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PYROLYSIS – BIOCHAR – BONECHAR– PHOSPHORUS
FAQ - Frequently Asked Questions

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This FAQ is based on the successful results and experiences of the EU co-founded (coherently integrated science, technology development, industrial engineering, field demonstration, industrialization and commercialization) ***collaborative projects applied science and field demonstrations between years 2002-2015 under European Commission contract numbers FP5-NNE5/363/2001; FP6-Food-CT-2005-514082-PROTECTOR; CIP-Ecoinnovation-ECO/08/238984-PROTECTOR; FP7-289785-REFERTIL; biochar accredited laboratory investigations and EU regulations based accredited Authority permitting since 2005, furthermore Terra Humana Ltd. advanced pyrolysis and biochar RTD 1989 – 2015 in the fields of pyrolysis, carbon refinery, biochar, bonechar and innovative fertilizer Phosphorus recovery.*** *The REFERTIL (289785) collaborative project is co-funded by the European Commission, Directorate General for Research, within the 7th Framework Programme of RTD, Theme 2 - Food, Agriculture and Fisheries, and Biotechnology.*

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

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CHAPTER 1: General consideration for pyrolysis process

1.1. What is the pyrolysis process in general?

Pyrolysis or low temperature carbonization is a thermo-chemical decomposition of organic material between 450°C and up to 850°C material core temperatures in the absence of oxygen (air) for the main added value processing purpose to produce chemically modified carbon solid products. As such, **pyrolysis is a reductive thermal treatment process for the main purpose of refined carbon production** and opposite to the oxidative incineration and semi oxidative gasification processes for the main processing purpose to produce energy and gas. Pyrolysis is a gas-out separation process under reductive thermal treatment conditions, which involves the simultaneous change-modification of chemical composition and physical phase, separate production of solid carbon products (the main product and objective of the pyrolysis processing), pyrolysis gas-vapours (containing non-condensable gases and pyrolysis oils - organic chemistry products) and is irreversible process.

1.2. What is the general 19th and 20th century history of the pyrolysis systems?

The pyrolysis – carbonization processing - concept has been known since long time. In modern age after the **Second Industrial Revolution** 1870, also known as the Technological Revolution, rapid industrialization made for pyrolysis advancements in manufacturing and production technologies, for the purpose of production organic chemistry products. However, after the mid-nineteenth century development of radical new direction progressed in chemistry: instead of simply analyzing existing molecules, chemists began to synthesize them—including molecules that did not exist in nature. This multistep synthesis chemistry of complex organic compounds with molecules of high complexity led to full industrial development of the advanced synthetic chemical industry during the 1930's. As a result, the modern age synthetic organic chemical industrial products became less costly, 100% pure, productions made in large industrial scale, therefore rapidly phased out the costly and not pure pyrolysis organic chemistry products.

Since 1930's the organic chemistry industry lost its interest for large industrial scale pyrolysis and only smaller research projects implemented, although the activated carbon industrial connection remained**.** During the rising Digital Revolution, known as the **Third Industrial Revolution** or Information Age, from the 1970's new laboratory instruments developed and adapted, which results provided clear evidence for the complex nature of the environmental pollutions that required more strict environmental regulation in a dense populated Europe.

In early **1980's new and more strict environmental norms and standards targeted in Europe,** while the costs to achieve these new emission standards by traditional incineration turned to be expensive. Therefore, since early 1980's and following decades many alternative technologies designed (including industrial scale pyrolysis systems) by highly professional industrial teams with variating experience from different and industrially practiced traditional thermal treatment disciplines, such as incineration and gasification, but not truly specialized on pyrolysis. In many cases, design elements of known and well proven standard industrial assembly incineration and gasification elements considered as modification conversion base for pyrolysis technology alternative new design. In this context the Siemens, Babcock, Thyssen, PKA, Chemical Waste Management and others developed oxidative thermal treatment design modification conversions

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into reductive thermal treatment designs (pyrolysis). As a result for this **design modification conversion**, in many cases the different technical and economical efficiency reached at new pyrolysis applications have been low and overall performance insufficient to be market competitive. Despite spending of billions of euro since early 1980's most of these design modified pyrolysis conversions technically failed and economically closed down by now.

