him and tactfully remind him of the safe way.

• Only correct tools(in safe condition) for the job shall be used.

• Never watch any type of wielding without wearing protective equipment.

• The proper tools and equipment for the job must always be obtained and used.

INTRODUCTION

Fertilizers are indispensable components of modern agriculture. They help replenish essential nutrients in the soil, enabling high crop yields and meeting the growing food demands of the global population. Among several types of fertilizers, phosphatic fertilizers play a key role in promoting root development, flowering, and overall plant health. **Diammonium Phosphate (DAP), with the chemical formula $(NH_4)_2HPO_4$**, is one of the most widely used phosphatic fertilizers. It offers a balanced supply of **nitrogen and phosphorus**, making it highly effective for a variety of crops and soil types.

DAP is appreciated for its high nutrient content, ease of handling, water solubility, and compatibility with other fertilizers. Its standardized composition of **18% nitrogen and 46% phosphorus pentoxide (P_2O_5)** makes it a favoured choice for farmers across the globe.

This report presents a detailed study of the DAP manufacturing process as observed during my **industrial training at IFFCO Paradeep**. The training allowed me to explore various facets of fertilizer production, **from raw material sourcing and chemical reactions to mechanical handling, granulation, drying, and quality control.** The objective of this project is to provide a comprehensive understanding of:

- **The chemistry behind DAP formation**
- **The design and operation of major process equipment**
- **The integration of safety and environmental systems**
- **Process control and instrumentation techniques.**

DAP MANUFACTURING PROCESS

DAP Plant, IFFCO

The production of **Diammonium Phosphate (DAP) at IFFCO Paradeep** is a sophisticated, continuous chemical manufacturing process, emphasizing precision in reaction kinetics, heat and mass transfer, solid handling, and emissions control. **The DAP Plant commissioned in 2005** and the leading-edge technology provided by **M/S Jacobs Engineering Group Inc, USA** is a designed process to **maximize product yield, efficiency, and environmental compliance.**

Process : Jacob's Engineering Inc (USA)

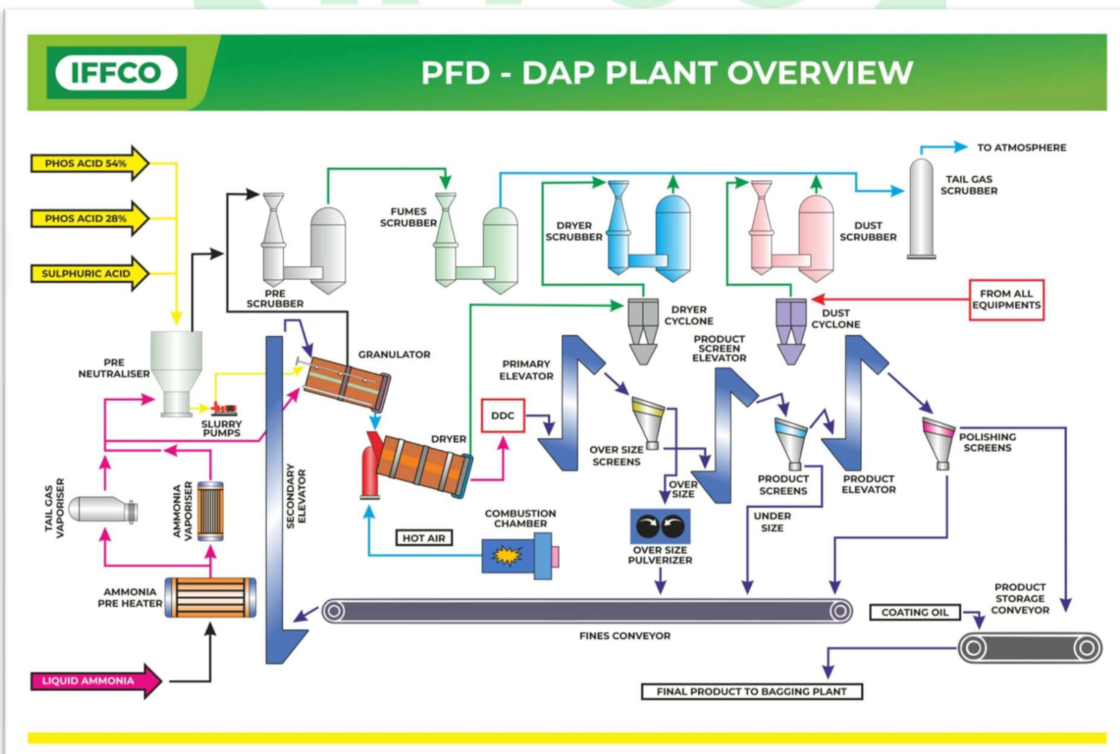
Plant Capacity : 1.92 MTA of DAP

Process Flow and Material Balance

Typical material balance (**per train – 2090 TPD output**):

