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Nutrient and energy recovery from sewage: An integrated approach

A completed Water Research Commission (WRC) study explored phosphate recovery possibilities from wastewater, relative to its potential South African market and developments in wastewater treatment.

Background

The transition to a low-carbon and resource-efficient economy has begun, also in South Africa. Wastewater is increasingly viewed as a 'water-carried waste', presenting opportunities for recovery of nutrients and energy, as well as water.

Ecologically and economically more sustainable sanitation and wastewater management solutions are being explored and implemented. Among the sewage-borne resources, phosphorus is an important, non-substitutable nutrient for all life forms, particularly in the growth of plants, and is therefore essential in ensuring universal food security.

Human activities have disturbed the natural phosphorous cycle and remain heavily dependent on mining of non-renewable rock phosphate. As a result, there is a particular interest in phosphorous recovery.

This WRC-project explored phosphate recovery possibilities from wastewater, relative to its potential South African market and developments in wastewater treatment. It is structured to address the following aims:

- Investigate available nutrient recovery technologies and their products, focusing on phosphate;
- Describe a number of cases that have adopted nutrient recovery and assess these from a sustainable perspective;
- Investigate the characteristics of recoverable fertiliser products and obtain viewpoints of experts along the fertilizer-produce value chain on likely social acceptance;
- Present and analyse two cases of how a nutrient recovery process could be incorporated together with energy recovery via anaerobic digestion.

Technology review

Within nutrient removal wastewater treatment works (WWTWs) some 40% of the phosphorous load reports to the sewage sludge and another 55% may have to be removed in tertiary treatment. The main points of recovery from wastewater treatment systems include:

- Liquid phase: secondary effluent, anaerobic digestion side stream, sludge liquor or source-separated urine;
- Solid phase: sludge, digested sludge, sludge ash.

For liquid phase extraction, a minimum concentration of 50-60 mg/L of orthophosphates is required for economically feasible recovery. Source separated urine contains 300-570 mg/L and together with sludge liquor and the anaerobic digestion (AD) side streams (20-100 mg/L) makes up the liquid streams that are economically feasible for phosphate recovery.

Of all nutrient extraction techniques, industrial crystallisation technologies are common due to their ability to produce high purity, water-free and marketable final products, namely Struvite and Calcium Phosphates. Crystallisation methods typically achieve a recovery of >90% and an effluent phosphate concentration of 0.3-1 mg/L and are often located at WWTWs with anaerobic digesters.

The most efficient phosphorus removal methods would involve the use of both chemical and biological methods simultaneously to reach levels between 0.5 and 1 mg/L. However, to meet phosphorous levels less than 0.1 mg/L (required to avoid eutrophication in receiving wetlands), additional tertiary treatment is required.

Case studies

Three industrial scale installations and one community-scale pilot project were investigated. These case studies illustrated crystallisation and wet chemical phosphate recovery processes, producing struvite for fertilizer use.

The Ostara Pearl®, Multiform Harvest and the Seaborne processes are centralised and are located at WWTWs with anaerobic digester units, treating the anaerobic digestion sludge liquor and sewage sludge, respectively.

The Nepal struvite precipitation of source-separated urine project (STUN) was a decentralised attempt at phosphate recovery at community scale, with potential relevance to the situation in peri-urban eThekweni where 85 000 urine diversion toilets have been installed. The two competing struvite production processes installed at WWTWs in the US appear to be both fully operational and economically sound, addressing a technical plant problem in a way that saves costs for tertiary phosphate removal at the end of the process.

Products, markets and acceptance

Struvite is reported to be a good slow release phosphate fertilizer derived from human waste, which may replace rock phosphate derived fertilizers. Despite health and safety concerns, it is likely that struvite will pass toxicity, pathogen and metal content regulation and be comparable to most phosphate fertilizers on the market.

Expert interviews revealed that health and safety was the universal concern of most stakeholders, over and above fertilizer quality and quantity. To date, there are no South African policies or organic agriculture or certification.

Although most stakeholders recognised the importance of phosphate recycling in tackling food security and achieving sustainable water and nutrient cycles, it is believed by industry experts that the South African organic markets and its consumer appear not ready for fertilizers produced by human waste.

More feasible markets may lie within ornamental plant fertilization, commercial fertilizer production and fertilizer use within closed community gardens. Therefore, there is potentially a larger market for lower grade struvite.

Feasibility of nutrient and energy recovery as part of urban infrastructure

The potential for recovery of energy and nutrients was investigated through two techno-economic prefeasibility studies:

- Of three means of achieving of achieving phosphate discharge limits at a large centralised wastewater treatment plant in Cape Town and
- Of a conceptual design for energy and nutrient recovery plants in Cape Town's Foreshore precinct on the site of the current pump station directing sewage to ocean outfall.

The first assessment shows that production of low-grade struvite would have lower lifecycle costs than either chemical precipitation (yielding an additional waste) or high-grade struvite production, and would thus be the most cost-effective way of lowering phosphate discharge levels of an established large WWTW with existing AD plant to within regulated limits.

The second assessment shows that diverting half of the urine from commercial building male urinals could produce around 75 kg/d of dried struvite fertilizer. The co-digestion of primary sludge from the Foreshore wastewater with 10% of the available food waste generated in the Foreshore could result in an electrical surplus of 27 kW to be fed to the grid.

Over a 20 years forecast period, the times the costs incurred by the existing scheme (wastewater to ocean outfall and food waste to landfill). The additional labour and maintenance requirements (and costs) associated with new treatment infrastructure makes the recovery of nutrients and energy unattractive when compared against the existing cheap yet increasingly unacceptable disposal schemes – but they appear to be within the cost envelope for more standard sewage treatment.

The project demonstrated that technologies for phosphate recovery from waterborne wastes have reached the state of early full-scale use at reasonable cost, if fed from well-selected sources. Crystallisation-based technologies, to produce struvite, a potentially marketable phosphate fertilizer, are central in this regard, and often draw from side streams of anaerobic digesters, thus providing link to energy recovery.

The South African fertilizer markets are immature for phosphates from wastewater sources, least of all the organic production route, which might well bar them, but other market segments may not have any significant concerns. A concept design and pre-feasibility cost estimation for a retrofit to lower phosphate discharge levels of a large WWTW to within regulated limits showed that production of low-grade struvite would have lower lifecycle costs than either chemical precipitation (yielding an additional waste) or high-grade struvite production.

A second pre-feasibility study considered nutrient and energy recovery at the central city precinct scale and estimated them to be four times more expensive than outmoded disposal options, but well within the cost envelope for standard treatment.

Further reading:

To obtain the report, *Nutrient and energy recovery from sewage: Towards an integrated approach* (WRC Report No: TT 661/16) contact Publications at Tel: (012) 761-9300 or Visit: www.wrc.org.za to download a free copy.