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Phosphorus recovery potential in Sofia WWTP in view of the national sludge management strategy

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ABSTRACT

In view of the vital importance of phosphorus and its increasing scarcity as a natural resource, phosphorus recovery has recently gained significant scientific and technical interest. The aim of this study is to support the implementation of the Bulgarian national sludge management strategy, particularly its objective to achieve more efficient resource management of phosphorus in waste water treatment plants (WWTPs). The study estimates the potential for phosphorus recovery from the municipal WWTP at Sofia, the largest in Bulgaria, serving some 14% of the Bulgarian population. The phosphorus content of five process streams (thickener supernatant, dewatering centrate, sludge before digestion, sludge after digestion and ash) is analysed on the basis of one year of measurements. It is estimated that 170–250 t phosphorus could be recovered annually from the WWTP from digested sludge or ash, depending on the phosphorus recovery technology used.

1. Introduction

Phosphorus is an essential element to life. It is widely used in agricultural fertilisers and industrial processes following mostly a “cradle to grave” mode. Demand for rock phosphate is such that there is a global threat of phosphorus scarcity. In 2014 rock phosphate was added to the European Commission list of Critical Raw Materials, having a substitutability index estimated at 0.98 (COM, 2014). This index is a measure of the difficulty in substituting the source, scored and weighted across all applications and has values between 0 and 1, with 1 being the least substitutable (4). Several authors note that “peak phosphorus” consumption is not far into the future. Cordell et al. (2009) estimate that this peak will occur between 2030 and 2040, after which demand will exceed supply. Other authors estimate that the available geological sources of phosphorus will be sufficient for 100–400 years consumption (Van Vuuren et al., 2010). The difference between these two prognoses comes from the fact that although available, future extractable natural phosphorus reserves will be of lower quality, with lower phosphorus content and greater concentrations of heavy metals such as cadmium and uranium (Schröder et al., 2010).

In view of its potential scarcity, increasing efforts are being made to use phosphorus efficiently, and where possible to recover it. Phosphorus recovery is the process of extracting phosphorus from waste streams and making it available for re-use. It is motivated by several environmental, economic and political factors. Fig. 1 gives an approximation to the fate of mined rock phosphorus, and can provide in indication of possible routes for phosphorus recovery.

The budget shown in Fig. 1 illustrates well that there are two major stages which could contribute to the mitigation of phosphorus scarcity:

1) Agricultural application: 90–95% of phosphorus production is used for agricultural purposes, of which only 20–25% reaches the human food chain. Modifications to agricultural practices have high potential for reducing phosphorus losses.
2) Sewage treatment: This is the only “end of pipe” stage where phosphorus is available in concentrated form for recovery. The total amount of phosphorus entering WWTPs is not negligible, comprising some 10% of phosphorus production.

The traditional means of re-using phosphorus from WWTPs is the direct application of sludge to fields as fertiliser. Although

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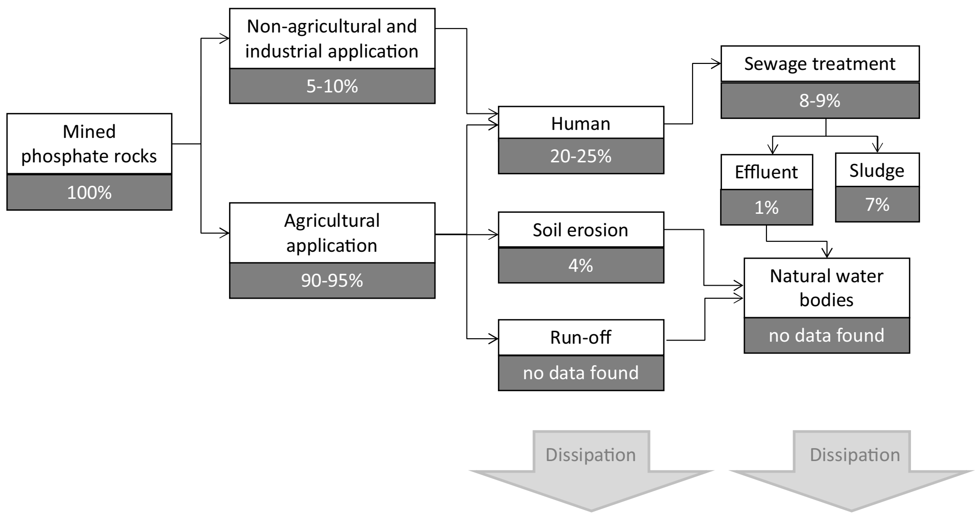

