REFERTIL

Improvement of comprehensive bio-waste transformation and nutrient recovery treatment processes for production of combined natural products

Advance Compost and Biochar Processing: Solution for Economical Phosphorus Recovery Conference

CONFERENCE PRESENTATIONS ABSTRACT BOOKLET

In a world with finite resources there is no infinite development opportunity with sustainability, unless a resource efficient circular economy is fully implemented.

17-18 September 2015.

Toledo, Spain

REFERTIL (Grant 289785) projects is co-funded by the European Commission Directorate General for Research, within the 7th Framework Programme RTD/theme 2 KBBE.

FOREWORD

By Edward Someus - Coordinator, biochar S&T senior engineer

The EU-funded REFERTIL FP7 project (EC contract 289785, October 1, 2011 –September 30, 2015) provided advanced applied science and industrial engineering developments to convert local organic biowaste and by-product streams into safe biochar and compost products produced under market competitive, economical and EU/MS legalization industrial conditions. Based on some REFERTIL partners 30+ years experience in the fields of biochar S&T and industrial engineering, the REFERTIL project successfully developed, field tested, accredited laboratory evaluated and Authority permitted industrial biochar production and safe products.

The REFERTIL BIOCHAR key enabling biochar technology and products are completed and qualified by 2015 under EU FP7 REFERTIL 289785 programme at RTD Technology Readiness Level TRL8 according to the Commission Decision C(2013)8631 for definition of research status for agri technology and product developments. From October 1, 2015 the REFERTIL BIOCHAR is ready for implementation of market competitive safe biochar TRL9 manufacturing in economical full industrial operational environment for high added value processing of 20,800 t/y biomass throughput. The TRL9 level is the final stage of any agri research for key enabling technologies and products, such as the biochar, and the only true value and convincing tool to demonstrate research results viability and feasibility in operational environment and market competitive production conditions for the interest and benefits of the SME farmers.

The core elements of the biochar case are the production technology performance industrial design, safe product economical manufacturing and understanding of legalized applications for the interest and benefits of the SME farmer users. The production technology performance industrial design is one of the most important factor that is impacting the biochar product quality, where the maximum allowable limit of PAH_{19} 1-6 mg/kg is key performance indicator. Manufacturing and application of ABC Animal Bone bioChar organic Phosphorus fertilizer require far higher technological level than plant based biochar soil improver. Usually the analytical characteristics of the biochar product quality performance is the fingerprint of the pyrolysis/carbonization processing technology quality performance. Schlock technology resulting schlock products with low quality, low market potential and value. There is no one fit for all biochar technology and product solution, however in all cases the environmental safety, product performance, legalized Authority permits, economical and market competitive applications are key drivers. In the EU biochar production and application above 1 t/y require official and mandatory EU/MS Authority permits (EC 2003/2003 Fertilizer Regulation revision for EC biochar is under progress), REACH registration for importing/manufacturing/placing on the market of the biochar chemically modified substance and Extended Producer Responsibility certificate.

Biochar application always works, if not than wrong quality biochar produced and/or wrongly applied.

SESSION I:

THE REFERTIL PROJECT: COMPOST AND BIOCHAR FROM BIOWASTE, PRODUCT EVALUATION AND AGRONOMICAL RESULTS

INTRODUCTION OF THE REFERTIL PROJECT

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Current farming practices rely heavily on external inputs such as mineral fertilisers and chemicals to achieve intensive agricultural production. The EU-funded (REFERTIL) project aims to convert local organic biowaste and by-product streams into safe biochar and compost products produced under market competitive and economical conditions. These products are designed to be affordable, environmentally sustainable and in accordance with strong policy and food safety regulations informed by rigorous scientific and technical data from proven field demonstrations.

Progress thus far includes a guarantee of a high-level of protection for human health and the environment for added value recycling of organic waste and agriculture residues, including the organic Phosphorus recovery case in economical industrial scale. This was achieved by meeting stringent requirements on the quality criteria and detailed analyses for compost and biochar feed material sustainability; advanced technology developments towards zero emission production ensuring output product safety, efficiency and market competitiveness. All REFERTIL developed biochar are high grade, fully quality controlled and fully safe products under any climatic and soil conditions.

Beyond the key enabling technological/product development, the REFERTIL applied science researchers and industrial engineers together developed an extensive regulation policy to accompany the biochar and compost, which aims to increase the confidence of farmers using it for food and feed production. In this context improved compost/biochar quality and safety criteria and standards developed and determined. Full industrial scale ABC Phosphorus recovery and recycling plant with market competitive industrial manufacturing installation is prepared. They also provided market viability information and scientific data for setting up organic by-product and biowaste recycling targets, which supports policymakers in revising EU fertiliser regulations. The REFERTIL converted science into legalized industrial practice. 2000 tons of different compost and 100 tons of different biochar materials (plant, waste, animal based) "product like" field test processed and all steams accredited laboratory analyzed. Advanced industrial biochar production technology developed and implemented for all types of biochar processing, including ABC Animal Bone bioChar that require far higher technological design and processing level than plant based biochar processing. Mandatory EU/MS permits developed for legalized industrial production and applications of biochar. Advanced, comprehensive and detailed EU biochar policy and law harmonization support reports developed for the Commission.

The results of the REFERTIL project have the potential to reduce by 20% at EU scale the import of Phosphate mineral fertilizers and avoid producing 10 million tonnes of carbon dioxide-equivalent emissions in Europe.

