Chapter 3
Systems Based on Physical–Chemical Processes:
Nutrient Recovery for Cycle Closure

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ABSTRACT

High strength waste streams, namely rejected water from a wastewater treatment plant, livestock slurry, and agro-food wastewater, are characterized by its high organic matter and nutrient content which favours processes aiming to recover energy and nutrients, instead of removing them. In this regard physical-chemical processes are suitable technologies to attain these objectives. Among others, stripping coupled with absorption, struvite precipitation, membrane separation, and vacuum evaporation, are all physical-chemical processes aiming to concentrate nutrients in a stream that can later be reused as fertilizer. In this chapter the main physical-chemical processes will be defined and described in terms of the objective of each process technique, their theoretical fundamentals, environmental effects (air, water and soil emissions, resource depletion), technical indicators (efficiencies, energy consumption, etc.), and by-product characteristics.

INTRODUCTION

An increasing food demand and the sharpening of agricultural detrimental effects on the environment raise urgent technological challenges. The inadequate nutrient supply, mainly nitrogen (N) and phosphorous (P), that characterizes agricultural practices in most developing countries, lead to soil quality depletion, water bodies and atmosphere pollution (Vitousek et al., 2009; Galloway et al., 2003).

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On the other side, up to about 2-3% of the global energy consumption is ascribed to energy intensive fertilizer production processes (EU-BAT, 2006), with nitrogen fertilizers accounting for about 70% of it (Ramírez and Worrel, 2006). Almost all nitrogen fertilizers are synthesized from ammonia and around 80% of the world production capacity, estimated to be 109 Tg in 2003, is used for this purpose (EU-BAT, 2006). Direct energy requirements for the production of one Mg (tonne) of ammonia are between 40-45 GJ (Ahlgren et al., 2008) with an average cost of 100$ (Erisman et al., 2008). Moreover, fossil fuel use, mainly natural gas, is reported to represent 70-90% of these costs, thus exposing fertilizers and, indirectly, food sectors to international energy price fluctuations and instabilities (EIA, 2009).

Phosphorous, in its turn, is a mining resource with a very limited predicted lifetime; it is said that within the next 100 years it will be completed depleted (Zhang et al., 2015). This fact makes P a geo-strategic resource for most countries. Moreover, P recovery technologies and the subsequent marketing of phosphorous-rich solid products could have important positive environmental implications, as a replacement of inorganic-based P in the fertilizer industry would generate a global warming potential offset via reductions in climate emissions from P mining and production.

Management and technological solutions leading to an increase in nutrient use, and recycling efficiencies within agro-ecosystems, are receiving a renewed interest for their significant potential contribution in reducing fertilizer inputs and nutrient losses. Nevertheless, a development towards bio-base and circular economies is dependent on a more cost-effective nutrient recycling technologies from waste streams.

In this sense, both the quality and marketability of those end and by-products are relevant issues which could contribute to this economic balance. By-products from processing wastewater technologies (namely struvite, ammonia water, concentrates, etc.) are relatively new on the market, and legislations applicable to them are not always clear. Some products are not yet included and market operators are in doubt about their classification and requirements. Furthermore, due to associated logistic challenges, they have a considerably lower market price, even if also linked to market prices for mineral fertilisers (Foged et al., 2011). Besides this, end users are not always sure about the fertilization characteristics and harmlessness of these products; in this sense a lot of information is still missing.

In this chapter the main physical-chemical processes (Table 1) will be defined and described in terms of objectives of the technique, theoretical fundamentals, environmental effects (air, water and soil emissions, resources depletion, etc.), technical indicators (efficiencies, energy consumptions, etc.), side stream and by-products characteristics and destiny/use, etc. A detailed scheme of each technology and specificities for each waste stream application will also be presented.

MECHANICAL SEPARATION TECHNOLOGIES

Mechanical separation can be an effective technique to remove solids from a (semi) liquid stream obtaining a liquid fraction containing soluble components such as mineral nitrogen (N), potassium (K) and other ions, and a solid nutrient-rich fraction containing the majority of the organic matter, including a significant proportion of phosphorus (P) (Jorgensen and Stoumann, 2009). Decanting by gravity or natural settling is usually used to easily obtain these two fractions. However, the long times and large spaces required, makes this technology not always feasible. A quicker separation can be obtained using mechanical separators which are able to reach, at the same time, high removal efficiencies and a thick stream with high dry matter and most of the nutrients.

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