Fig. 1. A general phosphorus budget, based on literature data (inspired by Desmidt et al., 2015).
Note: Values in these figures were set as follows: Rock phosphate is set to 100% as a starting value. 90–95% agricultural application is after van Dijk et al. (2013) and Desmidt et al. (2015). Phosphorus which reaches human (food or household applications) is taken from Cordell et al. (2009), Schröder et al. (2010) and Rosemarin and Jensen (2013). The value for soil erosion and the phosphorus reaching WWTPs were calculated on the basis of figures given by Cordell et al. (2009). The proportional distribution in the WWTP between final effluent and sludge is taken from Desmidt et al. (2015).

this is still acceptable in some countries, many no longer allow the practice due to the threat of introducing micropollutants and heavy metals into the soil (Hospido et al., 2010). This restriction on disposal has in part motivated the development of phosphorus recovery technologies from WWTPs in recent decades, and currently some highly efficient technologies are being implemented (Egle et al., 2015). Phosphorus may be precipitated directly from the liquor (including thickener supernatant and dewatering centrate) in the form of struvite when using enhanced biological phosphorus removal (Egle et al., 2015; Sartorius et al., 2012). However, a higher yield of phosphorus is obtained by leaching from sewage sludge using mineral acids followed by precipitation as struvite. Phosphorus may also be recovered from sewage sludge ash, in this case by wet-chemical and thermo-chemical processes (Egle et al., 2015; Donatello and Cheeseman, 2013). All these technologies are based on physical-chemical processes and although applied in a number of WWTPs, they are not yet widely used. Installation costs remain high and, depending on the process, there may be a high consumption of chemicals. Alternative technologies aimed at reducing negative environmental impact and based on biological processes (for example, assimilation of phosphorus in green microalgae) have emerged recently, but have not yet been applied at a large scale (Perez et al., 2015).

NSP (2014)The National Sludge Management Strategy of Bulgaria for the period 2014–2020 aims at sustainable and reliable sludge management, in line with the corresponding EU and national legislative framework as well as with national economic and environmental objectives. The strategy considers three scenarios: realistic, optimistic and pessimistic. All three give prognoses of an increasing amount of sludge due both to the construction of new WWTPs and to the upgrading of old plants in accordance with the requirements of EU Directive 91/271. The realistic scenario forecasts the generation in Bulgaria of 124,500 t of dry substance (DS) per year in 2020. The scenarios for the potential of sludge utilisation and disposal routes estimated under the strategy are given in Table 1.

Currently the greatest individual component of the sludge generated (49%) is disposed of to landfills or is temporarily stored at WWTP sites (Table 1). Until very recently, landfill disposal was permitted but not adequately controlled. After implementation of the EU directives and national law, which do not allow such disposal, the water operators faced a number of difficulties in changing to new practices, including the production of unsuitable sludge, and long and burdensome procedures for obtaining permissions for use in agriculture. As a result sludge has been accumulating at some WWTP sites, waiting for a decision and actions.

In compliance with the legislative requirements for utilisation of bio-wastes, the strategy considers routes such as use in agriculture, re-cultivation, landfill remediation and co-combustion in cement kilns. The strategy does not provide particular solutions, but explains the overall philosophy, and the relative merits of each of these routes, paying particular attention to phosphorus recovery. The strategy concludes that the long-term target is ecologically friendly sludge utilisation, with enhanced renewable energy generation and phosphorus recovery. Our study aims to support the implementation of the strategy at the Sofia WWTP with respect

Table 1
"Realistic" scenario for the potential of sludge utilisation and disposal[a].

Disposal route	2010–2011	2018 scenario[b]	2020 scenario[b]
	% total sludge generation		
Use in agriculture	26	100	100
Re-cultivation	23	50	49
Landfill remediation	no data	10	8
Co-combustion in cement kilns	0	22	22
Co-combustion in power plants	0	0	36
Landfill disposal and temporary storage	49	–	–

[a] According to the National strategic plan for management of the sludge from municipal WWTPs in Bulgaria in the period 2014–2020.
[b] Estimated in the National strategic plan according to the prognoses for generated sludge, available fields and a combination of sludge management options.