ABC - ANIMAL BONE BIOCHAR, A HIGH GRADE RECOVERED P-FERTILISE

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Phosphorus (P) is an essential, non-renewable and critical nutrient resource for maintaining soil fertilization. It cannot be manufactured or destroyed, and there is no substitute or synthetic version of it available. Phosphate rock identified as the single most irreplaceable raw material, with only 2% of applications having a viable substitute. In this context the urgent substitution of mined P with efficient recovered P-product is key target the whole European community. There is increasing legal and economical and social demand for recycling of high concentrated (>30% P_2O_5) P-from European sources, such as food industrial by-products and organic waste, for sustainable and safe organic phosphorus supply from domestic EU sources.

ABC is Recovered organic phosphorus fertiliser and a renewable Phosphorus source that can substitute the increasingly scare mineral phosphates. ABC having high concentrated (30% P_2O_5) pure Phosphorus and Calcium (40% CaO) content with sequenced release P-fertilization effect. ABC is highly macroporous, formulation optimized for significant enhancing of soil microbiological life, having high water holding and macromolecular organic nutrient retention. The fully safe ABC is used at low doses, such as 200 – 600 kg/ha and in cases when justified even up to 1,000 kg/ha.

ABC Animal Bone bioChar processing requires higher efficient thermal processing, complex and higher level of technology. **Revolutionary innovative thermal process with specific horizontally arranged indirectly heated rotary kiln** construction for efficient and high yield production of 'ABC' animal bone biochar recycled phosphorus fertiliser. The innovative construction provides highly efficient indirect heat transfer, energy efficiency and maintenance of true reductive thermal processing conditions with high material core temperatures up to <850°C under negative pressure conditions and high feed flexibility. The efficient process technology providing safe and high quality ABC output product performance.

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BIOCHAR QUALITY & SAFETY – ACCREDITED BIOCHAR ANALYSIS

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As the accredited laboratory partner of REFERTIL project hundreds of samples from 11 countries have been investigated by WESSLING Hungary in a wide range of materials (e.g. biochar, soil, compost, input waste materials, plant parts).

With this high number of tests the quality of the input materials and the output products were characterised. Measurements were directed on one hand to examine useful plant nutrients, phosphorous/carbon/nitrogen content and on other hand to the detection of potential risk factors (PAHs, potential toxic elements, PCBs and dioxins).

In spite of their similar appearance, the microstructure and chemical properties of plant based biochars (PBC) and animal bone biochars (ABC) are quite different, but they can be analysed using the same laboratory methods.

During pyrolysis and other thermal treatment processes PAHs are the main indicator contaminants, its limit value has been defined as 6 mg/kg for biochars. With various biochar processing conditions it has been verified that the technology influences the quality of the product. Between appropriate treatment conditions, high quality biochars were made with low PAH content (< 1 mg/kg).

PCBs were not detected from biochars, but high chlorine content of the input material was also not expected. As dioxins were never shown too, we have concluded that PCB presence is a good indicator of these persistent and bioaccumulative chemicals.

After the development of the methods for biochar examination in 2014 we have succesfully gone through the accreditation process for biochar quality testing as the first and only laboratory in Europe.

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USE OF COMPOST AND BIOCHAR IN AGRICULTURE: EXPERIENCES FROM THE REFERTIL PROJECT

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The agricultural sector is encouraged to innovate and change strategies for crop nutrition and protection, with the need to revisit the methods of management to satisfy the requirement of environmental sustainability, by the adoption of integrated systems. Compost and biochar are an important tool for agriculture and food security and their impacts and benefits need to be further investigated.

The use of compost and biochar has been evaluated by Agroinnova – University of Torino within the Refertil project, with the aim to provide farmers more information about their efficacy.

Some examples of the experiences carried out in Italy are reported. Potting trials in greenhouse have been carried out on vegetable crops to evaluate the use of compost and biochar as soil improvers, organic fertilizers or growing media. Suppressiveness trials in greenhouse have been carried out to evaluate the capacity of compost and biochar to reduce plant diseases and field trials on tomato, pepper and lettuce, to validate the use of compost and biochar in farms located in Italy. Composts deriving from animal manure and municipal biowaste reduced seeds germination and plant growth when used as growing media, and consequently they are not recommended to be applied at dosages higher than 15-20% v/v. However they have a good fertilization effect when applied to soil, and increased yields when applied at 10-30 t/ha. Green waste composts are more suitable to be used as growing media and in soil-less systems, and 50% of them suppressed soil-borne plant pathogens such as *Fusarium* wilt. Animal bone char showed a good fertilization effect on crops, while plant based biochar had few effects on the yields and results were variable according to soil type. The application of compost with biochar had also good effects on crop development, however it was not possible to identify a common outcome.

Different strategies are critically discussed, and new trends for the use of compost and biochar in agriculture are suggested.

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BIOCHAR: FIELD TRIALS AND AGRONOMICAL EVALUATION

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Field Tials: In autumn 2012, biochar from wood waste was applied before sowing of winter wheat at 3 different locations and soil types. The biochar were mixed into the soil by plough or harrow. The application rates were 0-20 t C/ha. The trials continued in 2013, 2014 and 2015. In 2014 one new trial with application of biochar from straw before sowing of spring barley was started with application rates of 0-10 t/ha. Because of a very dusty product, the biochar was mixed with sand 1:4. The trial was followed up in 2015. No trials showed significant yield response to the biochars. A small decrease in yield with increasing application of biochar is observed in year 1 after application of biochar from wood waste (-2,1%) and straw (-5,6%).

