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From wastewater to fertilisers — Technical overview and critical review of European legislation governing phosphorus recycling

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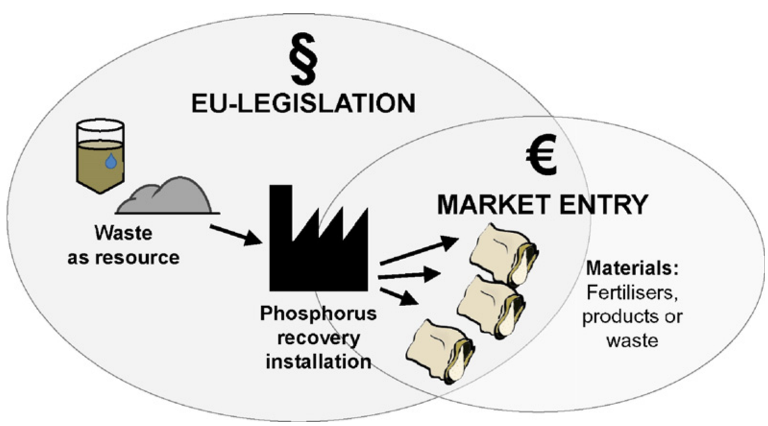
HIGHLIGHTS

- We examine EU-legislation affecting future P-recyclers: WWTPs, start-ups, industry.
- Meeting legal requirements is possible under extensive permit processes.
- Implementation of the legislation differs regionally and is not institutionalised.
- Active support for P-recycling is lacking.
- Clarification and harmonisation generate safer products and promote market access.

GRAPHICAL ABSTRACT



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ABSTRACT

The present paper is based on an analysis of the EU legislation regulating phosphorus recovery and recycling from wastewater stream, in particular as fertiliser. To recover phosphorus, operators need to deal with market regulations, health and environment protection laws. Often, several permits and lengthy authorisation processes for both installation (e.g. environmental impact assessment) and the recovered phosphorus (e.g. End-of-Waste, REACH) are required. Exemptions to certain registration processes for recoverers are in place but rarely applied. National solutions are often needed.

Emerging recovery and recycling sectors are affected by legislation in different ways: Wastewater treatment plants are obliged to remove phosphorus but may also recover it in low quantities for operational reasons. Permit processes allowing recovery and recycling operations next to water purification should thus be rationalised. In contrast, the fertiliser industry relies on legal quality requirements, ensuring their market reputation. For start-ups, raw-material sourcing and related legislation will be the key.

Phosphorus recycling is governed by fragmented decision-making in regional administrations. Active regulatory support, such as recycling obligation or subsidies, is lacking. Legislation harmonisation, inclusion of recycled phosphorus in existing fertiliser regulations and support of new operators would speed up market penetration of novel technologies, reduce phosphorus losses and safeguard European quality standards.

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1. Introduction

To balance the demands for increased self-sufficiency, increase crop yields and the associated increase in fertiliser consumption with limited resource availability, science and policy call for more sustainable phosphorus use (European Commission, 2013, 2011a; Scholz et al., 2015; Schröder et al., 2010; Science Communication Unit, 2013). Recovery and recycling of phosphorus from wastewater, a highly concentrated and partly unexploited phosphorus stream (Van Dijk et al. this issue; Binder et al. 2009), presents a significant step towards achieving sustainability (Koppelaar and Weikard, 2013). Several companies (cnp-Technology Water and Biosolids GmbH, 2015; Ecophos, 2015a; Ostara Nutrient Recovery Technologies Inc., 2015) and international research efforts (P-REX, 2015; RecoPhos, 2015) have made concerted efforts to this end.

In Europe, the number of technologies for phosphorus recovery from wastewater which are operating at either full or demonstration scale has increased from 2 in 1998 (Morse et al., 1998) to 22 in 2014 (Stemann et al., 2014). Eleven of these technologies were under evaluation in the P-REX demonstration project (2015). The struvite-crystallisation processes Pearl, AirPrex and NuReSys and a few others have been implemented at full scale. Others, such as ASH DEC, Leachphos and Ecophos have been demonstrated and are considered technically feasible (Herzel et al. this issue; Ewert et al. 2014; Stemann et al. 2014; Kabbe et al. 2015). Consequently, from a technical point of view, recovery of mineral phosphorus from wastewater could be implemented Europe-wide today. However studies on the different recovery technologies at regional, national and international scales show that challenges remain; large-scale Europe-wide implementation of recovery is not profitable in the current market (Cornel and Schaum, 2009; European Commission, 2013; Pinnekamp et al., 2011), poor plant availability could compromise recycling efforts (Binder et al., 2009; Kratz and Schnug, 2010) and the aims of those using or incinerating sludge today are not in line with recycling (Binder et al., 2009; Cornel and Schaum, 2009).

