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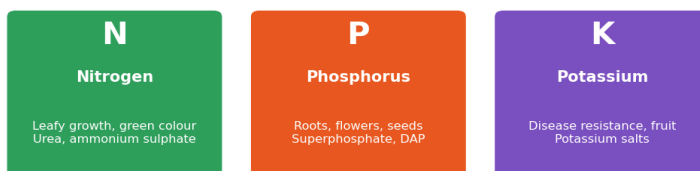
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FSc / ICS Part-II Chemistry — Punjab Board

CHAPTER 15

Common Chemical Industries in Pakistan

The Three Main Plant Nutrients (NPK)



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Figure 15.1 — The three main plant nutrients supplied by fertilizers (N, P, K).



1. Chapter Overview

Chemical industries turn raw materials into the products a country needs, and they are a major part of Pakistan's economy. This chapter looks at three of the most important chemical industries in Pakistan — the fertilizer industry, the cement industry and the paper industry. Because Pakistan is an agricultural country, the fertilizer industry is especially important: it supplies the nutrients that keep our soils fertile and our crops productive. We study the raw materials, the manufacturing steps and the uses of the products of each industry.

2. Learning Objectives

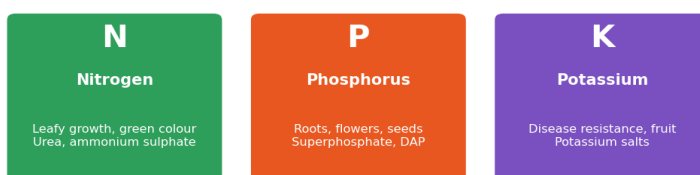
- Explain the importance of the fertilizer industry for Pakistan.
- Name the three main plant nutrients and the fertilizers that supply them.
- Describe the manufacture of important fertilizers such as urea.
- Describe the raw materials and manufacture of cement.
- Describe the raw materials and manufacture of paper.
- Appreciate the role of these industries in the national economy.

3. Key Concepts

3.1 The Fertilizer Industry

Fertilizers are substances added to the soil to supply the nutrients that plants need for healthy growth. The three most important nutrients are nitrogen (N), phosphorus (P) and potassium (K), together called NPK. Nitrogen promotes leafy, green growth; phosphorus helps the roots, flowers and seeds; and potassium improves disease resistance and the quality of fruit. Because Pakistani soils are often short of these nutrients, fertilizers are essential for good crop yields.

The Three Main Plant Nutrients (NPK)



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Figure 15.2 — Roles of the NPK nutrients.

Fertilizer	Nutrient supplied	Formula
Urea	Nitrogen (highest N%)	$\text{CO}(\text{NH}_2)_2$
Ammonium sulphate	Nitrogen	$(\text{NH}_4)_2\text{SO}_4$
Ammonium nitrate	Nitrogen	NH_4NO_3



Fertilizer	Nutrient supplied	Formula
Superphosphate	Phosphorus	$\text{Ca}(\text{H}_2\text{PO}_4)_2 + \text{CaSO}_4$
Diammonium phosphate (DAP)	Nitrogen + phosphorus	$(\text{NH}_4)_2\text{HPO}_4$

Manufacture of Urea

Urea is the most widely used nitrogen fertilizer in Pakistan because it has the highest nitrogen content (about 46%). It is made from ammonia (from the Haber process) and carbon dioxide in two steps: the two gases first combine to form ammonium carbamate, which is then decomposed by heat to give urea and water. The overall reaction is $2\text{NH}_3 + \text{CO}_2 \rightarrow \text{CO}(\text{NH}_2)_2 + \text{H}_2\text{O}$. Pakistan has several large urea plants that use natural gas as the source of hydrogen for the ammonia.

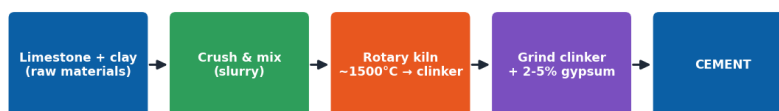
Memory Trick

NPK roles: N = 'Naya patta' (leaves), P = 'Phal-phool & roots', K = 'Kamzori se bachao' (disease resistance).

3.2 The Cement Industry

Cement is the grey powder that, when mixed with water, sand and gravel, sets into concrete — the basis of nearly all modern building. Its main raw materials are limestone (which provides calcium) and clay (which provides silica, alumina and iron). The manufacture has four main steps: the raw materials are crushed and mixed, the mixture is heated in a rotary kiln at about 1450–1500 °C to form small lumps called clinker, the clinker is ground to a fine powder, and a small amount of gypsum (about 2–5%) is added to control the setting time.

Manufacture of Cement



Gypsum controls (slows) the setting time of cement.

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Figure 15.3 — The manufacture of cement.