In year 2 after application of biochar from wood waste, a small increase in yield is observed in two trials in winter wheat on clay soils (+2,3%), while a similar decrease is observed in winter barley on sandy soil. Plant analysis show no differences in concentrations of nutrients between treatments and there are no differences observed in infections from pathogens.

Soil analysis of mineral nitrogen in 2013-2015 show a decrease with increasing application rates of biochar during all 3 years, indicating that the high C/N immobilizes N and that the effect remains. A reduced nitrate content can reduce the risk of leaching and the effect need further investigation

Consumers acceptance: A successful recycling of organic wastes in agriculture needs a demand of the products to be used in the plant production. A questionnaire about biochar and compost has been answered by 400 farmers from Denmark, Italy, Spain and Poland and shows a very limited knowledge and practical use of biochar. From the farmers' point of view, the products must contain nutrients or soil improvements substances and have a standardized quality. Plant based biochars in general have a high content of carbon (about 80%) but a low content of nutrients. The value of the biochar comes from the carbon enrichment; the increased water holding capacity, cation exchange capacity and high pH-value at acid soils. The yield effects are very depended on the soil type, climate and crop.

Price: The prices of biochar are very variable. In the Refertil project, prices from 100 – 1.000 euros per ton are obtained. From the questionnaire, farmers know too little about biochar, being willing to pay the actual price. The needed yield effects depend on the assumptions for investment, but most biochars are not relevant to Danish soils for field use at the actual price level. It might be relevant to greenhouse cropping of high value crops.

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NUTRIENTS (N AND P) RECOVERY OPTIMIZATION THROUGH COMPOSTING: THE REFERTIL RESULTS

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REFERTIL Consortium has been developing from 2011 to 2015 a wide range of scientific technical and dissemination activities related to Composting and Pyrolisis technological assessment and development and Compost and Biochar evaluation and improvement.

Hundreds of organic residues and by-products as well as compost and biochar samples have been sampled and analysed, 23 composting facilities mainly treating EoW kind of input materials have been visited and evaluated with the open and fruitful collaboration from owners and managers. One of these extensive works main objectives is to collect first hand quality information about these technologies for converting organic materials into high quality final products like compost and biochar related and the optimal conditions for its use mainly in agricultural application.

REFERTIL Consortium has also performed a close follow up as well as collaboration with the development of the *"EoW Criteria for Compost and Digestate"* that ended in December 2013 with the non-applied Final Proposal. In consequence **REFERTIL** considers that the objectives of the EoW initiative are far from being attained, considering *that the objective of end-of-waste criteria is to remove the administrative burdens of waste legislation for safe and high-quality waste materials, thereby facilitating recycling. It is achieved by requiring*:

- *high material quality of recyclables*
- *promoting product standardisation and quality assurance*
- *improving harmonisation and legal certainty in the recyclable material markets*

REFERTIL Consortium has been and will be developing field, lab and cabinet reports and technical guidance documents that will be summarised in WP9 Reports related with Composting process and Compost standardisation with the aim of contributing to the imperative need of an harmonised frame at EU level.

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TRANSFER OF P FROM BIOCHAR AND COMPOST TO PLANTS WITH THE HELP OF ARBUSCULAR MYCORRHIZA

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The majority of crop plants lives in symbiosis with beneficial fungi being hosted in the cortex tissue of the plant roots. In return the symbionts improve in many ways plant development and health. A key aspect of this beneficial fungal activity is the uptake and handing over of P.

Aim of this work was to document how plants can take up, with help from mycorrhizal fungi or alone, nutrients from biochars and composts amended into the substrate, and to investigate possibilities and methodology of a combination of biochars/composts with mycorrhizal fungi.

To approach these aim experiments were conducted using 3 arbuscular mycorrhizal fungi (AMF, 2 isolates of *Glomus intraradices* and one *Glomus etunicatum*). Biochars used were different batches of ABC (made from animal bone material) and two different plant-based biochars. 5 different compost delivered from Spain (COES), Hungary (COHU), and the Netherlands (CONL) were used, too. Experimental plants was *Tagetes erecta* cv. Luna Lemon

Inoculation with AMF isolates often resulted in a clear increase of plant growth; the symbionts increased plant growth significantly by transferring P from ABC to the roots. When different ABC and plant-based biochar materials were compared, clear differences between ABC materials and plant-based biochars became visible: due to the much higher nutrient contents of ABC their beneficial effects were much better compared to plant-based biochars. Batches of ABC differed regarding accessibility of the bound P for non-mycorrhizal plants.

When 5 composts were compared regarding their growth effects in interaction with AMF isolates. 4 composts increased clearly plant growth with COHU3 and CONL1 being best. A synergistic interaction with the AMF was observed above all with COHU3. With this compost tagetes plants need the help of arbuscular mycorrhizal fungi for an optimal access to the given nutrients. One of the five composts used had negative effects on plant growth (COES5). To find out how compost organisms were involved, the two most beneficial composts were sterilized by γ-radiation. Sterilization had no effect on the beneficial compost effect in the case of CONL1. When COHU3 was sterilized the growth promotion by this compost was clearly reduced regardless of the mycorrhizal status of plants. The outstanding beneficial effect of COHU3 and the positive interaction with arbuscular mycorrhizal fungi is at least partly due to compost organisms.

