

CO₂ capture from phosphate fertilizer production

CO₂ capture technologies are critical for reducing the high carbon footprint of conventional phosphate fertilizers and essential to maintaining international competitiveness in a carbon constrained world. By Stephen B. Harrison, sbh4 consulting.

Diammonium phosphate (DAP) is the most common phosphate fertilizer. It is popular because it is safe to handle, can be applied conveniently as granules and introduces both nitrogen and phosphorus to the soil. High volume commodity crops such as wheat, maize and rice all benefit from DAP.

OCP is the world's largest producer of phosphate fertilizers with 31% global market share. Jorf Lasfar is the world's largest integrated fertilizer complex in the world, from which OCP exports phosphate fertilizers worldwide.

In addition to leading world production of DAP, OCP is leading the world in CO₂ capture and utilisation to decarbonise phosphate processing.



Phosphate fertilizer production and phosphogypsum waste

Geogenic CO₂

DAP is produced where phosphate rock is mined. This rock is rich in a phosphorus-bearing mineral, fluorapatite. In addition to CO₂ emissions from the heat and energy requirements of DAP production, geogenic CO₂ is produced during DAP production because the fluorapatite mineral is contaminated with calcite (calcium carbonate, or limestone).

Prior to DAP production, the ore is beneficiated to remove sand, clay, and as much calcite as possible. The beneficiated fluorapatite ore is mixed with sulphuric acid, to yield phosphogypsum as a solid waste material and phosphoric acid. The phosphoric acid is reacted with ammonia, then granulated and sieved to produce DAP.

High quality ores, such those found in Morocco and Jordan contain between 10 and 15% calcite. In other main phosphate rock mining locations such as Florida and Saudi Arabia, the calcite content can be up to 20%.

However only about half of the calcite is separated from the fluorapatite and the calcite is mixed with the sulphuric acid, along with the

fluorapatite. During the reaction between calcite and sulphuric acid, CO₂ is released.

The flue gas from the chamber where the rock is mixed with sulphuric acid mixing is hot, moist and contains hydrogen fluoride (HF), which is released from the fluorapatite ore. The off-gas is scrubbed with water to remove the HF. The resultant gas mixture is hot, moist CO₂-rich, and is generally vented to atmosphere.

If the calcite content of the beneficiated ore is reduced to 6%, as would be the case in Morocco, approximately 0.05 tonnes of geogenic CO₂ per tonne of DAP produced. For Saudi Arabian DAP production, the geogenic CO₂ emissions liberated during the production of phosphoric acid are close to 0.1 tonnes of CO₂ per tonne of DAP.

To partially decarbonise DAP production, recover and separation of the geogenic CO₂ from moist flue gas can easily be achieved using cooling and condensation. The resultant

dry, pure CO₂ can then be liquefied for rail or sea shipment, or compressed for pipeline transmission at low marginal cost.

Utilisation and sequestration of CO₂

The idea to capture CO₂ from phosphate fertilizer production will be implemented from 2027 by OCP Nutricrops in partnership with OCP Green Water and INNOVX at OCP's Jorf Lasfar industrial platform in Morocco.

The initiative is part of OCP Group's decarbonization roadmap, which aims to achieve carbon neutrality across scope 1, 2 and 3 emissions by 2040. It also addresses international competitiveness by reducing the CO₂ intensity of DAP which is important when exporting to the EU where the Carbon Border Adjustment Mechanism will impose tariffs on carbon-intensive imports starting in 2026.

The captured CO₂ will be used by OCP

Green Water for pH adjustment and re-mineralisation of drinking water in support of a local reverse osmosis desalination plant. This will support Morocco's goal to meet 100% of the nation's water needs through unconventional resources by 2027.

INNOVX will develop a plant to use captured CO2 and waste phosphogypsum to produce ammonium sulphate fertilizer. The Merseberg Process is one of the pathways to achieve this. It reacts aqueous ammonia with CO2 to produce ammonium carbonate.

Phosphogypsum is reacted with ammonium carbonate to yield calcium carbonate and the target product ammonium sulphate. Calcium carbonate is a recognised permanent sink for CO2, so this pathway sequesters CO2 gas emissions from the DAP process and enables integrated production of ammonium sulphate.

Ammonium sulphate was the first commercially available nitrogen fertilizer. However, it was displaced in many markets by ammonia and urea due to their higher nitrogen content. However, it is still used extensively in Brazil, which imports about 4 million tonnes per year, mostly from China.