Teacher's Note

Link this back to Chapter 2: gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is added to cement to SLOW its setting so it can be worked before it hardens — a point that connects two chapters.

3.3 The Paper Industry

Paper is made mainly from cellulose fibres obtained from wood or, in Pakistan, from bagasse (the fibrous residue left after crushing sugar cane). The process has several steps: the raw material is digested (pulped) with chemicals to separate the cellulose fibres, the pulp is bleached and beaten



to the right texture, and it is then spread out, pressed and dried into thin sheets of paper. The paper industry is closely linked to Pakistan's large sugar industry, which supplies the bagasse.

Manufacture of Paper



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Figure 15.4 — The manufacture of paper.

3.4 Importance for Pakistan

These industries are vital to the national economy. The fertilizer industry supports agriculture, which employs a large part of the population and provides food and raw materials. The cement industry supplies the construction and infrastructure sector. The paper industry supports education, printing and packaging. Together they create jobs, reduce imports and add to the country's wealth.

4. Important Definitions

Term	Definition
Fertilizer	A substance added to soil to supply nutrients for plant growth.
NPK	The three main plant nutrients: nitrogen, phosphorus and potassium.
Urea	A nitrogen fertilizer, $\text{CO}(\text{NH}_2)_2$, with the highest nitrogen content.
Clinker	The lumps formed when the cement raw mixture is heated in the kiln.
Bagasse	The fibrous residue of sugar cane, used to make paper.
Pulping	Digesting raw material with chemicals to free the cellulose fibres for paper.

5. Formulas / Rules

Must-Know Facts

NPK: N (leaves), P (roots/flowers/seeds), K (disease resistance/fruit).

Urea: $2\text{NH}_3 + \text{CO}_2 \rightarrow \text{CO}(\text{NH}_2)_2 + \text{H}_2\text{O}$; ~46% N (highest).

Cement raw materials: limestone + clay; heated in kiln $\rightarrow$ clinker; + gypsum.

Gypsum (2–5%) controls the setting time of cement.

Paper: cellulose from wood/bagasse $\rightarrow$ pulp $\rightarrow$ bleach $\rightarrow$ sheet.



6. Diagrams / Illustrations

Key diagrams for revision:

Manufacture of Cement



Gypsum controls (slows) the setting time of cement.

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Diagram 1 — Cement manufacture.

Manufacture of Paper



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Diagram 2 — Paper manufacture.

7. Solved Examples

Example 1 — Choosing a fertilizer

Q: A farmer's crop has pale, poor leafy growth. Which nutrient is likely deficient and which fertilizer would help?

Solution: Pale, poor leafy growth suggests a nitrogen deficiency. A nitrogen fertilizer such as urea, $\text{CO}(\text{NH}_2)_2$, would help.

Example 2 — Cement

Q: Why is gypsum added to cement?

Solution: A small amount of gypsum (2–5%) is added to slow down (control) the setting time of the cement, so that it can be mixed and used before it hardens.

Example 3 — Paper

Q: Which by-product of the sugar industry is used to make paper?

Solution: Bagasse — the fibrous residue left after the juice is crushed out of sugar cane — is used as a source of cellulose for paper.



8. Short Questions

Q1. Why is the fertilizer industry important for Pakistan?

Ans. Because Pakistan is an agricultural country, and fertilizers supply the nutrients needed for good crop yields.

Q2. What are the three main plant nutrients?

Ans. Nitrogen (N), phosphorus (P) and potassium (K).

Q3. Which fertilizer has the highest nitrogen content?

Ans. Urea, $\text{CO}(\text{NH}_2)_2$ (about 46% nitrogen).

Q4. Write the reaction for the manufacture of urea.

Ans. $2\text{NH}_3 + \text{CO}_2 \rightarrow \text{CO}(\text{NH}_2)_2 + \text{H}_2\text{O}$.

Q5. Name the raw materials for cement.

Ans. Limestone (calcium) and clay (silica, alumina, iron).

Q6. What is clinker?

Ans. The lumps formed when the cement raw mixture is strongly heated in the rotary kiln.

Q7. Why is gypsum added to cement?

Ans. To control (slow down) the setting time of the cement.

Q8. What is bagasse used for?

Ans. As a source of cellulose fibres to make paper.

9. Long Questions

Q1. Describe the fertilizer industry and the manufacture of urea.

Because Pakistan's economy depends heavily on agriculture, the fertilizer industry is one of its most important chemical industries. Fertilizers replace the nutrients that crops take out of the soil, the three most important being nitrogen, phosphorus and potassium (NPK): nitrogen encourages green, leafy growth, phosphorus develops the roots, flowers and seeds, and potassium improves disease resistance and fruit quality. Different fertilizers supply these nutrients, for example urea and ammonium sulphate for nitrogen, superphosphate for phosphorus, and diammonium phosphate (DAP) for both nitrogen and phosphorus. Of these, urea is the most widely used in Pakistan because it has the highest nitrogen content, about 46%. Urea is manufactured from ammonia (made by the Haber process using hydrogen from natural gas) and carbon dioxide. The two gases first combine to form ammonium carbamate, which is then decomposed by heat to give urea and water; overall, $2\text{NH}_3 + \text{CO}_2 \rightarrow \text{CO}(\text{NH}_2)_2 + \text{H}_2\text{O}$. Pakistan has several large urea plants, which help the country grow enough food and reduce its dependence on imports.

