IEA Bioenergy

Workshop Report

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Nutrient recovery from waste

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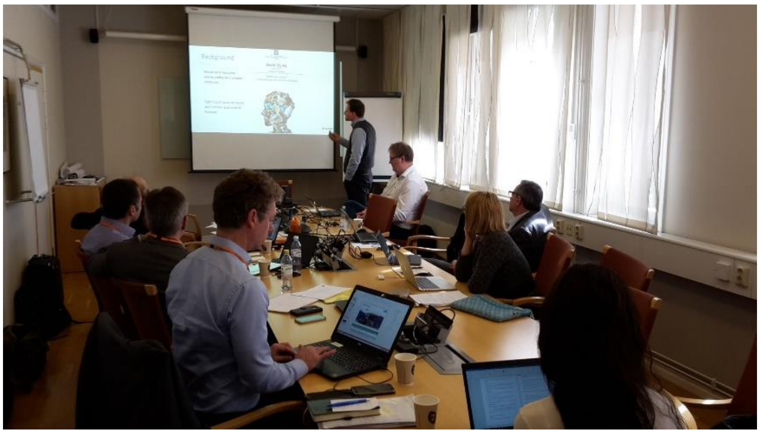
Summary

There is increased focus on nutrients in waste streams that are lost through linear use and/or waste treatments. Recovery of nutrients from waste allows to reduce the need of extracting nutrient resources while diversifying the markets. The case of phosphorus has been in focus in Europe for a few years now. Phosphorus is used in the formulation of chemical fertilizers. It is generally mined from phosphate rock, but **phosphorus can also be recycled from food/organic waste fractions in municipal solid waste or from sewage sludge**. Nutrient recovery technologies cover traditional methods such as composting to recently new developed technologies for recovering of (primarily) phosphorus. Some of these technologies are connected to thermal treatment of the waste.

This workshop aimed to provide an overview of the status of the nutrient recovery from waste (particularly phosphorus) covering technological, legislative and socio-economic aspects around the world, with emphasis on the countries participating in IEA Bioenergy Task 36[1]. The workshop was arranged by IEA Bioenergy Task 36 at the RISE office in Drottning Kristinas väg in Stockholm. The presentations are available on the Task 36 website: IEA Bioenergy Task 36 Workshop on Nutrient recovery, Stockholm, May 7 - Task 36



[1] IEA Bioenergy Task 36 focuses on Material and Energy valorisation of waste in a Circular Economy. Australia, Germany, Italy, Norway, South Africa, Sweden and the United States are currently participating in this Task.

Current situation

Phosphorus is a scarce resource that is used in the formulation of chemical fertilizers. It is unevenly distributed globally, with up to 70 % of the reserves located in Morocco. The price has fluctuated over the years reaching a peak in 2008. Since 2014, phosphate rock is on the EU list of critical raw materials. Phosphorus is a slow release nutrient and therefore only needs to be added on average every 5 years, compared to nitrogen and potassium that need to be added every year.

Apart from being mined from phosphate rock, phosphorus can also be found in large amounts in three types of waste streams: manure, food waste and sewage sludge. Recycling and/or recovery of phosphorus from these waste streams would reduce the need of mining phosphorus, close the nutrient cycle and create a market less dependent on some specific countries while having a better control on the prices.

The two main processes for phosphorus recovery from food waste are based on recycling as: (i) compost: simple and affordable technology, but a low value product is obtained, and (ii) digestate: more complicated process than composting, but a more usable fertilising product (digestate) is obtained, and biogas is also obtained as an valuable output.

Phosphorus can also be recycled within wastewater treatment plants (WWTP) in the treatment process, mainly as struvite. But it could also be recycled further downstream starting with the dewatered sewage sludge. In this case mainly thermal processes such as incineration or pyrolysis are used. The recycling potential varies between 25 % and 95%, depending if phosphorus is recycled within the WWTP or by a thermal process respectively.