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ORGANIC AMENDMENTS TO IMPROVE DISEASE SUPPRESSIVENESS OF SOILS

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Soil-borne pathogens can cause serious economic damage in agricultural crops. However, disease resistant cultivars are not always available and chemical control has environmental draw backs. Soil disinfestation as well as preventive pesticide application is often not allowed anymore. Improving plant resilience and enhancing soil suppressiveness against diseases are environmentally friendly strategies to grow healthy crops. The addition of organic (waste) products in soil is one management strategy that supports soil quality as well as soil suppressiveness against certain diseases.

In our research we demonstrated a reduction in *Pythium* infection in tomato plants when compost was added to potting soil. Disease reduction varied from 30-60% in different experiments. Biochar was less effective in reducing *Pythium* infection than compost. However, addition of a microbial inoculant, an antagonistic strain of *Pseudomonas chlororaphis*, improved suppressiveness of the biochar. These results show that compost as well as the addition of a microbial inoculant to potting soil or supplied in animal bone char, will enhance the disease suppressiveness of the growing system.

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SESSION II:

P AND N NATURAL SOLUTIONS EFFICIENCY AND NATURE PROTECTION

STRUVITE PRODUCTION PLANT FOR MADRID SUR WWTP

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The industrial phosphorus "cycle" is linear; from mining to oceans, lakes, and rivers. Phosphorus mining create environmental damage from runoff, also liberating cadmium and radioactive materials. Phosphorus fertilizer (MAP, DAP) is highly unsoluble and inefficient and its production generates phospho-gypsum waste.

In the biological nutrient removal reactors (BNR) of modern WWTPs, anaerobic zones create an environment for biological phosphorus uptake and phosphorus moves from dissolved form to solid form, causing 2 problems:

- Centrate recycle increases nutrient load on secondary process.
- Struvite formation

Madrid SUR Wastewater Treatment Plant (WWTP) is the biggest WWTP in Madrid Region, Spain, being operated by Canal de Isabel II Gestión. It was designed for a treatment capacity of 2,900,000 PE, although nowadays is treating a 1,200,000 PE.

The uncontrolled struvite precipitation ($NH_4MgPO_4 \cdot 6(H_2O)$) has been a constant problem in this WWTP, leading to pipe blocking in the sludge line after digestion and high maintenance costs associated.

Veolia Water Technologies worked with Canal de Isabel II at defining the best technological solution to solve this historical problem and at the same time to recover this phosphorus. Modelling studies, based on a specific analytical program of the centrates from the centrifuges, were carried out, showing **a potential estimated capacity of 2,400 kg/day of struvite recovery**..

Veolia Water Technologies resulted as the awarded company for this tender at the end of January 2015, which scope includes 1) **Construction of a turn-key plant for the installation of a struvite production reactor**. Total amount of the project: 2.3 M€; 2) Initial **purchase agreement for the first four years operation** (extended to 2 more years), in an agreement to purchase the produced fertilizer at 300 €/t to Canal de Isabel II. Crystal Green obtained at SUR WWTP, as used in agriculture, is 4-5 times more efficient than conventional fertilizers because of its slow release characteristics.

This project represents **the first industrial reactor for the struvite recovery in Spain** and a key project for Veolia Water Technologies and Canal de Isabel II as an example for other municipalities in the country.

SELECTIVE STRATEGY FOR P RECOVERY FROM WWTPS

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Concern about phosphorus recovery and reuse has increased in recent years due to Phosphorus limited resources, increasing demand and European dependency on external reserves. It has also to be advised the environmental damage that phosphorus discharges induce into the environment and the increasingly strict legislation, making WWTPs crucial systems to enhance phosphorus recovery.

Phosphorus reaches WWTPs through the influent water, being removed biologically toward the excess sludge. Is therefore in this treatment line where it can be recovered either directly at the sludge or at the side streams. PHORWater project begins with the study of the fluxes involved in the process of Calahorra WWTP (La Rioja, Spain) based on a complete characterization and comprehensive study of different configurations by the simulation program, DESSAS. This study points anaerobic digestion as the main phosphorus loss point and the results suggest an elutriation of the mixed sludge previous anaerobic digestion as the optimal configuration that reduces phosphorous precipitation and maximises the available phosphorous to be recovered.

The development by computational fluid dynamics simulation and setting up of the crystallization reactor at Calahorra WWTP has allowed reducing the amount of phosphorus returning to the activated sludge process, the associated operational problems due to uncontrolled precipitations and the phosphorus sludge concentration providing struvite as a result, a valuable product, that will be valorised as fertiliser, guaranteeing the supply of fertilizers in areas near to the WWTPs while reducing the phosphorus discharges into the environment.

RECYCLING P AND N FROM MUNICIPAL WASTEWATER BY BIOFILM-IMMOBILIZED MICROALGAE

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Over millions of years of evolution microalgae have developed very efficient nutrient uptake mechanisms, in particular for phosphorous, making these organisms suitable for plant-based nutrient recovery concepts. State-of-the art cultivation methods for microalgae rely on suspension cultivation. However, these established technologies have major drawbacks, such as high costs and energy consumption. Therefore, recent advances in bioreactor design focus on new reactor types making use of immobilized cultivation of microalgae in biofilms. These developments offer several advantages for algal production, in particular for nutrient recovery from liquid waste streams.

