ExtraPhos®

Innovative process for the Recovery of phosphorus from sewage sludge

Background

As essential component of all living beings and plants, phosphorus cannot be replaced by any other substances. Phosphorus is a key limiting factor for plant growth. Over 80 % of phosphate rock mined worldwide ends up in fertilisers. Phosphate supply and price is thus strongly linked to food security.

Phosphate rock is a non-renewable, fossil resource. Estimates of how long these resources may last are variable. They are concentrated in a few countries/regions and Europe is almost entirely dependent on imports posing geopolitical supply security risks and vulnerability to price fluctuations. Alternative sources of phosphorus therefore need to be found. Recovery from sewage sludge is a promising approach as it contains nutrients, like phosphates, which are valuable for agriculture.

Now one might assume that applying the treated sewage sludge (e.g. after digestion or composting) directly onto the fields would be the easiest way of fertilizing and so re-using phosphates. However, this method is increasingly rejected by authorities, farmers or the food industry because of concerns about contaminants, as well as logistic obstacles.

Sewage sludge is the “pollutant sink” of the sewage plant. Many pollutants and contaminants are extracted from the sewage water and concentrated in the sludge, meaning that it contains not only valuable components (organic carbon, nutrients) but also pollutants such as heavy metals, pharmaceutical residues persistent chemicals or pathogens.

In some countries in Europe and under certain conditions, sewage sludge can also directly be used as a fertiliser on fields. In Germany, at present, about 30% of the sewage sludge generated is still used in agriculture. Stricter limits will however lead to a decrease of this quantity (see following table).
Changes in contaminant limits –
applicable to the use of sewage sludge in agriculture in Germany

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Former German Regulation until end of 2014*</th>
<th>Current German Regulation since 2015*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>900</td>
<td>150</td>
</tr>
<tr>
<td>Cadmium</td>
<td>10</td>
<td>1.5</td>
</tr>
<tr>
<td>Nickel</td>
<td>200</td>
<td>80</td>
</tr>
<tr>
<td>Mercury</td>
<td>8</td>
<td>1</td>
</tr>
</tbody>
</table>

* figures according to German Sewage Sludge Regulation applicable until end 2014 and German Fertiliser Regulation applicable to sewage sludge use on farmland since 2015

For more than 100 years Budenheim has been operating in the phosphate industry as a manufacturer and developer of high-purity phosphate specialties. With the project of recovering phosphorus from sewage sludge the company shares its expertise in phosphate chemistry, aiming at developing an environmentally friendly, sustainable and cost-efficient method to be used in sewage plants. The ExtraPhos® process invented by Budenheim enables recovery of phosphorus as quality phosphate products. To extract the phosphorus from sewage sludge it uses pressurised carbon dioxide at ambient temperatures.

**Description of the Budenheim ExtraPhos® process**

For the extraction of the phosphates only carbon dioxide is used, which is run through the process in a cycle. The process can be roughly subdivided into three process stages. These are carbon dioxide extraction, solid/liquid separation, and phosphate precipitation.

For the extraction, the sewage sludge/water suspension is aerated with carbon dioxide under pressure of approx. 10 bar. With this treatment, carbon dioxide becomes carbonic acid in the sewage liquor, the pH decreases to a value of between 4.5 and 5.5 and a part of the phosphates bound to the sewage sludge matrix is dissolved.
In the following solid/liquid separation, the sewage sludge particles are separated from the liquid phase, using state-of-the-art sewage sludge dewatering coagulants. The remaining, dewatered sewage sludge can be used for further recycling.

The carbon dioxide used to lower the pH value comes back out of the liquor when pressure is released (off gassing), captured, condensed, and recycled back for reuse in the process. The sludge liquor is introduced into the third process stage, phosphate precipitation, in which the dissolved phosphates are precipitated as dicalcium phosphate (DCP). In order to accelerate the precipitation process, a small quantity of lime (calcium hydroxide) is added, so pH increases, whereas most of the calcium required is already present in the sewage sludge liquor. After separation, drying and granulation the calcium phosphates are used as fertilisers.