- **Ammonia: ~350 TPD**
- **54% Phosphoric Acid: ~900 TPD**
- **Filler, Urea, MOP: ~200 TPD (optional)**
- **Recycle: ~6000–6300 TPD**
- **Final Product: 2090 TPD**

The system uses mass flow meters and weigh belts to monitor process rates and maintain inventory control.



Raw Materials and Feed Handling

The essential raw materials used in DAP production are:

- **Phosphoric Acid (H_3PO_4): Two grades—54% (46–49% P_2O_5) and 28% (26–27% P_2O_5)**—are used. The former is fed directly to the **pre-neutralizer**, while the latter is also used in the scrubbing circuit.
- **Anhydrous Ammonia (NH_3):** Delivered at -33°C and preheated before vaporization.
- **Urea ($CO(NH_2)_2$):** Sometimes included for NPK variants.
- **Muriate of Potash (MOP)** and **filler (silica sand):** Used in granulation and grade balancing.

Raw materials are stored in dedicated tanks and silos and conveyed via mechanized systems with instrumentation for weight and flow control. Dust control mechanisms are active in transfer areas.

The table below shows the various raw materials used and the sources and fundamental uses in the plant.

Material	Source	Purpose
Phosphoric Acid	In-house (from rock phosphate)	P source; reacts with NH_3 to form DAP
Anhydrous Ammonia	Middle East imports	N source; reacts with acid in vapor form
Sulfuric Acid	SAP unit	Grade control, auxiliary reaction
Urea	Domestic/Imported	NPK fertilizer production
Potash (KCl)	Canada, Peru	Provides K in NPK grades
Silica Sand (Filler)	Local	Maintains physical structure
Scrubber Liquor	Internal recovery loop	Nutrient recovery, reduces waste
Steam & Air	Utility Systems	Heating, vaporizing, combustion, control

Chemical Reactions

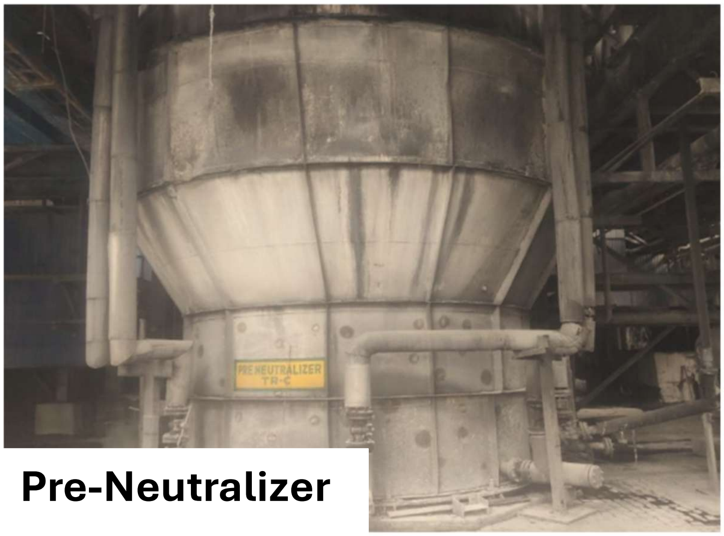
The production of Diammonium Phosphate (DAP) is driven by a series of well-defined chemical reactions involving phosphoric acid and ammonia as the primary reactants. These reactions are highly exothermic and occur in both the pre-neutralizer and granulator stages under controlled temperature and mole ratio conditions. In addition to the main neutralization reactions, several secondary and side reactions take place due to the presence of impurities in raw materials such as rock phosphate and wet process phosphoric acid. A detailed overview of these reactions is essential to understand process efficiency, product purity, and the strategies used to mitigate operational challenges in a high-throughput DAP plant like IFFCO Paradeep.