It is noteworthy that the cost to recycle phosphorus from dewatered sludge is expected to increase from 20–70 €/ton (which is the cost when dewatered sludge is directly applied on agricultural land) to 100–150 €/ton (if a thermal process will be used). Unfortunately, it is difficult to solve all problems regarding phosphorus recovery from sewage sludge, and therefore some problems such as side streams with high levels of heavy metals, carbon loss due to incineration, or difficulties to sell the recycled phosphorus on a conservative agricultural market need to be solved. The most viable recovery route of phosphorus from sewage sludge in Europe right now is recovery from phosphorus ash: Ash2Phos (based in Sweden), TetraPhos (based in Germany) and Phos4Life (based in Switzerland).

Status of nutrient recovery from waste around the world

AUSTRALIA

Thermal waste to energy (WtE) in Australia is immature, without large-scale facilities, so nutrient recovery from WtE residues is not an area of high activity. Nutrient recovery in Australia is emerging as a medium-to-long term strategic priority, mainly driven by a need to solve the environmental problems caused by nutrients, along with ongoing waste project development. While there are no thermal WtE plants in Australia, there is some combustion residue experience, primarily with coal ash. This material is not used as fertilizer or as a good source of nutrients, and it has limited industrial application outside of construction. Biochars with agricultural applications as a soil ameliorant that improves solid performance is an area of interest in Australia at this moment. Recovery of phosphorus in the form of struvite from wastewater treatment is emerging. There are some on-going research projects on the conversion of biosolids to energy, which offers the opportunity to include nutrient recovery at the technology development stage.

CANADA

Sewage sludge in Canada is spread on farmlands according to the Non-Agricultural Source Material (NASM) quality control system, but an important part is also incinerated. Phosphorus is mainly recycled through struvite production.

DENMARK

Approximately 75% of the sewage sludge in Denmark goes to farmland. However, some phosphorus is recovered and extracted in the form of struvite from WWTP. There is also incineration of dewatered sewage sludge around Copenhagen. The incineration ash is temporarily stored in a special landfill (phosphorus bank) waiting for phosphorus extraction technologies to be developed.

FINLAND

Most of the sewage sludge in Finland is spread on farmland and no incineration takes place. Finland has the only phosphorus mine in Europe. From 2017, Finland has started a specific program with the aim of becoming frontrunner in nutrient recycling. There are several ongoing projects on this topic, with 'RAVITA' being one of the largest (aim: nutrient recycling from wastewater)

GERMANY

Despite being an important source of phosphorus (2–55 g P_2O_5/kg dry matter), sewage sludge is manly co-incinerated in Germany. In January 2018, regulation regarding phosphorus recycling from sewage sludge came into force. It stipulates that a certain amount of phosphorus should be recycled from the sewage sludge or the sewage sludge ash. The regulation should be fulfilled by 2029 or 2032, related to the size of the WWTP. A number of mono-fraction incineration facilities are now under construction in the country in order to fulfil the requirements set by the new regulation.

ITALY

Recovery of phosphorus is not in focus in Italy. Due to the low influent phosphorus concentration in the Italian WWT plants, almost no WWTPs in Italy operate with biological phosphorus removal. In addition, the use of iron and aluminium salts for chemical precipitation of phosphorus makes it a challenge to extract phosphorus from ashes. The difference in price between recovery and mining phosphorus (2–3 €/kg P recovered versus 1–1.5 €/kg P), points out the need of incentive actions to develop a recovery phosphorus market. The 'SMART–Plant' project aims at automatization of 7 pilot systems for optimizing nutrient recovery, minimize energy production and decrease greenhouse emissions.

NORWAY

There is a significant focus on circular economy in Norway, including awareness regarding the potential for better utilisation of phosphorus, a limited resource that poses challenges concerning security of supply. Phosphorus is also an environmental concern due to runoff to water. Norway has an excess of phosphorus, also if the import of phosphorus for mineral fertiliser is excluded. The challenge is to make better use of Norway's phosphorus resources despite their uneven regional distribution within the country. There is a need to redistribute phosphorus from the West of Norway to areas in demand of phosphorus in the East of Norway. Available organic P resources are generally not optimally utilised, for several different reasons (economy, logistics, etc.). Furthermore, the plant uptake of P depends on the P carrier and the balance between nutrients (P, N, K, Ca) that should be taken care of. Regarding P in mineral form, its recovery from waste streams is costly. In general, more action is needed to better utilise P in waste streams to reduce the dependence on mineral fertilisers. One option is to use biochar as a substrate for nutrients.