At present the recovery rate is approx. 50% of the phosphorus in the sewage sludge. A patent application titled “PHOSPHATE RECOVERY FROM SLUDGE” has been filed under number DE20091020745 20090511.
Current state of process development

In 2010, the idea for the process was born and first laboratory tests were carried out and demonstrated the proof of principle. The project and construction of technical test plants was subsidized with more than 400,000 € from the ERDF (European Regional Development Fund) but Budenheim also put in money and human resources. Two small sized technical test plants were then built to carry out tests under defined conditions. One of these test plants was operated at the Fraunhofer Institute for Chemical Technology in Pfinztal, the other at Budenheim itself. The Budenheim ExtraPhos® test plant has extraction dissolution reactor volume of 50 liters and is operated batchwise.

ExtraPhos® test plant for phosphate extraction at Budenheim

A change to continuous operation is now ongoing with the construction of a pilot plant for approx. 2 m³ sludge per hour in the Mainz-Mombach sewage plant with 360,000 p.e. (= person equivalent) and chemical P removal with FeCl₂ planned to be commissioned by the end of 2016. Around 2% of the digested sewage sludge from the sewage plant will be
treated for recovery of phosphorus (max. capacity allows treatment of 10%). This pilot plant is subsidized with almost 600,000 € by the Deutsche Bundesstiftung Umwelt (DBU, German Federal Environmental Foundation) and the federal state of Rhineland-Palatinate, whereas Budenheim is still contributing financially and with human resources. The objective is that, based on experience of operation of this pilot plant, rollout to full scale in further municipal sewage plants will be possible from 2018.

Properties of the recovered fertilizer product

The product generated in the Budenheim ExtraPhos® process is dicalcium phosphate (DCP), initially as an aqueous suspension. The solids are separated by filtration and a relatively viscous phosphate suspension remains. The final process stage is drying to phosphate powder.

Depending on its intended purpose this powder can be further processed. For use in agriculture for example it would generally be granulated in order to enable application using farmers’ existing equipment. In plant availability trials at the University Bonn, the product from the Budenheim ExtraPhos® process has been rated comparable to conventional phosphate fertilizers.

Currently, the use of the recovered phosphates is only planned for agriculture.

Environmental Aspects

The raw material used for the extraction of phosphates is carbon dioxide. This is compressed after depressurisation and used again for extraction.

As the Budenheim ExtraPhos® process operates in the wet sewage sludge phase, a fine or granulated phosphate fertiliser can be produced directly at the sewage plant. This can be used as a fertiliser in the surrounding region, thus saving transport costs. The dewatered phosphate-depleted sewage sludge can be used in various valorisation routes, e.g. co-incineration in the cement industry.
Cost efficiency of the Budenheim ExtraPhos® process

Detailed cost and economic efficiency calculations will be made once the pilot plant in the Mainz-Mombach sewage plant is in operation. Initial calculations carried out so far are based on the test plants and suggest that the Budenheim ExtraPhos® process is potentially competitive compared to other recovery processes. In particular the low consumption of chemicals is important, because the carbon dioxide used to lower the pH value is used cycled and is thus not consumed but reused.

The Budenheim ExtraPhos® process is suitable for all sewage plants, with or without anaerobic sludge digestion. Its successful implementation is also regardless of the type of phosphate removal, both chemical and biological approaches can be pursued, because part of the phosphorus precipitated with iron or aluminum chemicals can be remobilized by the carbon dioxide treatment. This means complex and expensive process changes within the sewage plant are unnecessary. Currently, approx. 91% of all waste water volumes in German sewage plants are treated by phosphate removal.

In general, coagulant chemicals already used in the sewage plants can be used to dehydrate the sewage sludge. This has a positive effect on the investment costs for phosphate recycling because the no additional storage tanks are needed.

The Budenheim ExtraPhos® process runs under ambient temperature. An additional use of thermal energy is not required.

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Sources
- Federal Institute for Geosciences and Natural Resources, Hanover July 2014
- German Sewage Sludge Regulation
- German Fertilizer Regulation