S.No.	Type of Reaction	Chemical Equation	Description
1	**Main Reaction 1** (Monoammonium Phosphate formation)	$NH_3 + H_3PO_4 \rightarrow NH_4H_2PO_4$ + Heat	First step in DAP formation, exothermic reaction in pre-neutralizer
2	**Main Reaction 2** (Diammonium Phosphate formation)	$NH_3 + NH_4H_2PO_4 \rightarrow (NH_4)_2HPO_4$ + Heat	Final product formation: mole ratio adjusted in granulator
3	**Ammonium Sulphate Formation**	$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$ + Heat	Used in NP production or for grade control using sulfuric acid
4	**Reaction with Fluorosilicic Acid (H_2SiF_6)**	$NH_3 + H_2SiF_6 \rightarrow (NH_4)_2SiF_6$	Byproduct formed from impurities in wet process phosphoric acid
5	**Decomposition of Ammonium Fluorosilicate**	$(NH_4)_2SiF_6 + 2H_2O + 4NH_3 \rightarrow 6NH_4F + SiO_2$	Produces ammonium fluoride and silica as solid waste

6	**Gypsum Formation (from CaO impurity)**	$CaO + H_2SO_4 + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O$	Forms gypsum crystals during filtration; common in PAP process
7	**Formation of Iron Phosphate**	$NH_4^+ + Fe^{3+} + H_3PO_4 \rightarrow NH_4(FeH)(HPO_4)_2$	Removes Fe impurities as insoluble complexes
8	**Formation of Magnesium Ammonium Phosphate**	$Mg^{2+} + NH_4^+ + PO_4^{3-} \rightarrow MgNH_4PO_4$	Precipitates Mg impurities as slow-release phosphate salt
9	**Formation of Calcium Hydrogen Phosphate**	$Ca^{2+} + HPO_4^{2-} + 2H_2O \rightarrow CaHPO_4 \cdot 2H_2O$	Forms stable calcium phosphate complex

- **Reactions 1 & 2 are the core DAP-forming reactions.**
- **Reactions 3–5 handle byproducts and side-stream purification.**
- **Reactions 6–9 deal with impurities commonly found in raw materials like rock phosphate and wet phosphoric acid.**

Pre-Neutralizer



Pre-Neutralizer

This is a **CSTR (Continuous Stirred Tank Reactor),** mixing phosphoric acid, ammonia vapor, and scrubber liquor. The pre-neutralizer at IFFCO Paradeep is of a **reduced retention type**, developed by **Jacobs Engineering**. It has a **conical base (narrower bottom and wider top)**, designed to:

- Promote rapid mixing.
- Prevent solid buildup at the bottom.
- Minimize residence time to control product composition.

The reactor is equipped with:

- **Top-entry agitator** for continuous stirring.
- **Eight ammonia sparger pipes** located below the liquid surface.
- **Multiple feed inlets** for strong/weak acid and scrubber liquor.

The targeted mole ratio is **1.45–1.48** with a temperature of ~122°C. Deviations in this ratio can result in unreacted acid or excess ammonia, leading to downstream operational issues such as poor granule formation, product softening, or excessive ammonia slip into the scrubbers.

Additionally, **sulfuric acid (98%)** may be introduced in small quantities during NP (20:20:0) production to adjust the slurry composition, forming ammonium sulphate ($(NH_4)_2SO_4$) as a secondary nutrient and controlling the overall N:P balance.

The pre-neutralizer functions as the **heart of the chemical conversion system**, where a delicate balance of temperature, flow rate, mole ratio, and concentration are maintained through automation and real-time sampling. The stability and performance of this unit have a direct impact on the granulation quality, product grade, and energy efficiency of the entire DAP manufacturing process.

The reactor receives acid from three sources:

- **54% P_2O_5 acid (main reactant)**
- **28% P_2O_5 acid (scrubber liquor supplement)**
- **Weak phosphoric acid from scrubbers (with dissolved ammonium phosphate)**

Why are two acid grades used ?

Using two different grades of phosphoric acid — 54% (strong) and 28% (weak) — helps in **optimizing reaction efficiency, plant flexibility, and waste minimization**.

54% P_2O_5 (Strong Acid):

- Pumped directly from storage to the pre-neutralizer.

- Participates in the main reaction with ammonia to form ammonium phosphates.
- High concentration ensures an efficient, heat-driven reaction.

28% P_2O_5 (Weak Acid):

- Used in the scrubbing system to recover escaped ammonia and dust.
- Recycled back into the process via the pre-neutralizer.
- Maintains plant-wide N:P ratio balance while reducing effluent losses.