The LIFE+ TL-BIOFER project aims on demonstrating the removal of nitrogen and phosphorous from primary effluent municipal wastewater by means of a biofilm photobioreactor. To close nutrient cycles, P and N are captured and incorporated into growing algal biomass, e.g. for further use as bio-fertilizers.

To find suitable algal strains adapted to local conditions, microalgae were sampled at the WWTP of prototype installation. Isolation from samples resulted in the establishment of 32 clonal cultures, including unicellular or filamentous green algae, cyanobacteria and diatoms. All isolated strains were successfully grown in a biofilm bioreactor with maximal biomass productivities of 8-12 g m^{-2} d^{-1}. Laboratory-scale tests were conducted to determine nutrient uptake performances and to show the potential of this technology. Based on these results dimensioning and mode of operation of the bioreactor prototype are being determined. By end of 2015, a prototype for the treatment of 12 m^3 wastewater d^{-1} will be installed and operated in El Viso-Villaralto, Córdoba, Spain.

MICROALGAE FOR NUTRIENT RECOVERY IN DECENTRALIZED SANITATION

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Global food production has a growing demand for agricultural fertilizer [1]. Bearing in mind an impending phosphorus shortage and the high energy demand of chemical nitrogen fixation [2], the need for recovery schemes of these essential plant nutrients becomes apparent. Domestic wastewaters contain large amounts of organic substances and nutrients. Treatment of this water is an environmental concern as well as a potential point of energy and nutrient recovery [3]. In line with an effort to construct a more sustainable built environment, these compounds, traditionally viewed as pollutants, should be seen as resources to be recycled. Domestic wastewater can be, in descending order of resource concentration, separated into black water (faeces), yellow water (urine) and grey water (shower, laundry, sink). In conventional approaches these streams are pooled, leading to a dilution of the contained resources. The wastewater is transported over long distances through sewage systems, were it is further diluted with rain water other streams. This results in large volumes of water that need to be handled in centralized treatment plants, leading to high energy demand and cost of operation. Decentralized, source separating sanitation considers the different wastewater streams as resource mines and aims to recover resources locally. The most dilute stream, grey water, can be purified with relatively simple means, e.g. sand filtration. The "toilet-streams" are collected separately with specialized installations that minimize the use of diluting water, e.g. vacuum toilets and waterless urinals. Black water, combined with kitchen waste, is an excellent source for anaerobic digestion. The production of biogas can make such system net energy positive. Urine, which contains about 78% of total nitrogen and 52% of total phosphorous present in domestic waste water, is an attractive medium for recovery of nutrients [4]. Microalgae are suitable organisms for the recovery of nutrients from concentrated wastestreams [5]. Using directed isolation strategies, strains that can grow well in such harsh environments can be found. When growing rapidly, they require large amounts of inorganic nutrients for their biomass buildup. This biomass could be used as a slow release fertilizer in food production, effectively closing nutrient cycles locally.

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FLASH PYROLYSIS OR SUBLIMATION - FROM BIOMAS TO GAS AND BIOCHAR

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FRICHS LTD is a global supplier of flexible and environmentally friendly energy systems. The company both develops and produces engines and thermal power systems. Moreover Frichs offers a wide range of special engines, gas turbines, emergency generators and accessories from leading engine producers. Frichs is bringing a new generation of energy plants into the market. Our **SUBLIMATOR plants** are able to convert all kinds of organic material into gas and a sort of activated carbon or BioChar in a fast and efficient way without the use of bacteria or enzymes. Our plants are environmentally friendly and economically feasible. The capacity of the plants can be adapted to the individual requirements of our customers. SUBLIMATION means going from solid form to gas form without passing through the liquid phase. It is a FLASH PYROLYSIS system. The FRICHS Energy Process is not a burning, combustion, anaerobic digestion, or incineration process. A clean gas can be delivered to gas engine/turbine-generators or for other uses.

In the case of biomass being used as raw material a BioChar is formed, which can be used as a valuable fertilizer. Conversion of the material is contained within piping and sealed equipment without emission and the process is classified as a closed loop system. There is no waste water; no odor or particulate; no ash; no tars, oils or liquors. As a closed loop system it has the inherent ability to avoid emissions of hazardous fractions such as heavy metals, sulfur oxides, dioxins and furans.

The FRICHS Energy Process is a **Flash Pyrolysis** process which means that is very important that all the volatiles are transformed into gas in seconds in order to avoid the traditional problems with tar as seen in traditional gasification. The process temperature of minimum 750 ° C will be decided in each case depending on the raw material. Before start up the system is flushed with Nitrogen in order to create an inert atmosphere. As the feedstock enters the FRICHS Energy Process Unit, it is heated, almost instantaneously, to over 750 °C. The entire "hot zone" is enclosed in a shell that is highly insulated for high thermal efficiency. In seconds all of the volatiles are "cracked" and driven from the material and captured as a combustible gas.

No oxygen is added at any time to the process. Since the gas travels the same path as the carbon being produced, the carbon chemically captures any "nasty" elements leaving the gas clean and sweet (devoid of any sulfur, chlorine, etc.). The rapid expansion of the gases performs the function of activating the remaining carbon material.

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ENGINEERED BIOCHAR: TOOL FOR MITIGATION OF PHOSPHORUS LOSSES?

