Struvite

Technology description

Struvite (magnesium ammonium phosphate) is a phosphate mineral with formula $NH_4MgPO_4 \cdot 6H_2O$. Struvite is therefore a co-precipitate when magnesium, ammonium and ortho-phosphate are present in concentrations above the solubility constant. Struvite results from a coordinated precipitation process from the liquid phase of manure. In general this precipitation process follows the equation:
$NH_4^+ \; Mg^{2+} + H_nPO_4^{n-3} + 6H_2O \rightarrow NH_4MgPO_4.6H_2O$ (struvite) + nH^+

Ammonium (NH_4^+) can be substituted by potassium leading to a potassium struvite ($MgKPO_4.6H_2O$). In the liquid phase of manure several reactions can occur simultaneously which leads to the formation of other crystal minerals such as $MgNH_4PO_4.H_2O$ (Dittmarite), $MgHPO_4.3H_2O$ (Newberyite) and a wide range of calcium phosphates. Struvite is one of the processes to recover phosphorus from wastes, animal manure and digestate. Full scale technologies for recovering phosphorus have been implemented. More full scale technologies are in force. All depend on pH, composition (PO_4^{3-}, NH_4^+, Mg^{2+}, Ca^{2+}), operational mode and reactor type. Most struvite reactors recover phosphorus from waste waters, very few from manure.

Product characteristics

Product characteristics are well known in the public domain for struvites made from waste water. There is only limited data available on characteristics of struvite from manure from a full scale plant (Table 1).

Data available on struvite from different origins points to a lower content of nutrients (N, P, Mg and/or K) than is theoretically possible. Lower contents are caused by the presence of other minerals, organic matter and water. With current processing techniques it is not possible to obtain higher nutrient contents. Challenging new techniques and (costly) investments are needed to obtain purer struvite.

Table 1. Chemical composition of struvite from waste water and manure[1]

Origin	Parameter	N	P	K	Ca	Mg
Theoretical	Average	57	126			99
Waste water	Average	46	116	4	32	98
	Standard deviation	11	19	3	49	31
	Number of publications	28	38	10	13	24
Manure, K struvite	Average	8	59	48	15	80
	Standard deviation					
	Number of publications	1	1	1	1	1
Manure, struvite	Average	58	101	37		64
	Standard deviation					
	Number of publication	1	1	1	1	1

[1] Full references will be given in the report on these fertilising products which will be published on the Systemic website later this year.

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Agronomic aspects

The agronomic effectivity of struvite originating from waste waters has been tested and published in 80 peer reviewed articles. Not surprisingly, the effectivity of phosphorus and not nitrogen is tested. The main general findings are:

- Struvite acts as a slow release fertiliser (Ganrot et al, 2007, 2008). Acting as a slow release lowers the environmental risk of leaching and can contribute to a higher efficiency;
- Struvite has an equal effectivity for phosphorus compared with regular mineral phosphorus fertilisers (Johnston and Richards (2003), Römer (2006), Gell et al (2011) or even better (González-Ponce et al. (2009)).

Nitrogen in struvite is not determining its use/usefulness. The ratio N/P of 0.45 prevents the use of struvite as a nitrogen fertiliser. The use of struvite as a phosphorus fertiliser leads to sub-optimal use of nitrogen, thus nitrogen from other nutrient sources is needed. An application of 30 kg P/ha leads to an application of 13 kg NH_4-N/ha.

The effectivity of nitrogen as such has not been tested and thus nitrogen fertiliser replacement values are not available in the public domain or peer reviewed articles.

Environmental aspects

An effect of struvite formation during composting is that the ammonia volatilisation is reduced as reported by several peer reviewed articles (e.g. Wang and Zeng, 2018). Environmental performance of struvite was tested on their effects to prevent leaching of phosphorus. Few peer reviewed articles address nitrate accumulation in soil or nitrate leaching. Ammonium nitrogen in struvite is considered as an advantage as nitrification is needed before leaching can occur. Struvite formation is considered as a conservation of nitrogen. As an example, data of Rahman et al. (2011) on nitrogen leaching is given in Figure 1. Nitrogen leaching was measured in columns packed with soil. Losses by leaching were low, those for struvite were lower than for urea.