Advantages of using both grades-

Using both 54% and 28% phosphoric acid allows:

- Efficient reaction with ammonia.
- Recycling of scrubber byproducts.
- Heat recovery and water reduction.
- Flexibility to control fertilizer grade.
- Reduced environmental discharge.

Sparging

Sparging refers to the process of **intentionally dispersing a gas into a liquid as fine bubbles**. The slurry's density and temperature are crucial for pumpability and to avoid crystallization before granulation. Ammonia is sparged through **8 sparger pipes**, and the mole ratio is controlled based on real-time sampling.

Scrubber Liquor

Scrubber liquor is the **circulating aqueous solution** used within **wet scrubbers**, air pollution control systems. It acts as the primary **contact medium** to remove pollutants (acid/alkaline gases, particulates, some VOCs) from industrial exhaust gases. Typically, water-based, it contains added **reactive chemicals (reagents)** like caustic soda (NaOH), lime slurry ($Ca(OH)_2$), or oxidizing agents (e.g., NaOCl) tailored to target specific contaminants.

Pollutants are captured via **absorption and chemical reaction**. The liquor is continuously **recirculated**, with reagents replenished as consumed. A controlled **bleed stream (blowdown)** removes accumulated reaction products and solids, generating a wastewater stream requiring treatment. Its composition and pH are critical for efficient operation.

Ammonia Vaporization System

In the DAP manufacturing process, ammonia (NH_3) is a primary reactant and must be fed into the system in **vapor form** to ensure rapid and complete reaction with phosphoric acid in the **pre-neutralizer** and **granulator**. Since ammonia is stored as a cryogenic liquid at around **–33°C**, it cannot be directly used in its liquid form. Therefore, a dedicated **Ammonia Vaporization System** is employed to heat and vaporize ammonia to the required conditions, typically **~33–35°C** in gaseous state.

This system plays a critical role in:

- Maintaining the correct mole ratio of nitrogen to phosphorus.
- Ensuring uniform distribution of ammonia.
- Minimizing ammonia slip and losses.
- Reducing overall steam consumption by heat integration.

Functional Components of the Ammonia Vaporization System-

The vaporization system consists of **four key units**, each with a specific role in converting cold liquid ammonia into hot, dry ammonia gas:

Ammonia Pre-Heater

- **Purpose**: To preheat liquid ammonia from its storage temperature of –33°C to +5°C.
- **Working Fluid**: Low-pressure steam is used to gently raise the temperature.
- **Construction**: Shell-and-tube heat exchanger.
- **Control**:
  - Steam flow is controlled using a temperature controller, which monitors the condensate temperature.
  - If outlet temperature drops too low, downstream vaporizers are protected by closing the control valves.

This unit does **not vaporize** the ammonia—its role is simply to **raise the temperature** to avoid thermal shock or freezing in the downstream vaporizers.

Tail Gas Vaporizer (TGV)-

- **Purpose**: To vaporize most of the ammonia using **waste heat** from the **tail gas scrubber system**, making the process energy efficient.
- **Working Principle**:
    - Hot scrubber gases are circulated through a heat exchanger.
    - Liquid ammonia flows through the exchanger and is vaporized by this recovered heat.
- **Control**:
    - A **three-way valve** controls the flow of scrubber liquor to maintain proper vapor pressure in the discharge line.
    - Liquid ammonia flow into this unit is controlled by the **liquid level** in the vaporizer.
    - If the level rises too high, inlet ammonia valves automatically close to prevent flooding.

The TGV system significantly **reduces steam consumption** and simultaneously lowers **ammonia emissions** by integrating heat recovery from tail gases.

Steam-Heated Ammonia Vaporizer-

- **Purpose**: Acts as a **supplementary** or **backup** vaporizer when the Tail Gas Vaporizer cannot handle the full load.
- **Working Fluid**: High-pressure steam.

- **Operation Modes**:
    - Under normal conditions, this unit handles only a small fraction of the total load.
    - If the TGV is shut down (maintenance or failure), this unit **takes over the entire vaporization duty**.
- **Control**:
    - Steam flow is regulated based on the ammonia vapor outlet pressure and temperature.
    - Two **condensate control valves** manage heat input depending on the load.

This ensures uninterrupted plant operation even in cases where waste heat recovery is unavailable.