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Carbonaceous materials have been used for a long time as sorbents for xenobiotics and hazardous substances in soil and water technologies. Sorption interactions and separation of contaminants from soil solutions or waste effluents can be affected by a wide range of parameters (anionic or cationic form of contaminant, concentration of contaminant, contact time, effects of competitive substances). Biochar as a porous material produced under high temperature (350-700°C) and strict anoxic conditions represents a promising sorption material due to extensive surfaces and various binding sites. The natural negative charge of the biochar-derived sorbent predetermines the sorption efficiency for cationic forms of pollutants. However, an effective modification of the sorbent or pre-treatment of feedstock can improve sorption properties also for anionic forms. These engineered biochars could be remarkable tools in sorption separation of different oxyanions such as phosphates which represent both an important raw material for industry and fertilizer production and a challenge for environmental management. The main aim of our work was to study the effect of feedstock Cu-, Fe-, Mg-, K-, Al-enrichment and also biochar post-treatment by Fe-impregnation on sorption capacity of wood-derived biochar for phosphates. The obtained results confirmed the crucial role of biochar modification methods in improving biochar sorption efficiency for phosphates and thus the option for mitigation of P-losses that contribute to the eutrophication of surface water systems.

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SESSION III:

PHOSPHORUS RECOVERY: NEEDS TECHNOLOGIES, DRIVERS AND LEGAL ISSUES

SUMMARY OF THE REFERTIL POLICY SUPPORT WORK AND BIOCHAR PERMITTING

Edward Someus

Interconnected video presentation: Dr Eric Liegeois EU DG Grow D.2.

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When biochar is irrevocable applied to open and complex soil ecological system, there is also a direct interlink to subsurface water systems, therefore only qualified and safe biochar must be applied. The aim is to ensure that the proposed biochar quality and safety criteria are fully consistent with EU-wide Directives and Regulations for long term.

Fertiliser regulation (EC No. 2003/2003) is only regulating the mineral fertilizers and in current form is not applicable for biochar products. One of the key objective of the REFERTIL project is providing a strong policy support for the EU Commission in revision of the Fertiliser Regulation (Reg. EC No. 2003/2003) and possible inclusion of biochar - as safe organic fertiliser and soil additive. The REFERTIL consortium integrateded the biochar applied scientific research, industrial engineering, legal and economical aspects. Harmonized and standardized analytical measurements have been developed for determination of the physic-chemical properties, potentially toxic element content and organic pollutants in the biochar materials. A proposed biochar quality and safety criterion system has also been set up which is maximizing the Potential Toxic Element and Organic Pollutant content for safe application.

The complex environmental/climate protection challenge and the high responsibility for biochar manufacturing, importing, supply, use and irrevocable soil applications; provides justified strict EU/MS regulations and legal/technical control on the biochar case. **Manufacturing/ import/ placing on the market and using of all types of biochar products in the EU require mandatory Authority permits and certificates,** such as: (1) Member State Authority permits for biochar production. (2) Member State Authority permit for biochar applications, that is valid for issuing MS only. Mutual Recognition procedure needs to be extended to other MS. EC 2003/2003 Fertilizer Regulation revision is under progress to include biochar, valid for EU28. (3) REACH registration (in 2015 >10 t/y, from 2018 >1 t/y). (4) Extended Producer Responsibility certificate.

The first European biochar national Authority permit has been issued in Hungary in 2009 under protocol number 02.5/67/7/2009 (applicant: Terra Humana Ltd./Edward Someus). This specific biochar product is classified as yield enhancing substance. The permit and test procedure has been executed in the accredited test fields and accredited laboratories of the Government Authority between 2005-2009.

Dr Eric Liegeois from the EU DG Grow D.2. made comprehensive video conference presentation during the event about the EC 2003/2003 Fertilizer Regulation revision progress and status and also answered questions from the audience about the subject.

