PHOSPHORUS RECYCLING OF MIXED SUBSTANCES
BONUS PROMISE

PHOSPHORUS (P) RECYCLING IS NECESSARY TO REDUCE EUTROPHICATION, TO SAVE THE DECREASING P RESERVES AND TO SUPPLY AGRICULTURAL CROPS WITH P.

Different organic materials suitable for recycling differ in their P content and bioavailability but also in their content of harmful contamination. In recycling of organic materials all these aspects must be taken into account. Therefore, for planning environmentally safe recycling pathways, the risk of contaminating farmland with harmful heavy metals, organic pollutants and pathogens (disease causing mircro-organisms) needs to be evaluated.

Today P is recycled to farmland in:

- Farmyard manures
- Digestates of biogas plants
- Sewage sludge
- Composts, plant residues
- Meat and bone meal

Other recycled materials (ashes from sewage sludge or meat and bone meal; precipitates from sewage streams such as struvite, biochar products and many more).

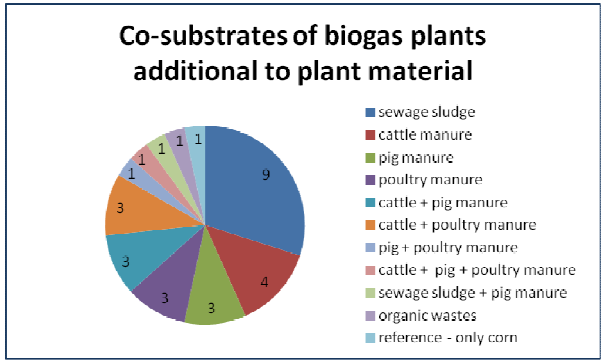
Shift from direct application of farmyard manures to the application of digestates from biogas plants can have considerable effects on nutrient supply and contaminations. For example in Germany the number of biogas plants increased during the last decade to more than 8000, producing about 66 million m^3 of digestate which end up on agricultural fields.

To facilitate efficient P recycling, thermal treatment of the mixed materials is one option to destroy pathogens and organic pollutants. Combined with separation of heavy metals from the ash the treatment can produce a clean P fertilizer, *i.e.* a fertilizer free from contaminants.

Even the Mangalitsa pigs leave behind manure that needs to be recycled

BONUS PROMISE produces knowledge to evaluate the risks by investigating the impact of the biogas process on P availability as well as on contamination with heavy metals, antibiotics and pathogens. Moreover, a new option of thermal treatment that aims to produce clean fertilizers from these organic materials is also evaluated.

As the study materials for **BONUS PROMISE**, thirty biogas plants in Sweden, Finland and Germany have been sampled, most driven with mixture of materials (manures originating from different animal species, energy plants and sewage sludge in different proportions). All substrates and digestates will be analysed for contaminations by heavy metals, antibiotics and pathogens, and digestates for P availability.



Number of biogas plants sampled per substrate in BONUS PROMISE

FIRST, PRELIMINARY MID-TERM RESULTS ON:

1. CONTAMINATION WITH HEAVY METALS

High concentrations of heavy metals in manures and sewage sludge restrict their full potential as fertilizers in plant production. Copper, zinc and arsenic are used as feed additives in animals' diets and they eventually end up into manure and thereby to agricultural soils. Even more concern is associated with spreading of sewage sludge due to the risk of heavy metals entering into a food chain or polluting soils and the environment. **The first results of BONUS PROMISE** showed that manures contained clearly less heavy metals (cadmium, lead, arsenic, mercury, copper, zinc, nickel and cobolt) than sewage sludge in all three countries, with the biggest difference, up to ten-fold, in lead and mercury concentrations. For arsenic, poultry manure contained about double of the concentration to that in cattle and pig manure, whereas the concentration in sewage sludge was about four-fold compared to that in poultry manure. Obviously repeated use of these recycled materials will increase heavy metal pool in soil, requiring caution unless heavy metals are removed.