Vapor Distribution System-

- **Purpose**: To route hot ammonia vapor from the vaporizers to:
    - **Pre-Neutralizer**
    - **Granulator**
- **Configuration**:
    - Vapor lines are heat-traced and insulated to prevent condensation.
    - Spargers are used at injection points to ensure **uniform dispersion** below the liquid level (especially in the pre-neutralizer).
- **Flow Control**:

- Precise flow control is necessary to maintain N:P mole ratio.
- Flowmeters and control valves are used to automate ammonia injection based on grade requirements (e.g., DAP vs NP).

Importance of the Vaporization System-

Function	Impact
Heat integration (TGV)	Saves energy, reduces steam demand
Stable ammonia vapor supply	Ensures consistent chemical reactions in pre-neutralizer and granulator
Flow regulation	Enables precise control over fertilizer grade and product quality
Redundancy (backup vaporizer)	Ensures uninterrupted operation during maintenance or failure
Emission minimization	Reduced ammonia slips due to improved vapor utilization

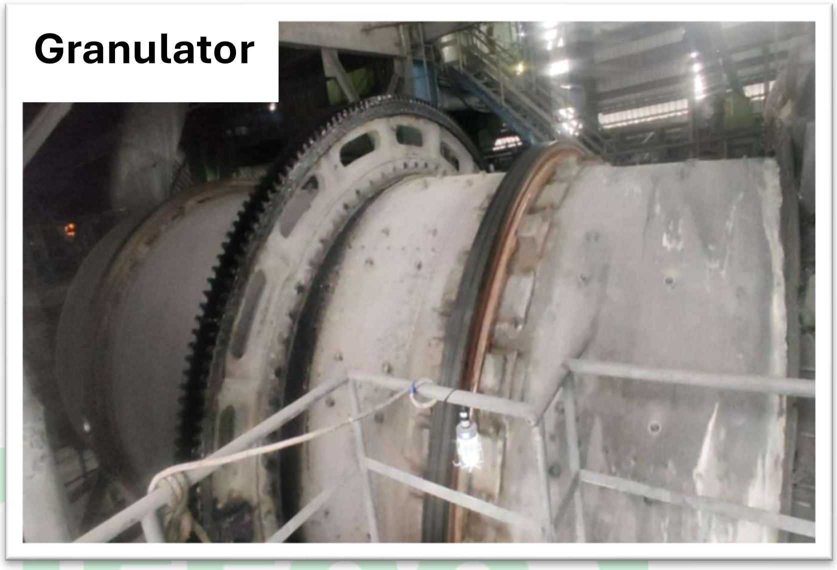
Operational Challenges and Mitigation-

Issue	Effect	Mitigation Strategy
Pre-heater underperformance	Cold ammonia → freezing in pipelines	Improve steam regulation, inspect fouling
Flooding in tail gas vaporizer	Poor vapor quality	Use level sensors and interlocks on ammonia inlet
Ammonia slip	Environmental hazard	Tight mole ratio control, optimize scrubbers
Steam loss in backup vaporizer	Higher utility cost	Use only as needed; monitor condensate losses

Granulation

Granulation is one of the most critical steps in the Diammonium Phosphate (DAP) production process, where the chemical slurry produced in the pre-neutralizer is transformed into solid granules of the desired size and composition. This transformation is carried out in a specially designed **rotating drum granulator**, which plays a pivotal role in determining the **physical properties, strength, and commercial value** of the final fertilizer product.

At IFFCO Paradeep, the granulator is engineered for **continuous operation**, handling both fresh slurry and recycled material to ensure uniform granule formation, proper nutrient distribution, and efficient downstream processing.



The process not only completes the chemical reaction (to reach the final N:P mole ratio) but also shapes and sizes the product into market-ready granules.

Objective of Granulation

- Convert liquid slurry into **solid granules**.
- Ensure **final ammonisation** of the slurry (adjust N:P mole ratio).
- Achieve **uniform particle size distribution** (~2–4 mm).
- Promote **layered growth** of granules via controlled recycle and spray patterns.
- Enhance **physical properties**: hardness, roundness, and bulk density.
- Enable **efficient drying and screening** downstream.