PROCESS OF BIOCHAR ACTIONS IN THE ENVIRONMENT

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Meanwhile, biochar has reached human and animal nutrition. Increasing contradictory scientific results urgently request a more detailed investigation of mechanisms of how biochar interacts with the environment. I will summarize current state of the art of theoretical and observed biochar mechanisms under different ecological aspects. The chemical structure of fresh biochar is characterized by a high proportion of condensed aromatic moieties and low proportions of functional groups, biologically degradable organic carbon, and ash. From a physical point of view, biochar is a porous media. The big surface area is dominated by pores in the nm range, while the plant-available water-holding capacity is dominated by pores bigger than 20 µm. Ash components can serve as mineral fertilizer for plants and microorganisms. Labile (not aromatic) organic carbon can be assimilated by soil microorganisms, probably explaining the rapid initial microbial activity and respiration (CO_2 emission) after biochar addition to soil. Condensed aromatic moieties of biochar are much more stable than natural organic matter and can act as long-term C sink in soil due to its intrinsic chemical recalcitrance. Interaction of biochar with soil minerals will occur only after partial oxidation and formation of functional groups such as phenolic or carboxylic groups. Enhanced biological activity especially during composting will facilitate and promote such reactions. Biochar influences many physical soil properties such as primary and secondary structure, porosity, permeability and density. The chemical structure of biochar is dominated by hydrophobic poly-condensed aromatic moieties repelling water, while the physical structure of biochar is dominated by macro and micro pores attracting water. If water is in contact with biochar, it is attracted by hydrophilic functional groups (phenolic, carboxylic) and by capillary forces of pores. New scientific evidence provided interactions of water with graphene sheets of biochar despite their hydrophobic chemical character. The stability of biochar was controversially discussed in scientific literature. Potential explanations for this discrepancy are methodological aspects as well as the variable proportion of stable poly-condensed aromatic carbon of biochar. A quantification of this poly-condensed aromatic C is crucial with respect to the C sequestration potential of biochar. On the other hand, reactivity of biochar is crucial for other positive ecosystem functions such as nutrient holding capacity and formation of stable organo-mineral complexes and / or soil aggregation. Soil microbial diversity is a function of soil (especially pH) and site properties (temperature and precipitation). As biochar can influence those properties, it has also indirect effects on soil microbial diversity. Therefore, for a proper investigation of direct biochar effects on soil microbial diversity, these factors need to be kept constant, which is most often not the case. Nevertheless, direct biochar effects on soil microorganisms has been reported, which can be explained by the high surface area and the occurrence of easily degradable organic carbon attached to this surface. Thermochemical conversion of organic matter involves production of low molecular weight condensed aromatic moieties also known as polycyclic aromatic hydrocarbons and dioxins. Hydrothermal carbonization does not produce such compounds due to the relatively low temperature. On the other hand, hydrothermal carbonization produces a variety of low molecular organic compounds potentially toxic for plants. Contents of polycyclic aromatic hydrocarbons and dioxins can be kept low by technical parameters (temperature, separation of biochar and condensates). Phytotoxic low molecular weight organic compounds of hydrochars can be eliminated by biological post-production processes such as aerobic composting. Little scientific literature exists about the biological actions of biochar in men and animals. However, biochar should act similar to activated charcoal. The only constraint is particle size, which should be higher than 10 µm to avoid accumulation in lung tissue. From the physico-chemical structure of biochars, a number of biochar reaction mechanism in the environment can be deduced, especially with respect to stability and physical and chemical reactivity. More difficult and thus, less certain are biotic interactions with microorganisms, plant, animal, and men.

P BALANCES AND SOLUTIONS IN A EUROPEN PERSPECTIVE, BIOECOSIM PROJECT

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The intensive livestock production in Europe generates annually more than 1,800 million t of manure with high phosphorus (P) concentrations. Unfortunately, current manure management practices results in environmental problems and economic disadvantages for farmers.

The EU-Project BioEcoSIM comprises the development and demonstration of an integrated approach and business model that has wide EU27 applicability in the agriculture sector. BioEcoSIM aims to valorise livestock manure into 1) pathogen-free, organic soil amendment (biochar), 2) slow releasing mineral fertilisers and 3) reclaimed water.

In particular, P was recovered from pig manure and converted into a P-fertiliser product that can be easily handled, transported and applied. After manure acidification to pH 5, manure was separated into a solid fraction and a particle-free liquid fraction rich in P. The solid fraction was converted to biochar. From the liquid fraction, P salts were precipitated by base addition and separated. It was demonstrated that a high P-recovery rate is possible with this method. 92% of total P in manure was solubilised at pH 5 and 98% of the P present in the liquid fraction was precipitated as valuable P-fertiliser. After P-recovery the liquid fraction is used for nitrogen recovery as ammonium sulfate (AS).

A business model has been developed to enable impact within the medium term. It is currently projected that 100 units will be sold, installed and will be operating within five years of the completion of the BioEcoSIM project. It is projected that each unit will be processing 10,000 m3 of manure annually. This will result in 1 million m3 of wasted manure processed per annum to generate over 18 000 t biochar, 10 000 t of AS and 10 000 t of P-fertilisers.

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REFERTIL COMPOST AND DIGESTATE: THE NEED FOR POLICY, TECHNOLOGIES AND GOOD PRACTICES

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REFERTIL Consortium has been developing different technical evaluation activities on Composting and Compost oriented to technology and product development and improvement.

During the first stages of the Project, main attention has been paid to the elaboration of a criteria for "Input material selection for End-of-Waste production of Compost and Digestate" (plus Biochar), including the contribution to the works of JRC, in charge of this initiative. In this phase, the EU relevant background for biowaste and future orientation was also reviewed: increasing of biological treatment, fixing a European minimum target for biowaste recycling, setting common compost standards in a harmonised frame.

REFERTIL also produced as *Deliverable 1.2. Annex IV, a Table of Legal quality requirements and pollutant limits for compost at EU-27 MS,* that shows the enormous dispersion at MS and regional level clearly indicates the need for EU standardisation of Treatment and derived Biowaste product standards for the common market and fostering recycling and resources recovery (Bioeconomy, Circular Economy...)

The next step was the Composting technologies and Compost product survey through an evaluation process that included the analysis of 21 composting plants and 32 compost in 6 EU countries suitable to comply with End-of-Waste criteria. Based on this information a review was performed by REFERTIL summarising the "Activities developed / and to be developed at EU level" and the "Activities developed / to be developed at EU level" regarding biowaste-compost fostering policies and harmonisation.

A technology review with composting technologies improvement and good operational practices proposals was also developed based on a REFERTIL evaluation model.

Finally, in the last months of REFERTIL Project, a synthesis proposal aiming at harmonisation on European level for Biowaste full management process and final products, with technical guidance documents is being developed in the different deliverables of WP9.

The REFERTIL project is co-funded by the European Union, Seventh Framework Programme under Grant Agreement number 289785.