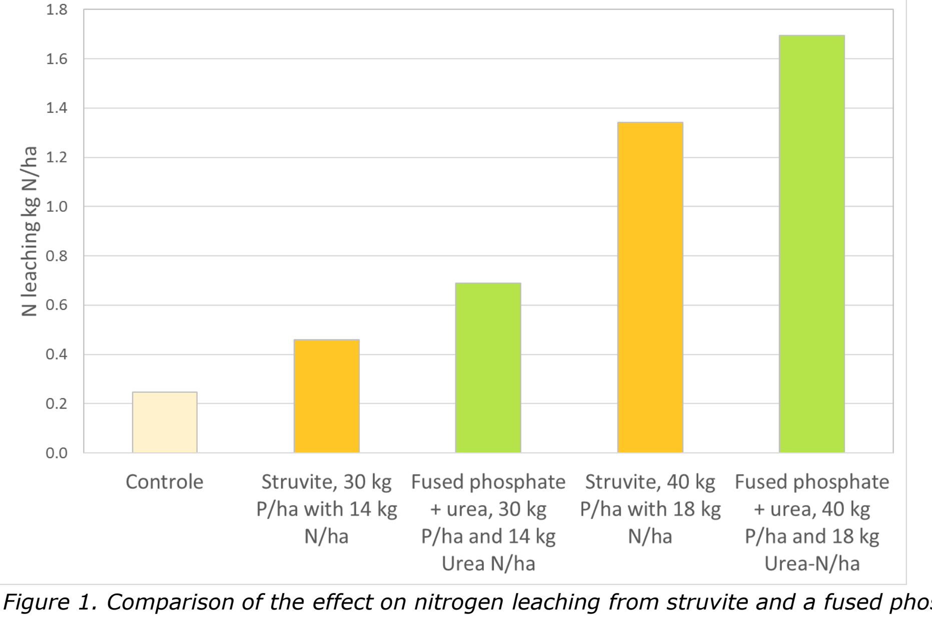

Figure 1. Comparison of the effect on nitrogen leaching from struvite and a fused phosphate fertiliser blended with urea for two phosphorus application rates leading to two nitrogen application rates (Rahmann et al, 2011).

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Current legal view on struvite

Relative to chemical fertilisers struvite has a similar agronomic effectivity as chemical phosphorus fertilisers. Relative to chemical nitrogen fertiliser several publications assume an similar effectivity but lack the data to support this assumption. This year JRC will publish the study on the end-of-waste criterions for precipitated P salts. It will then become clear if the agronomic or environmental effectivity of the ammoniacal-nitrogen is part of their recommendations for end-of-waste criterions.

Struvite recovered from waste waters or other waste streams is generally considered to be initially a waste, unless or until end-of-waste status is obtained. However, EU countries differ in the legal status they give to manure surplus. Some Member States designate manure surplus as a fertilising product, others a waste. Consequently, struvite based on animal manure is sometimes acknowledged as fertilising product and sometimes as waste. If an end-of waste status is reached for struvite from manure, its use as a fertilising product becomes possible within the framework of the new facultative European regulation on fertilising products.

Yet, although the chemical characteristics of struvites from waste water treatment plants and from processing manure are identical, their legal status is not. Manure is an animal by-product, and therefore struvite recovered from manure is classified as an animal by-product. Currently, it is not clear if an inclusion of struvite based on manure requires inclusion in CMC 11. In addition, struvite from animal manure is still regulated under article 2(g) of the Nitrates Directive. The Nitrates Directive defines this product as animal manure. Therefore the use of the product is treated with the same regulations as manure under the directive, and therefore has no financial value. In the Netherlands this situation has led to the closing of a full scale production plant. This is in contrast to struvite from waste water treatment plants which can be used as recovered phosphate salt. Struvite from designated production processes from processing waste water is acknowledged in some EU countries (e.g. UK), as regular mineral fertiliser.

Main reference

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