CHEMICAL MILL PRODUCES GREEN FERTILISER

X-ray experiments at DESY's synchrotron light source PETRA III allowed scientists from the Ruđer Bošković Institute (IRB) in Zagreb (Croatia), the Lehigh University in Bethlehem (US-State Pennsylvania), the fertilizer company ICL, the University Zagreb and DESY to optimize a purely mechanical process for the production of Nitrogen and Calcium. The beamline P02.1 is one of the few in the world where mechanochemistry can be routinely performed and analyzed using X-rays from a synchrotron.

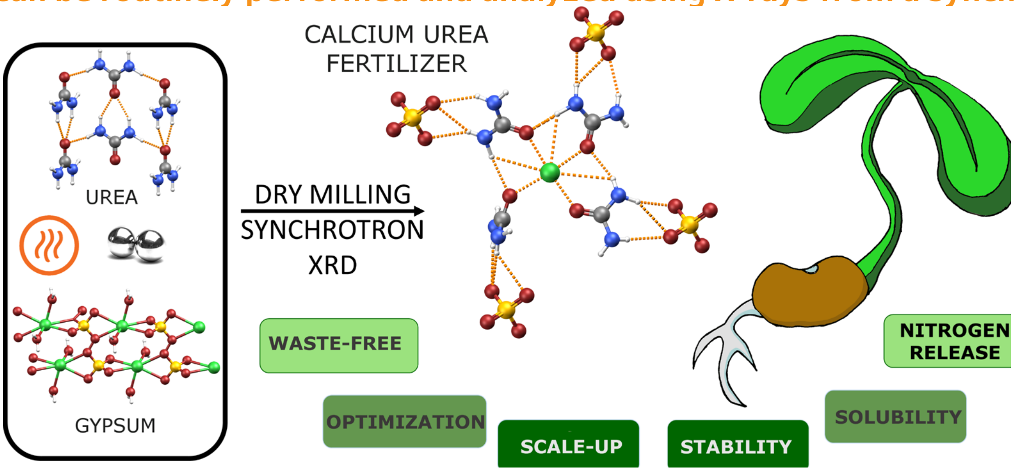

FIGURE 1 | Milling gypsum and urea with steel balls creates a so-called co-crystal that releases its nitrogen only slowly. (Credit: Ruđer Bošković Institute, Krunoslav Užarević)

CHALLENGE

For several years, scientists from DESY and IRB have been collaborating to explore the fundamentals of mechanical methods for initiating chemical reactions. This method of processing, called mechanochemistry, uses various mechanical inputs, such as compressing, vibrating, or, in this case, milling, to achieve the chemical transformation. However, in order to gain precise insights into the reactions during the processes, special experimental setups are required and are therefore only possible in a few places in the world.
Not only production can benefit from this process. Only about 47 per cent of conventional nitrogen fertilizer applied to fields in the form of urea, is actually absorbed by the ground, with the rest washing away and causing potentially massive disruptions in water systems. In the North Sea and the Gulf of Mexico, massive "dead zones" are growing, wherein algal blooms fed by excess fertiliser absorb all the available oxygen in the water and thus kill sea life.
Additionally, production of common fertilisers is energy-intensive, consuming every year four percent of the global natural gas supply via the Haber–Bosch process. Over 200 million tonnes of fertiliser is produced via the more than a century-old Haber–Bosch process, which traps atmospheric nitrogen into urea crystals. The new method provides an opportunity to reduce energy and natural gas consumption.

METHOD

The starting materials urea and gypsum were placed as powders in a grinding container containing two steel balls. By shaking, the powders were ground smaller and eventually combined chemically. The team used the bright X-ray light from PETRA III to observe the reaction live at beamline P02.1 using in-situ powder X-ray diffraction. The different reaction temperatures and water content of the gypsum were taken into account for process optimization.

FIGURE 2 | The co-crystals of the novel fertiliser (symbolized here with gypsum) release their nutrients much more slowly. (Credit: DESY, Gesine Born)

INSIGHTS AND ANALYSIS

The team used the special setup at the beamline P02.1 to gain insight into parameters governing the milling process and to optimize reaction conditions for preparing the target fertiliser. The setup at PETRA III allows direct insight into the evolution of the reaction mixture by applying synchrotron radiation to the milling vessel. This means that the reaction can be observed without stopping the procedure. The optimized process achieves 100 percent conversion of the feedstock into the desired fertilizer, i.e. without releasing any undesirable by-products or waste products.

BENEFITS

In this case, urea and gypsum were ground until a solid compound of both substances was formed. The resulting cocrystal then slowly releases the two chemical elements nitrogen and calcium, which are important for fertilization, little by little and can therefore reduce the pollution of water bodies and protect the climate. While the PETRA III analysis involved milligrams of fertiliser, the research team has managed to scale its procedures up with the help from the data taken at PETRA III. Thus far, they can produce hundreds of grams of fertiliser with the same procedure and efficiency. As a next step, the team plans to continue scaling up, in order to make an actual proof-of-principle industrial version of the process and testing of cocrystal fertiliser for application in real-world conditions.

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