SOUTH AFRICA

South Africa has no strategy or future plans for extracting phosphorus from waste, but for valorisation and integration of food waste into the waste management system. One of the main constraints is that technology and research approach used in developed countries cannot be applied in countries such as South Africa. Conversion of food waste into biochar or the use of crops for anaerobic digestion have recently gained interest in the country.

SWEDEN

Phosphorus is recycled to some extent from manure, food waste and sewage sludge. Spreading of manure on farmland is regulated by the Swedish Board of Agriculture. Sweden has set a national goal to treat 50% of the food waste biologically by 2020. The main products obtained from the digestion of food waste are a biological fertilizer ("biogödsel") and biogas. There has been a debate over the last 30 years about the use of sewage sludge. Revaq (a certification system owned by an association of the water- and sewage water companies in Sweden) certifies wastewater treatment plants in Sweden for improved quality sewage sludge and therefore of the nutrients recovered.

SWITZERLAND

The distribution of sewage sludge on farmland is forbidden in Switzerland since 2006 and, therefore, it is instead incinerated as a mono fraction, co-incinerated with waste or in cement incineration plants. Despite there are no phosphorus recycling activities going on, there is a high interest from recovering phosphorus from incineration ashes.

THE NETHERLANDS

Almost all the sewage sludge is incinerated in The Netherlands. However, there is an interest to extract phosphorus from ash, and there are also around 10 WWTP with phosphorus extraction.

UNITED KINGDOM

Most of the sewage sludge is spread on farmland and follow what is called The Biosolid Assurance Scheme (BAS), a quality assurance scheme for sludge treatment and its subsequence recycling as nutrients to agricultural land. Apart from this, there is no other phosphorus recycling strategies in the country.

UNITED STATES

It is estimated that the US phosphorus reservoir will only last for 40 years. There are several on-going research projects (i.e. case studies) on the field of nitrogen and phosphorus recovery. As an example, one of the projects aims to develop and demonstrate methods of wastewater and nutrient recycling (i.e. N and P) from algae biofuel production. Another interesting project used integrated landscape design to manage nutrient runoff and improve field productivity by using bioenergy crops.

Discussion and Conclusions

The barriers and opportunities to implement nutrient recovery systems differ widely from one country to another due to economic and technical feasibility, institutional barriers, policies, waste management strategies or social aspects. A closer look to the European countries shows big differences in how nutrient recovery is performed. However, there seems to be a common **trend to recover nutrients from incineration ashes in countries where waste-to-energy systems are well-established** and are readily accepted.

On the other hand, those countries with less developed waste-to-energy systems such as Australia and South Africa have the chance to **implement nutrient recovery systems more in line with a circular economy** than the traditional waste incinerators. The common denominator in all the countries performing well on nutrient recovery is economy. Therefore, investment in technologies seems to be the key to steer the transition towards a more circular economy in which nutrient recovery would be part in countries with scarce or no strategies on this matter.

When talking about nutrient recovery, most attention is paid to sewage sludge. However, some consolidate practices such as spreading sewage sludge on farmland are changing. In addition, there are also a number of waste streams/feedstocks with a high potential for nutrient recovery, e.g. poultry manure has a high phosphorus content.

In the last years biochars have been in the centre of attention due to their versatility. **Biochars can act as source of nutrients and enhance soil properties while sequestering carbon**. However, they should not be considered as a universal solution. Biochar properties and production depend on local feedstock and technology available. In addition, the presence of contaminants in the feedstock used for the production of biochars may lead to a contamination problem in the soils, and it is therefore important to control these contaminants.