Granulator Equipment Description

The granulator at IFFCO Paradeep is a **rotary drum-type granulator**, rubber-lined to avoid material buildup and corrosion. It operates as a **moving bed reactor** with tumbling action and includes:

- **Slurry Spray Header**: Uniformly sprays the neutralized slurry onto the moving bed of solids.
- **Ammonia Spargers**: Additional vapor ammonia is injected to complete DAP formation.
- **Rotary Drive**: Slowly rotates the drum to enable layer-by-layer particle growth.
- **Inclination**: Slight tilt (~2–5°) allows granules to move from inlet to outlet.
- **Lifters and Liners**: Promote internal mixing and prevent material buildup.
- **Vapour Exhaust Ducts**: Connected to scrubbers to handle reaction gases and dust.

Granulation Mechanism

The granulation process in the drum can be understood as a combination of **three overlapping mechanisms**:

a. Nucleation

- **Recycled fines (<2 mm)** from the screening section act as seeds or cores.

- These fines are fed onto the moving bed via the **fines conveyor**.

b. Layer Growth (Accretion)

- The slurry sprayed from the pre-neutralizer coats the fine particles.
- Ammonia is also added here to complete the reaction and increase the pH for solid formation.
- Continuous tumbling and agitation cause particles to **grow in layers**.

c. Consolidation and Rounding

- As granules grow, they are rolled repeatedly inside the rotating drum.
- This rolling action **smoothens and hardens** the granules into a round shape.
- **Excess slurry or unreacted particles** are absorbed by larger particles, reducing dust.

Chemical Reaction in Granulator-

Additional ammonia is injected into the granulator to complete the chemical reaction initiated in the pre-neutralizer:

$$NH_4H_2PO_4 + NH_3 \rightarrow (NH_4)_2HPO_4$$

This step increases the **N:P mole ratio** from ~1.45 (pre-neutralizer) to **~1.8–1.85**, which is required for **DAP-grade (18:46:0)** production.

Operating Conditions-

Parameter	Typical Value / Range
Granulator Diameter	~3.5 – 4.0 meters
Length	~10 – 12 meters
Rotation Speed	~4 – 7 rpm
Ammonia Mole Ratio (final)	1.80 – 1.85 (DAP), 1.12 – 1.17 (NP)
Granule Size Target	2 – 4 mm
Slurry Flow Rate	Controlled by downstream granule quality
Recycle Ratio	Typically, 3:1 (recycled solids: fresh feed)

Recycle Streams in Granulation

Granulation relies heavily on **solid recycle loops**, which stabilize the process:

- **Fines (<2 mm):** Recycled from the screen → used as seed material.
- **Oversize (>4 mm):** Crushed in chain mills → returned to the fines conveyor.
- **Dust from Cyclones/Scrubbers:** Captured and returned to the granulator via fines belt.

This **closed-loop solid circulation** ensures high yield, minimizes waste, and provides continuous nucleation sites.

Importance of Ammonia Control

- **Excess ammonia** leads to:
    - **Ammonia slip** → increased load on scrubbers.
    - Formation of soft granules due to excessive pH.
- **Low ammonia** leads to:
    - **Incomplete reaction → poor nutrient specification.**
    - **Sticky slurry → granule agglomeration or dusting.**

Thus, ammonia injection is carefully **monitored and automated**, often based on mole ratio feedback from the final product analysis.

Challenges and Mitigation-

Issue	Cause	Effect	Remedy
Slurry Overloading	Excess feed or low recycle	Sticky product, agglomeration	Adjust feed and recycle ratio
Fines Accumulation	Poor dust return, uneven spraying	Low yield, dustiness	Improve spray pattern and fines recycling
Oversized Granules	High recycle temperature, excess ammonia	Requires extra crushing	Reduce recycle temperature, fine-tune NH_3 addition

Granule Breakage	Low binder content, under-rolling	Poor product strength	Adjust slurry concentration and drum rotation

Final Product Discharge

Once granules reach the target size and chemical composition, they exit the granulator and are transported via the **Dryer Discharge Conveyor (DDC)** to the **Drying Section**, where their moisture content is reduced for safe handling and storage.

Drying & Combustion

Dryer

Hot gases from the combustion chamber dry the wet granules in a rotary dryer. Combustion is achieved using:

- Furnace oil atomized with air.
- Combustion air fans and quench air fans for temperature control
- Burner ignition systems with spark plugs

Typical conditions:

- **Inlet gas temperature:** ~700–800°C
- **Product moisture:** Reduced from 3.5% to <1%
- **Solids temperature:** ~90–95°C

Combustion Chamber

Tramp iron is removed using **electromagnetic separators**. The dryer operates under slight negative pressure (**-2 mm WG**) to prevent backflow.

