Chapter 1

Introductory Chapter: The Overview of Phosphorous Recovery

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http://dx.doi.org/10.5772/intechopen.85967

1. Introduction

Phosphorus (P) is a finite, non-substitutable, non-renewable, and geographically restricted resource. Substantial interest in P availability was sparked [1]. Some researchers demonstrated sufficient availability to sustain production beyond the twenty-first century, or a maximum occurring late twenty-first century [2–4]. But there are no financial incentives to support mineral resource inspections worldwide without the exploitation of phosphate deposits. The anthropogenic influences on this critical resource are likely to bring about a number of challenges to P sustainability. Advances in technology, public health, and food production over the last couple of centuries have fundamentally interrupted the natural global P cycle. Phosphate deposits have been mined to supply human production, which generated a mostly one-way flow of P from mines to farms to surface waters, ultimately impairing freshwater and coastal waters environment and function [5]. Rapid increases in human population and the subsequent need for high agricultural productivity have led to substantial increases in fertilizer use [6]. The P used as fertilizer consumes more than 80% of the P resources [7]. P is simultaneously an important non-renewable agricultural nutrient and an environmental pollutant [8].

The use of P resources in different countries or regions is different. But the basic P flow is as follows: phosphates are extracted from phosphate rock, passing through crops, animals and human, and ending up in landfill or emission into rivers and the sea (if sewage or animal wastes are not adequately treated) (**Figure 1**). The P cycle is extremely inefficient and wasteful. P loss from wastewater into natural water bodies accounts for about 10% of inorganic P source fertilizers in arable soils globally [9]. Eutrophication is the consequence of human behavior changing the natural P cycle. Researchers and practitioners in multiple fields have responded with numerous strategies to reduce P loading to aquatic ecosystems in an era of eutrophication control [10]. P has become the principal contributor and limiting factor to water eutrophication.

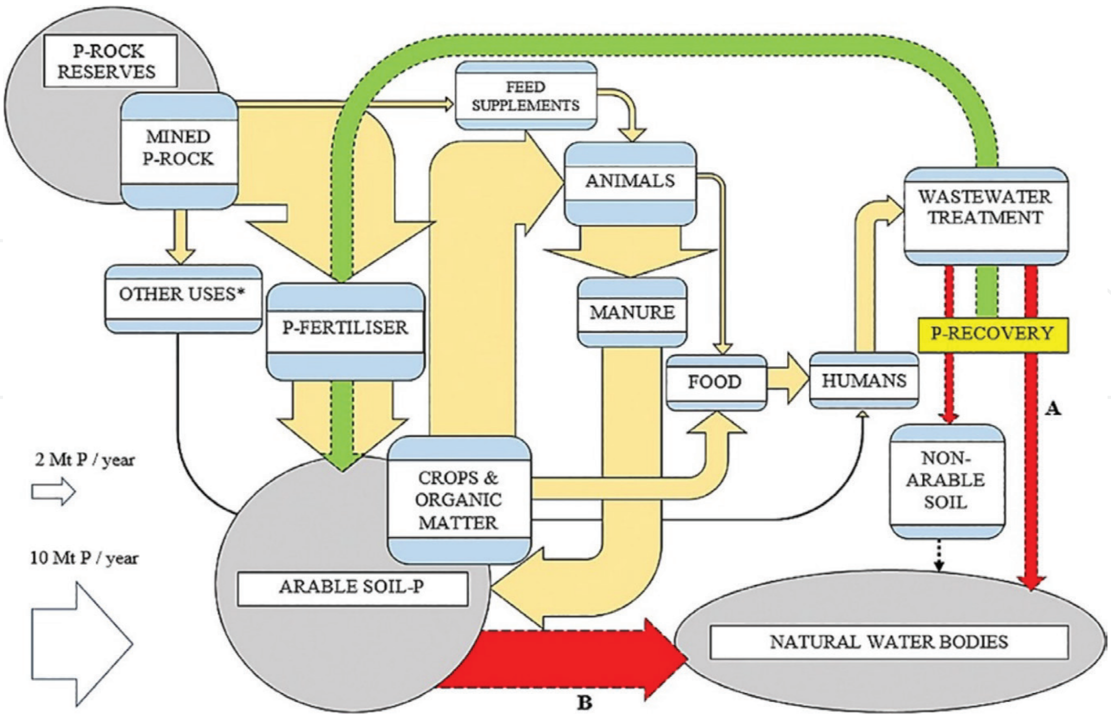

Figure 1. Diagram of key global P flows (the widths of the arrows semiquantitatively represents figures reported by Cordell [1] in million tons (Mt) of P per year Point "A" denotes the flow of P contained in treated or untreated sewage to natural water bodies and represents approximately 1.5 Mt P/year. Point "B" denotes the flow of P contained in erosion losses and is about 8 Mt P/year. *Other uses include industrial uses such as the production of some detergents) [9].

P, as a resource in fertilizer production or as a pollutant in wastewater treatment, is often simultaneous. The removed P has the potential to be reused as a substitute for mined P fertilizer [11]. With different fractions of P in different water or waste, direct use as fertilizer could not be the sustainable and efficient way and an increasing number of physical, chemical, or biological methods with various functions were designed to recover and reuse available P in the past few years: struvite crystallization, P adsorption, anaerobic digestion, membrane concentration technology, and integration technologies. Most of the P recovery processes are developed to be applied on industrial and municipal wastewater and only a few techniques are developed for P recovery from manure and digestate [12]. More sustainable techniques, such as P recovery techniques for both solid and liquid wastes, are important to maintain the P cycle in modern human society. Sustainable P use has been largely driven by pollution concerns and the shortage of P resources over the past few decades, which P will need to be recovered for productive reuse as a fertilizer to replace increasingly scarce P resource. But for P recycling and reusing, technological advances alone are not enough. There is no single solution to achieving a P-secure future. Partnerships and strategic frameworks to stimulate and support the development of renewable P is an urgent need to establish.

Acknowledgements

The work was supported by a grant from the National Key Technology Research and Development Program of China (Nos. 2017YFD0800202 and 2016YFD0501404-6).

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