Alternative sources of phosphorus for the fertilizer industry: from waste to valuable raw material

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Phosphorus, along with nitrogen and potassium, forms a classic trio of essential plant nutrients, ensuring high yields from crops. It is irreplaceable in fertilizers that are an integral part of modern agriculture. The continuous increase in the demand for fertilizers is stimulated by the food needs of the growing world population (Dąbrowska et al., 2018; Łuczkowska et al., 2016; Mikła et al., 2008; Nkebiwe et al, 2016).

The main source of phosphorus in fertilizers are phosphates, the world production capacity of which is estimated between 165 and 196 million tonnes / year. The phosphate reserves are far from being evenly distributed around the world. China, the US and Morocco currently process nearly two-thirds of total phosphate ore. There are no economically significant phosphate resources in Europe and the European market is almost entirely dependent on the export of this raw material. Agricultural practice is responsible for the consumption of nearly 90% of all extracted phosphorus. However, they are a non-renewable source, and their resources are gradually depleting due to the current intensive exploitation. According to the Communication of the European Commission (EC), in 2020 phosphorus and phosphorus are still included in the list of critical raw materials for the European Union (Dąbrowska et al., 2018; Łuczkowska et al., 2016; Jastrzębska et al., 2018; Pantano et al., 2016).

The content of heavy metals in phosphate deposits is also a potential concern. They are usually contaminated to varying degrees with cadmium, which is a toxic element. The primary route of human exposure is through the consumption of contaminated crops. Cadmium is relatively easily absorbed from the soil by plants, therefore it accumulates in the food chain (Cichy et al., 2014; Łuczkowska et al., 2016).

The average cadmium content in fertilizers sold in the EU is estimated at 45 mg Cd / kg P_2O_5. Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019, which enters into force on 17 July 2022, provides for a limit value of cadmium in inorganic mineral fertilizers of 60 mg / kg P_2O_5 for fertilizers with a total content of phosphorus minimum 5%. At present, this is an acceptable level for fertilizers based on phosphate rock. However, the further reduction of the limit content of cadmium in fertilizers announced by the EU may result in the need to use other sources of phosphorus (Cichy et al., 2014).

The progress of civilization forces the continuous development of many industries, which generates more and more amounts of undeveloped waste. Many of the waste contains chemical compounds that allow them to be used as raw materials for the production of fertilizers, including phosphorus. Hence, one of the main pillars of sustainable fertilization is the effective use of nutrients, while using waste materials. For this reason, it is important to recover phosphorus from the waste stream and convert it into a closed cycle (Kominko et al., 2017; Pantano et al., 2016).

In order to reduce its dependence on external markets, the EU has in recent years emphasized the need to look for alternative sources of phosphorus. Actions to recycle phosphorus would also have an impact on better soil management that would benefit the climate and biodiversity (Dąbrowska et al., 2018).

There are many phosphorus-containing wastes that are processed for agricultural purposes. However, much of the phosphorus waste is still wasted. There is a need for proper identification of such waste and development of treatment methods.

For example, in municipal wastewater treatment plants, phosphorus can be recovered at every stage of the treatment process, i.e. from wastewater and liquid-phase leachate, from dewatered sewage sludge, from solid phase ashes after thermal treatment of municipal sewage sludge. Due to the fact that over 90% of the phosphorus flowing into the wastewater treatment plant is discharged in sewage sludge, they are the richest source of phosphorus (Dąbrowska et al., 2018; Rafie et al., 2020).

Any reduction in food waste at the production and consumption stages would reduce the need to introduce new phosphorus from phosphate rock into the system. The food waste situation is very common. Every person living in the European Union wastes an average of 180 kg of food each year. In addition to preventing food waste, we can also make efforts to make better use of the food waste produced. Using biodegradable waste in the form of compost, digestate or ashes from green or kitchen waste would recover significant amounts of phosphorus and other nutrients. (Ahmed & Abdulla, 2018).

In addition, there are many sources of agricultural waste and by-products from food production that could be used to recover significant amounts of phosphorus if properly managed. A noteworthy example is bone meal and processed animal protein, due to the fact that phosphorus accumulates mainly in bone structures. Even though some meat and bone meal is burned and the ash is either used as fertilizer - directly as a soil improver - or to produce phosphorus, a lot of phosphorus is simply wasted. Processed animal protein is approved for use in feed and fertilizers and is commercially available in significant amounts (Chew et al., 2019).

The waste that can potentially be a source of phosphorus and is generated in the greatest amounts by the fertilizer industry is phosphogypsum, which is produced in the production of extractive phosphoric acid. Currently, only a few percent of this phosphogypsum is used economically in the world. The high water content of the waste, which must be removed during the production process, makes phosphogypsum a raw material much less attractive than anhydrite. The solution to this problem may be the production of suspension fertilizers (Dąbrowska et al., 2018; Rafie et al., 2020).

An interesting proposal for obtaining phosphorus is the management of sludge from the production of extinguishing agents. The phosphorus in this waste comes from the alkaline keratin hydrolysis step. Supplementing the fertilizer composition with additional ingredients in the form of an acetate solution provides a synergistic effect that additionally protects plants against pathogens. On the other hand, nitrogen in the organic form extends the operation time of the fertilizer (Górecki et al., 1995).

For the sustainable use of phosphorus, it is necessary to improve fertilizer application practices, develop methods to recover phosphorus present in waste, and minimize food waste. Such practices will have an impact on the economics of production, but also contribute to the improvement of the natural environment. These measures are necessary to ensure that phosphorus resources are not depleted in the short or medium term, allowing exploration to continue and the phosphorus recovery processes to be improved.

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