Screening & Crushing

The dried product is screened into three fractions:

- **Oversize:** Crushed in chain mills and recycled
- **Undersize:** Returned to the granulator via fines conveyor
- **Product grade:** 2–4 mm diameter

Screens are single or double deck, vibrated by motorized drives. Automatic feedback from the fines conveyor scale adjusts feed rates to maintain stable granulation beds.

Screens

Dust and Fume Collection

All operations are conducted under slight vacuum to draw fumes and dust into collection systems. Main equipment includes:

- **Pre-scrubber:** Uses weak acid to remove ammonia.
- **Dust & fume scrubber:** Removes solids and residual ammonia.
- **Dryer scrubber:** Handles emissions from the rotary dryer
- **Tail gas scrubber:** Final cleaning of exhaust gases

Collected scrubber liquor is recycled through tanks and pumps back to the pre-neutralizer. Ammonia mole ratios in the liquor are carefully adjusted for effective scrubbing and nutrient recovery.

Instrumentation and Automation

The DAP plant is equipped with a state-of-the-art Distributed Control System (DCS), including:

- **Transmitters and sensors**: pH, mole ratio, temperature, pressure, flow
- **Control loops**: Slurry feed, ammonia vapor flow, dryer temperature.

- **Alarms and interlocks**: High pressure, over-temperature, level alarms
- **Visualization tools**: DCS displays for trend analysis, recipe management, and diagnostics.

Automation helps in:

- **Controlling mole ratio dynamically**
- **Monitoring granule size and bed height**
- **Managing combustion air and furnace oil injection**

This ensures optimized energy use, reduced emissions, and consistent product quality.

NANO DAP- A Case Study

Introduction

IFFCO (Indian Farmers Fertiliser Cooperative Limited) has consistently pioneered sustainable and farmer-friendly innovations in the Indian fertilizer sector. As part of its mission to promote efficiency and environmental stewardship, IFFCO has developed Nano DAP—a breakthrough nano-formulated version of Di-Ammonium Phosphate. Traditional granular DAP suffers from low nutrient use efficiency due to volatilization and leaching. Nano DAP, by contrast, delivers nutrients directly to plant cells at the nanoscale level, ensuring better absorption and reduced wastage. The introduction of this product aligns with global efforts to reduce chemical load on soil while maintaining or increasing crop yield. This report delves into the production methodology, key process parameters, and implications of Nano DAP in the context of Indian agriculture.

Raw Materials Used

The raw materials used in Nano DAP production are similar to those in conventional DAP but undergo further processing and stabilization. **Phosphoric Acid (H_3PO_4)** serves as the phosphorus source and reacts with **Ammonia (NH_3)** to form DAP. However, to achieve nanoparticle formulation, deionized water is used to ensure purity, while **dispersants** and **stabilizers** are added to prevent clumping of the particles. These stabilizers can include polymers, surfactants, or chelating agents that ensure long-term particle dispersion. In some advanced formulations, **nanocarriers** such as silica, zeolites, or lignin nanoparticles may be introduced to allow controlled nutrient release and targeted delivery to plant roots or leaves.

Production Process of Nano DAP

The production process for Nano DAP begins with the conventional reaction of ammonia and phosphoric acid under controlled temperature and pressure, forming an aqueous DAP solution. This solution then undergoes **nano-sizing**, the critical step where particle size is reduced to below 100 nanometres using **bead mills, jet mills, or high-pressure homogenizers**. These technologies provide the mechanical shear needed to break down larger particles. Stabilizers are incorporated to maintain colloidal stability, and the suspension is continuously agitated to prevent settling. The suspension is filtered to ensure uniformity, and rigorous quality checks ensure size distribution and nutrient content are within specifications. The final product is a liquid nano-suspension, ready for packaging and application in the field.