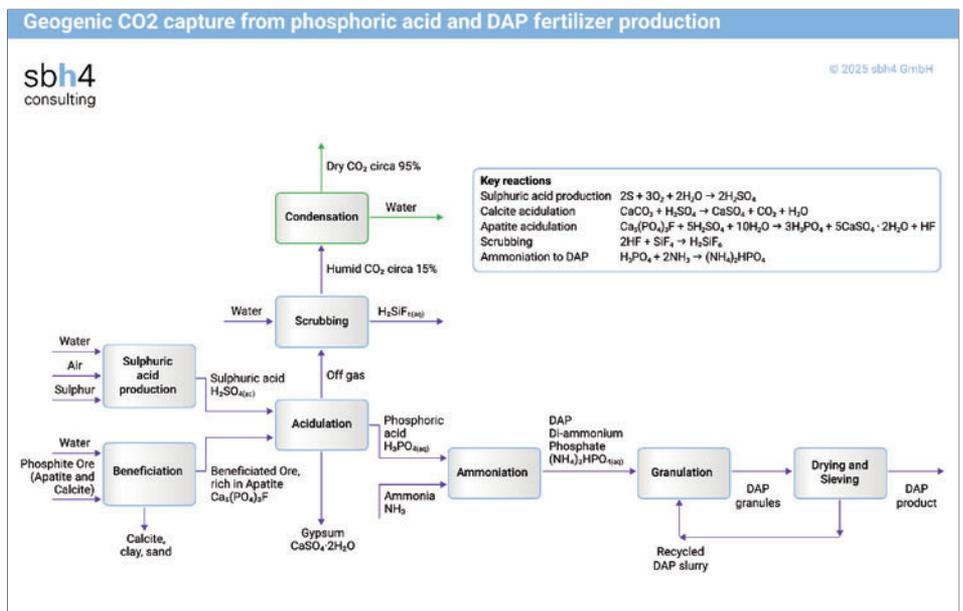
CO2 capture from ammonia production

For each tonne of DAP, 0.2 tonnes of ammonia are required to react with the phosphoric acid. Grey ammonia production releases about 1.8 tonnes of CO2 per tonne of ammonia. Thus, 0.36 tonnes of CO2 is released from the ammonia required to produce one tonne of DAP.

Comparing the CO2 emissions from ammonia production to the geogenic CO2 emissions for the Moroccan and Saudi Arabian cases above, this is about 3.5 to 7 times more than the amount of CO2 released from phosphoric acid production. To achieve deep decarbonisation of DAP production, capture of CO2 from ammonia production is also essential.

When ammonia is made from steam methane reforming of natural gas, CO2 leaving the reformer in the syngas must be removed to enable the catalytic Haber Bosch ammonia synthesis reaction to take place. This is normally achieved using an amine solvent based CO2 capture process.

The active ammonia catalyst is iron. All molecules containing oxygen, such as water, carbon monoxide or CO2 must be removed



from the syngas before it is fed to the ammonia synthesis loop. Otherwise, the catalyst is oxidised and becomes ineffective. Therefore, every natural gas-fed ammonia plant already has a CO2 capture facility.

In some facilities, about 60% of the captured CO2 is combined with ammonia to make urea. However, the residual 40% of the CO2 from the SMR and ammonia plants that do not utilise captured CO2 for urea production can sequester the captured CO2 to reduce the CO2 intensity of DAP and nitrogen fertilizer production with only a small incremental cost for CO2 sequestration.

Process integration to avoid fossil CO2 emissions

In addition to ore beneficiation, phosphoric acid production and DAP granulation, the end-to-end process at a fully integrated facility, such as Jorf Lasfar includes on-site production of sulphuric acid from elemental sulphur powder, which is imported by ship from refineries in Europe and the Middle East.

OCP Group's third integrated fertilizer production plant, Jorf Fertilizers Company 3 (JFC 3), has been fully operational since 2017 and can produce 1 million tonnes per year of granulated phosphate fertilizers.

JFC 3 includes a sulfuric acid line with a capacity of 1.4 million tonnes per year, as well as a phosphoric acid line of 0.45 million tonnes per year. The chemical reactions involved in the production of these acids are exothermic and at JFC 3 the resultant heat is used to generate 62 MW of electricity on a thermal power

plant. This process integration makes the JFC 3 unit independent in terms of energy consumption and reduces the requirement to burn fossil fuels for electricity generation.

Sulphuric acid circularity and CO2 mineralisation

Phosphogypsum is the white solid waste material that is generated during phosphoric acid production. Phosphogypsum heaps are common close to phosphoric acid and phosphate fertilizer plants.

Through calcination of phosphogypsum using high temperature heat, this waste can be converted to lime (CaO), sulphur dioxide (SO2), oxygen and water. The SO2 gas can be converted to sulphuric acid to introduce circularity to the DAP production process.

Lime can be used for cement and steel production. Also it is used in the pulp and paper industry and for pH modification of soils. Alternatively, the lime can be used to mineralise CO2 from DAP production to produce calcium carbonate which is insoluble and recognised as a permanent CO2 storage.

Putting theory into practice, Ma'aden Phosphate is collaborating with thyssenkrupp Uhde to recycle Phosphogypsum at Ras Al Khair in Saudi Arabia.

More information

<https://sbh4.de>