Nutrient and energy recovery from sewage

November 2016

A newly-completed Water Research Commission (WRC) study has investigated the potential for South Africa to adopt nutrient recovery technologies.

The transition to a low-carbon and resource-efficient economy has begun. Wastewater is increasingly being 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, phosphorous 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 firstly explored phosphate recovery possibilities from wastewater, relative to its potential South African market and developments in wastewater treatment.

Technology review

Within nutrient removal wastewater treatment works (WWTW), 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.

The most efficient phosphorous 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 water bodies), 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 fertiliser 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 eThekwini where 85 000 urine diversion toilets have been installed.

The two competing struvite production processes installed at wastewater treatment works in the United States appear to both be 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 fertiliser derived from human waste, which may replace rock phosphate derived fertilisers. Despite health and safety concerns it is likely that struvite will pass toxicity, pathogen and metal content regulation and be comparable to most phosphate fertilisers on the market.

Expert interviews revealed that health and safety was the universal concern of most stakeholders, over and above fertiliser quality and quantity. To date, there are no South African policies on 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 fertilisers produced from human waste. Most feasible markets may lie within ornamental plant fertilisation, commercial fertiliser production and fertiliser 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. 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 wastewater treatment works 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 fertiliser. 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-year forecast period, the additional operating costs incurred by the existing scheme would result in a net cost more than four 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.

Conclusion and outlook

This project demonstrated that technologies for phosphate recovery from waterborne wastes have reached the stage 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 sidestreams of anaerobic digesters, thus providing links to energy recovery.

The South African fertiliser 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 wastewater treatment works 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 dispersal options but well within the cost envelope for standard treatment.

The research team concluded that the project to develop a technology innovation for further reducing reactor costs for struvite precipitation was on a sound footing. This investigation has identified the minimum feed concentrations for which the innovation should cater as 50 mg/L but has also shown that there remains a big opportunity for crystallisation technologies to achieve the 0.1 mg/L effluent standard, as secondary treatment effluent still carries the majority of the phosphate load.

An essence report was produced, aimed to be a resource for infrastructure designers and decision-makers. There is also an extensive technical report mirroring the essence report structure available in electronic format.

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; Fax: (012) 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.