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Natural rock phosphate: a sustainable solution for phosphorous removal from wastewater

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Abstract

In application of the European Water Framework directive aiming to achieve a "good ecological status" for all waters, phosphorous removal from domestic wastewater can be of importance before discharging into natural receiving bodies, especially for small communities localized upstream of catchment areas or in zones sensitive to eutrophication.
As rural communities in France often choose to treat their wastewater with extensive treatment systems such as constructed wetlands, because these natural processes are easy to operate, equivalent P-removal technologies have been asked for. Research has therefore focused on adsorption or precipitation mechanisms on specific reactive materials. In this context, recent studies undertaken by Irstea (French public research institute, formerly Cemagref) in collaboration with SINT and Epur Nature have shown the interest of natural rock phosphate (apatite) as an efficient and sustainable solution for phosphorous removal from wastewater.
Epur Nature (Syntea group) has recently developed and patented a specific filter configuration filled with apatite pellets for high phosphorous removal efficiencies (P outflow concentrations < 2 mg P/L). The mechanisms and key factors for an optimal treatment (apatite quality, particle size, kinetics) are explained and synthetized in the paper. The results from lab scale columns and first results rom full scale wastewater treatment plants in operation since several years are also presented.
Finally the possible reuse of the apatite enriched with P from wastewater after 10 to 20 years of operation will be discussed.

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1. Introduction

As an essential nutrient growth for biomass, the intensive use of phosphates (detergent, food, agricultural use,...) has resulted in an increased P concentration level in surface water and consequently has led to eutrophication problems. Nevertheless, despite a reduction of P per capita (2.2 g/people equivalent/d in France) and in application of the European Water Framework directive aiming to achieve a "good ecological status" for all waters, P removal for wastewater treatment plant is steel needed in sensitive areas.

Rural communities in France often choose to treat their wastewater with extensive treatment systems such as vertical flow constructed wetlands (to date more than 3,500 VFCW in France), because these natural systems offer reliable removal efficiencies for low maintenance [1]. However, they don't ensure reliable P removal as i) plant uptake (between 0.1 - 0.4 g/m²/d) is negligible compared to the aerial P load applied [2], ii) bacterial uptake (and storage) is not suitable because the bacteria die off and will release the P and iii) adsorption/precipitation onto media/organic matter is not effective on the long term because of its mineralization that occurs in VFCW.

Since two decades, researchers have tried to improve reliable P retention in constructed wetlands by i) including chemical P precipation [3,4] which increases the complexity of the maintenance and ii) using specific materials that promote sorption and precipitation mechanisms [5,6].

Among the various materials that have been tested (steel slag, calcareous materials, iron/aluminium hydroxides materials) natural rock phosphate containing apatites ($Ca_5(PO_4)_3OH,F,Cl$) have shown the best results for this kind of application [7,8,9]. Recent research [7] has shown that this material allows to reach high saturation level (> 14 mgP/g apatite) and low outlet P concentration (<1 mg P/L).

Nevertheless the P removal and the hydraulic efficiency in such filters filled with natural rock phosphate are correlated to the nature and the kind of apatite in term of mineral composition and particle size distribution, for an optimal operation paired with constructed wetlands.

This paper aims to review the main research done on the key parameters influencing the efficiency of P-removal with apatites, the design and implementation of a P removal filter and to present the actual development of this process in France.

At first, the next chapter aims to give a general overview of wastewater treatment with constructed wetlands as P retention filters development is mainly associated to them.

2. Constructed wetlands

Since the 1950s treatment wetlands for wastewater treatment have been developed and appear nowadays as a reliable, effective and feasible solution in the field of wastewater treatment [10]. Among the different constructed wetlands (CWs) systems treating domestic wastewater, a two stage vertical flow (VF) CW is the most common design developed in France since the 1980s [11]. The originality of this 'French System' is that it accepts raw sewage directly onto the first stage and treats the primary sludge on the surface of the first stage beds. This greatly facilitates sludge management as compared to systems which need to deal with primary sludge.

The use of this system, developed by the CEMAGREF (now IRSTEA) in the early 1980's [12], really took off when it was developed by SINT in the 1990's under the brand name Phragmifilter® (figure 1). Indeed, if we add to the easier sludge management the good performances obtained for SS, COD and nitrification [1] and the low operating costs, it is easy to understand the choice that small communities (less than 5 000 PE) in France have made and are still making. "French systems" have also been recently built in Switzerland, Germany, Belgium, Spain, Portugal, Italy and several other countries, but they have not yet achieved the "Number 1" position. This technology is the most popular system for treating waste water streams from rural communities in France.

An estimated 3000 CWs treating raw sewage exist today in France, for capacities of 20 to 6 000 population equivalent (pe.). Roughly a third of these plants (around 900) have been designed, or designed and built by SINT or Epur Nature or companies associated with them.