2. CONTAMINATION WITH ANTIBIOTICS

Worldwide use of antibiotics is estimated to be 100,000 – 200,000 t/year with as much as 70% used in animal husbandry. While up to 90% of most antibiotics or antibiotic metabolites are excreted with urine and faeces, many different antibiotics can be expected to found in

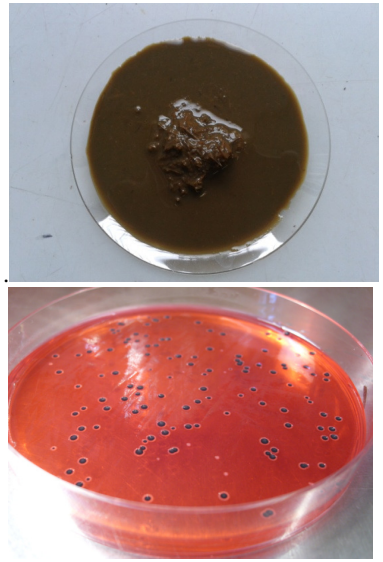
digestates which contain farmyard manures or sewage sludge as co-substrates.

Eight antibiotics have been screened, representing three major classes of antibiotics, tetracyclines, sulfonamides and fluorquinolones. **This first data of BONUS PROMISE reveal** that all the selected antibiotics are detected in digestates as well as in the input materials of animal origin with the same order of magnitude in digestates and substrates. Highest concentrations were determined for tetracyclines and enrofloxacine. Especially poultry dung digestates seem to be contaminated by antibiotics to a high extent. The data suggests that during the biogas process only part of the antibiotics are degraded, the tetracyclines and the enrofloxacines being very persistent during the process. All investigated digestates were at least contaminated by one antibiotic, but up to five different antibiotics were also found in one digestate. These findings are preliminary as not all samples are analysed yet.

Biogas plant in Germany

3. Contamination with Pathogens

Recycling of organic amendments may pose a risk for disease transmission to both humans and animals through contamination with pathogens. The pathogens may originate from diseased or infected but also from symptom-free human or animal carriers and can be excreted with faeces, urine and other secretions. They can also be present within the tissues of infected animals or on faeces-contaminated tissues and thereby found in organic waste fractions such as food waste. The pathogens possibly present in organic amendments may cause sub-clinical infections i.e. symptom-free infections, as well as more serious, even fatal, infections. Selected zoonotic pathogens have been screened, i.e. pathogens that may be transmitted between humans and animals, and indicator organisms, in samples collected from the biogas plants within the project. **These preliminary results of BONUS PROMISE show** that both *Salmonella* spp. and *Campylobacter* spp. can be found in manure received at the plant and used as substrate for digestion while no verotoxin producing *E.coli*, VTEC O157, also a zoonotic bacteria, has been detected in any of the samples. Meanwhile the results indicate that the pathogens are not as frequently detected in digested and stored materials. These findings are preliminary and additional analysis of samples and a thorough data analysis remain to be done.



Digestate sample (above) and Salmonella on a selective growth medium (below)

The way forward with Technical solutions for clean P fertilizer products

Thermal treatment is a potential and safe way to destroy pathogens, antibiotics and all other organic pollutants. While about 50% of the initial energy content of sludge and manure is still left after anaerobic digestion, thermal conversion produces energy for inorganic fertilizer production from digestates or energy (electricity, syngas or steam/heat) can be utilized elsewhere. Thermal conversion produces ash, usually containing calcium, silicon, phosphorus, potassium, iron, and aluminium as matrix elements as well as trace elements and some heavy metals.

The ash should be further treated with the ASH DEC process, to remove heavy metals (at least arsenic, cadmium and lead) and to improve P availability. The semi-product contains about 10-20% P_2O_5 and up to 15% K_2O, depending on the starting material. It may be processed to standard fertilizer granules in accordance with soil and crop requirements. In contrast to the conventional wet chemical processes producing 5 tonnes of waste per tonne of P_2O_5, only 30-40 kg of waste are produced by tonne of product.

Implications of BONUS PROMISE results to the Baltic Sea region

The data collected will be used to estimate development of P balances for the Baltic Sea region. Future trends with increasing numbers of biogas plants will deliver different budgets with respect to inorganic and organic contaminations and nutrients as well. Phosphorus is accumulated in the digestate during the biogas process while nitrogen (N) is partly lost as ammonia. Compared to original farmyard manures, application of digestates with lower N content may thus lead to higher P amounts applied to the field. We will calculate the optional P balances when adopting new technologies for being able to use P according to plant requirements. These will then be compared with the present situation and suggestions given for the potential actions needed.

Contact: KARI.YLIVAINIO@LUKE.FI

BONUS PROMISE project has received funding from BONUS (Art 185), funded jointly by the EU and Ministry of Agriculture and Forestry, PTJ and VINNOVA.