Q2. Describe the raw materials and manufacture of cement.

Cement is the essential building material that sets hard with water to bind sand and gravel into concrete. Its two main raw materials are limestone, which provides calcium oxide, and clay, which provides silica, alumina and iron oxide; a small amount of gypsum is also needed at the end. The manufacture takes place in four main steps. First, the limestone and clay are crushed and mixed together in the correct proportions, sometimes with water to make a slurry. Second, the mixture is fed into a large sloping rotary kiln and heated to about 1450–1500 °C, where chemical reactions



convert it into hard, marble-sized lumps called clinker. Third, the cooled clinker is ground to a very fine grey powder. Fourth, a small amount of gypsum (about 2–5%) is added and ground in with the clinker; the gypsum controls (slows) the setting time so that the cement can be mixed and placed before it hardens. The finished cement is then packed and sold. Pakistan has a large cement industry that supports its construction sector and exports.

Q3. Describe how paper is manufactured, and the link with the sugar industry.

Paper is made from cellulose fibres, which come from wood and, in Pakistan especially, from bagasse — the fibrous material left after the juice has been pressed out of sugar cane. The manufacture has several stages. First the raw material is cut up and digested (pulped) with chemicals, which dissolve away the substances that hold the fibres together and free the cellulose as a soft pulp. The pulp is then bleached to make it white and beaten to give the fibres the right texture. Next the watery pulp is spread out evenly on a moving wire screen, where the water drains away and the fibres mat together into a thin, wet sheet. Finally the sheet is pressed and dried over heated rollers to give finished paper. Because bagasse is a by-product of sugar making, the paper industry is closely linked to Pakistan's large sugar industry, which turns what would otherwise be waste into a valuable raw material. The paper industry supports education, printing, newspapers and packaging.

10. Multiple Choice Questions (MCQs)

1. The three main plant nutrients are:

- (A) C, H, O (B) N, P, K (C) Na, Ca, Mg (D) Fe, Cu, Zn

2. Which fertilizer has the highest nitrogen content?

- (A) ammonium sulphate (B) urea (C) DAP (D) superphosphate

3. The formula of urea is:

- (A) NH_4NO_3 (B) $\text{CO}(\text{NH}_2)_2$ (C) $(\text{NH}_4)_2\text{SO}_4$ (D) $(\text{NH}_4)_2\text{HPO}_4$

4. Urea is made from ammonia and:

- (A) O_2 (B) CO_2 (C) N_2 (D) H_2O

5. The main raw materials for cement are:

- (A) sand and gravel (B) limestone and clay (C) gypsum and coal (D) clay and salt

6. The lumps formed in the cement kiln are called:

- (A) slurry (B) clinker (C) slag (D) pulp

7. Gypsum is added to cement to:

- (A) increase strength (B) control setting time (C) give colour (D) reduce cost

8. Paper is mainly made of:

- (A) protein (B) cellulose (C) starch (D) nylon

9. Bagasse is a by-product of the ____ industry:

- (A) cement (B) sugar (C) fertilizer (D) paper

10. DAP supplies:

- (A) only nitrogen (B) only phosphorus (C) nitrogen and phosphorus (D) potassium

MCQ Answer Key

1-B 2-B 3-B 4-B 5-B 6-B 7-B 8-B 9-B 10-C



11. Quick Revision / Summary

- Fertilizers supply NPK: N (leaves), P (roots/flowers), K (disease resistance).
- Urea $\text{CO}(\text{NH}_2)_2$ = highest N (~46%); $2\text{NH}_3 + \text{CO}_2 \rightarrow \text{urea} + \text{H}_2\text{O}$.
- Cement: limestone + clay $\rightarrow$ kiln (clinker) $\rightarrow$ grind + gypsum.
- Gypsum controls cement setting time.
- Paper: cellulose from wood/bagasse $\rightarrow$ pulp $\rightarrow$ bleach $\rightarrow$ sheet.
- These industries are vital to Pakistan's agriculture, construction and economy.

12. Exam Tips

Teacher's Note

Learn the NPK roles and match each nutrient to its fertilizer.

Remember urea has the highest nitrogen content and its manufacturing equation.

Know the four steps of cement manufacture and why gypsum is added.

Link bagasse to the sugar industry for the paper question.

Mention the economic importance for Pakistan in long answers.

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