Furthermore, phosphate rock was listed as a critical raw material by the EU in May 2014 (European Commission, 2014), and it can thus be expected that recovery from wastewater and other renewable sources will gain importance. However policy alignment is a necessary step. The few regional actors active in the new phosphorus recovery sector have noticed that various aspects of phosphorus regulation, e.g. phosphorus as a resource in fertiliser production or as a pollutant in wastewater treatment, are often fragmented and contradictory. Barriers for phosphorus recovery and recycling can be observed, especially if current legislation is evaluated together with the constraints of the emerging recovery and recycling sectors (ERRS). Novel recycled phosphorus materials also need to adapt to a mature market with existing infrastructure and fertilisers.

Even though interest in Europe-wide implementation of recovery exists, no work so far has comprehensively summarised the laws affecting phosphorus recyclers on a European level. This paper gives an overview of European legislation governing technical phosphorus recovery and recycling and discusses these examples in the light of the ERRS. The aim of the study was to find out whether installations that recover and recycle phosphorus meet legal requirements when compared to conventional fertiliser producers. Similarly, challenges met when putting recovered phosphorus on the market (i.e. recycling it) were compared to fossil fertiliser marketing and conventional recycling of sewage sludge in agriculture.

2. Material and methods

In this study we reviewed European Union laws and directives governing the production, trading and use of recovered and recycled phosphorus. The legislation was analysed from the point of view of an EU-based recycler, manufacturer, importer or distributor and ERRS were identified for this purpose. The observed value chain begins at the waste water treatment plant (WWTP), includes one or more treatment steps and ends with a marketable material. The work was conducted within the European P-REX demonstration project, which focuses on sustainable sewage sludge management and phosphorus recovery. Laws of selected European nations (Spain, Czech Republic, Germany, Switzerland) were summarised within the P-REX project (Nättorp et al., 2014b). The reviewed legal texts are listed in the supporting information. The characterisation of the technologies and materials as well as the resulting recovery strategies are based on results of the P-REX demonstration project, literature research and expert opinions.

We focused on the use of phosphorus as a fertiliser, the largest market segment for phosphorus use in Europe and worldwide (Nättorp et al., 2014a). We chose the laws to be reviewed based on the experience of the stakeholders currently recovering phosphorus or planning to do so, stakeholders present in the P-REX consortium (P-REX, 2013) and an expert advisory board.

3. Terminology

The work in this paper concentrates on phosphorus recovery and recycling technologies from wastewater and sewage sludge ash (SSA), which aim to recover phosphorus in mineral form. This "technical phosphorus recycling" contrasts with "conventional phosphorus recycling" i.e. phosphorus recycling in organic form: application of sewage sludge in agriculture or for composting. Recovery processes precede recycling and create intermediates, so-called "recyclates". The difference between recycled "products" and "waste" is defined by the legally binding material status according to the Waste Framework Directive (WFD, Dir. 2008/98/EC (European Parliament, 2008a)). "Material" is used as an overarching term for recovered or recycled mineral phosphorus. The processes typically include both recovery and recycling, with no clearly definable intermediates. Further, the "recyclate", "recycled material" and "recycled product" can all be physically identical and can all have a market value (Fig. 1).

4. Results and discussion

4.1. Emerging recovery and recycling sectors

Phosphorus recycling from wastewater can be achieved through three main paths: 1) technical recycling from sewage sludge or sludge water, 2) technical recycling from ashes of mono-incinerated sewage sludge, or 3) conventional recycling through direct application of properly treated sludge in agriculture (Fig. 1). Schoumans et al. (2015) gives an overview of the options and illustrates practical examples of technical recovery, while the P-REX Technical factsheets (Kabbe et al., 2015) present the technical details of 8 advanced technologies.

Three ERRS, municipal WWTPs, start-ups and the fertiliser industry were identified. Their strategies differ due to their current market position, main obligations and options for material sourcing (Table 1).

Currently, phosphorus is recovered mostly by struvite precipitation at the WWTP, as part of the wastewater treatment process (first ERRS). WWTPs are characterised by direct access to P-rich waste for recycling purposes, but they are ultimately limited by the obligations of wastewater treatment according to EU regulations (e.g. phosphorus removal efficiencies (Art. 5 Urban Waste Water Treatment Directive)). Approximately 2000 tonnes P/year is technically recovered from municipal WWTPs today in Europe (Kabbe, 2015; Kabbe et al., 2015). However, this amount remains negligible in comparison to hundreds of thousands of tonnes of fossil phosphorus which are used as fertiliser annually in the EU-27 (Eurostat, 2012).

Several other processes recovering phosphorus from SSA or sludge have been tested on a pilot or full scale. They produce a broader variety of materials such as calcium phosphates, iron phosphates, slag, mixtures