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NEWFERT, NUTRIENT RECOVERY FROM BIOBASED WASTE FOR FERTILISER PRODUCTION (H2020-BBI-PPP-2014-1)

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P is essential for food production but there is only a low amount available for plants in the soil. That's why it has to be applied to many soils in order to guarantee normal plant growth and the improvement or maintenance of crop production. Most of the P in soil is not directly available for plants due to its great insolubility.

Therefore, it is necessary to keep an adequate P level in the soil solution and it is here where fertilizers play a key role. The main role of fertilizers is to increase the concentration of soluble P forms in the soil solution, in such a way that it will be more easily available for the roots. One of the main trends in the fertilizers world is to find new nutrient sources in Europe, with high quality and high available content.

To close the loop, giving the P uptake for the crops and the agricultural activity back to the soil is a matter of importance in Europe where nearly all the P needed is imported. It is important to guarantee the economic viability of the P recovery and transformation projects for the production of P sources ready to use as fertilizers. But also to ensure the safety, the final product quality and the supply capacity. NewFert Project, has recently been launched with the objective to recover nutrients from bio-wastes for fertilizer production.

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THE COMPOST IN CATALONIA

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Waste Agency of Catalonia-Agència de Residus de Catalunya: The ARC is a public company within the Planning & Sustainability Department of the Government of Catalonia and is responsible for the waste generated in Catalonia and any waste management entity within Catalonia.

Definition, uses, environmental benefits and Organic Matter Cycle

The compost is the product resulting from the aerobic decomposition of organic matter through the composting process. The environmental benefits of the use of compost are well known, as for example: it closes the cycle of organic matter by recovering the organic matter of organic waste, which will be used in farming for food production.

In the context of municipal waste we divide the Organic Matter Cycle in different stages: generation, selective collection, treatment and final product – compost, thus closing the cycle. In this cycle there is also the short-cut of home-composting, by doing domestic and commercial composting at origin.

ARC works on each stage with different actions, in order to obtain compost of high quality because it is mainly applied in agriculture.

Some facts from Catalonia about organic fraction, treatment facilities and compost: During 2014 in Catalonia we collected and treated 375.261,98 tons of organic fraction and we obtained approximately 30.000 tons of compost. This compost has been used mainly in agriculture (80%) and in gardening (20%). When compost is applied in agriculture, it must be registered at "*Registro de fertilizantes y afines*" according to Royal Decree 506/2013, of 8 July, concerning fertilisers. On the other hand, in Catalonia the use of the compost in agriculture is additionally regulated by Decree 136/2009, Nitrate Vulnerable Zones Program. This Decree explains the requirements in field applications of organic fertilisers in NVZ and non NVZ. For example, there are specifications about the distance to municipalities that must be respected when people apply organic fertilisers. Apart from the legal dispositions the compost must be applied in agriculture according to the requirements of each crop.

Compost vs bioestabilised material: The Spanish law differentiates compost from biostabilised waste. Compost is obtained from organic fraction that has been separated at source, whereas bioestabilised material derives from mixed residual waste without selective collection of organic fraction.At present, in Catalonia it is not possible to use bioestabilised material in agriculture. Only the use for restoring of degraded soils in public works (closure of landfill sites, regeneration of slopes...) or in restoration after extraction activities is allowed.

SEPARATE COLLECTION AND MODELING MSW ORGANIC FRACTION MANAGEMENT AT ESGH TOLEDO

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ESGHT (Superior Gastronomy and Hostelry School of Toledo) located in historical **city of Toledo** was created by a private foundation ("Fundación del Ciento") and provides official superior formation and diplomas for 200 students a year. During 2015 the ESGTH in collaboration with **BIOMASA PENINSULAR**, the ESGHT has been creating a system for separate collection of organic fraction form its catering waste, integrated with a management model that includes the use of 100% biodegradable bags designed and supplied by **NOVAMONT** and the further treatement by AD (Anaerobic Digestion) and C (Composting) in the nearby *"Algodor R&D&i and Experimental Production Centre"*.

The project received a grant from **CLAMBER Project** for "*Valorisation of municipal waste organic fraction*: research, development and innovation services*, for the integral resources recovery of agri-food industrial biomass by innovative pre-commercial public procurement in Castilla La Mancha Bio-Economy region",* co-financed with FEDER funds. CLAMBER project is being addressed by IRIAF (Institute for Research on Agri-food Industries and Forestry of Castilla La Mancha), which is developing a new experimental biorrefinery in Puertollano (Ciudad Real) and promoting the R&I activities of SMEs departing from biowastes and biomass resources.

This initiative is in line with the *DG Environment Policy for Biowaste* and *End-of-Waste initiative for Compost and Digestate*, which encourages MS to increase biological treatment of biowaste, the use of clean source separated input materials and the promotion of quality common standards for final products (compost, digestate, etc...) at EU level.

And also it is fully in line with the *Circular economy policy initiative*, in particular the resolution on *"Resource efficiency: moving towards a circular economy"* **of European Parliament of 9 July 2015**, which favours legally-binded targets on waste and resource use, urging the EC to submit the announced proposal on review of waste legislation by the end of 2015, applying the waste hierarchy, and **setting binding waste reduction targets** for municipal, commercial and industrial waste to be achieved by 2025 and to include **mandatory separate collection for biowaste by 2020, and** encouraging Member States to introduce **charges on landfilling and incineration**.

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REFERTIL (Grant 289785) project is co-funded by the European Commission Directorate General for Research, within the 7th Framework Programme RTD/theme 2 KBBE.