Equipment Involved

Equipment	Function
Reactor Vessel	DAP solution synthesis
Bead Mill / Jet Mill	Nano-sizing of DAP particles
High-Shear Mixer	Uniform dispersion

Ultrasonicator (optional)	Nano-emulsification
Particle Size Analyzer (DLS)	Quality testing
Filtration Units (Nano-Membrane)	Coarse particle removal
Filling & Packaging Machine	Final packaging

Quality Control Parameters

Quality control plays a vital role in Nano DAP production, as consistency in particle size and nutrient content directly affects product performance. Parameters such as **average particle size**, **pH**, **nutrient concentration**, **zeta potential**, and **shelf stability** are closely monitored. The target is to maintain particle sizes in the 20–70 nm range for optimal uptake by plant cells. Stability tests are performed by storing samples under different conditions and observing agglomeration over time. In addition, microbial contamination is also monitored to prevent spoilage. Advanced tools like **scanning electron microscopy (SEM)** and **Fourier-transform infrared spectroscopy (FTIR)** may also be used during R&D for structural characterization of the nano-formulation.

Benefits of Nano DAP

Nano DAP offers several transformative benefits over conventional DAP. Because of its ultra-small particle size and high surface area, nutrient absorption by plants increases dramatically, leading to better root development, improved shoot growth, and higher yields. This allows farmers to reduce the quantity of fertilizer applied per acre while maintaining crop productivity. Unlike granular DAP, which can leach into groundwater or volatilize into the air, Nano DAP stays available in the root zone. Additionally, its packaging in small bottles makes it easier to transport, store, and apply via foliar spray or drip irrigation. Over time, this can result in lower input costs, reduced soil contamination, and improved soil health.

Traditional DAP	Nano DAP
Low nutrient efficiency (~30–40%)	**High nutrient efficiency (>80%)**
Fixed dose per acre	**Lower dose (~4 ml/litre of water)**
Environmental runoff	**Reduced leaching and pollution**
Requires bulk handling	**Lightweight, easy-to-carry bottles**

Challenges in Nano DAP Production

While the benefits are significant, producing Nano DAP at scale presents several challenges. First, the **capital cost** of nano-sizing equipment and analytical tools is high. Second, maintaining **stability of nanoparticles** over extended periods is difficult due to the natural tendency of particles to agglomerate. Additionally, the **formulation must comply with national and international regulatory norms**—especially for nanomaterials used in agriculture. There are also **logistical challenges** such as farmer training, dosage accuracy, and creating awareness about application methods. Environmental and toxicological studies are still ongoing to ensure safety for long-term use. Hence, R&D and regulatory engagement are essential for successful commercialization.

Conclusion

In conclusion, Nano DAP represents a paradigm shift in how fertilizers are delivered to crops. The adoption of nanotechnology in fertilizer production opens new possibilities for enhancing crop yield, improving soil health, and ensuring environmental sustainability. Through this internship, I gained hands-on experience in observing the Nano DAP production line, understanding the principles of particle size reduction, and learning about quality control and industrial process management. It has given me a broader view of how innovation and engineering can work together to solve pressing challenges in agriculture. The experience has deepened my interest in process innovation and strengthened my resolve to contribute to sustainable chemical engineering solutions.

CONCLUSION

In conclusion, my industrial training experience at IFFCO Paradeep has been incredibly enriching and valuable for my future career. It offered me a unique opportunity to bridge the gap between academic knowledge and real-world industrial practices. Beyond acquiring practical skills and technical know-how, I had the chance to interact with experienced professionals and build a strong network that I believe will support me in my professional journey.

One of the most important lessons I learned during this internship is that real learning extends far beyond the classroom. The industrial environment is dynamic and fast-paced, requiring adaptability and a proactive mindset. This exposure has significantly broadened my perspective and prepared me for life after graduation. I also honed my time management and self-motivation skills, learning to organize tasks efficiently and perform under pressure. Furthermore, I developed a deeper sense of respect for teamwork, professionalism, and collaboration—key values that contribute to a healthy and productive workplace culture.

Overall, my time at IFFCO Paradeep has been a remarkable experience. I gained hands-on experience, improved my interpersonal and organizational skills, and made meaningful connections. I am truly grateful for this opportunity and confident that it has laid a solid foundation for my future as a professional engineer.

REFERENCES

- **IFFCO Paradeep Internal Training Manuals** Unpublished internal documents and training resources provided during the industrial training at IFFCO, Paradeep Unit.

- **IFFCO Paradeep Plant Operation Guidelines** Internal Standard Operating Procedures (SOPs), Process Flow Diagrams (PFDs), and Technical Datasheets used in the Phosphoric Acid, Sulphuric Acid, and DAP production units.

- **Indian Farmers Fertiliser Cooperative Limited (IFFCO) Official Website** https://www.iffco.in
(Accessed for general organizational structure, production capacity, and overview of plant operations)

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