One of the few original solution developed since 1980's is the "3R" Recycle-Reduce-Reuse zero emission pyrolysis technology, developed by the Terra Humana Ltd. (Lang Machine Works [since 1870, Alstrom Corporation subsidy] joint venture since 1989).

Terra Humana Ltd. – since 1989 - **is specialized on pyrolysis technology, carbon refinery and recovered phosphorus products** specifically for the temperate climatic zone countries conditions (EU, USA, Canada, Australia and Japan). As far as we know Terra is the only organization in Europe with full range and core specialization in the fields of pyrolysis and carbon products from science into full industrial engineering and product applications together.

The European pyrolysis status in 2016 is that **only few pyrolysis original design system solutions remaining on the market** that has been specifically developed and designed for pyrolysis only and meets the new 21st century advanced environmental and industrial norms and standards in the EU. Furthermore, most of the other solutions are still in pilot scale with still no economical scale of capacity and only few pyrolysis systems reached advanced and economical capacity industrial scale.

1.3. What lessons has been learned from the past 150 years pyrolysis processing?

In the industrial reality it is far more **complex challenge to implement and technically operate economically viable and market competitive pyrolysis system in commercial industrial scale** than it is overoptimistic research bias considered in laboratory or at small scale pilot level.

There is no one fit for all pyrolysis technology and/or carbon product, but rather each industrial carbon processing project and product case needs to be multi approach designed case by case to fully meet towards zero emission and low carbon circular economy targets with consideration of all costs and benefits included, including environmental and climate protection and safety cost as well.

1.4. What are the future challenges in biochar research?

1) **Plant based biochar**: this type of biochar is made of plant material residuals and characterized by high carbon content, usually at 90% level, and used as soil improver with 5 – 20 t/ha doses, in average approx. 10 t/ha in wide range of agricultural cultivations. Plant based biochar does not have any fertilizer direct effect with economical importance, but rather having water and nutrient retention effects, sequester carbon in the soil; improving crop yields, nutrient cycling and in some cases immobilize trace metals. Plant based biochar application has origin in the Amazon Basin Brazilian tropical area also known as Terra Preta, "Amazonian dark earth" or "Indian black earth" (terra preta do índio) created by humans between 450BCE and 950 CE. The adaptation of the tropical Terra Preta into temperate climatic and soil conditions and in new 21st century age required significant research efforts to understand how biochar additions affect European soil properties, processes and functions.

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Past twenty years over 3500 plant based or waste derived open access biochar publications made by hundreds of biochar scientific projects[1]. The quantity, quality and breadth of research connected to biochar have grown rapidly since 2010 when a number of books and reviews were published and only in 2012 almost 300 biochar research publications made. The numbers of additional biochar studies are also significant.[2]

The past twenty years extensive fundamental research resulted basic understanding from all relevant soil, environmental and plant science disciplines how biochar additions affect soil properties, processes and functions.

Claims about the environmental benefits of charring plant residual biomass and applying the resulting "biochar" to soil are impressive. Alleged benefits include increased crop yields, soil fertility, and water-holding capacity; the most widely discussed idea is that applying biochar to soil will mitigate climate change.

Majority of these biochar science projects are up to TRL (Technology Readiness Level) 4 maturity level (technology validate in lab) and few of them are at TRL5 (technology validated in relevant environment) to TRL7 (system prototype demonstration in operational environment). However, the ultimate research maturity TRL9 (competitive manufacturing, actual system proven in operational environment) that require fully industrially engineered and EU/MS Authority permit legalized biochar production technology, product and market competitive/commercial application research structures - is still missing.

The challenge is to convert plant based biochar science into legalized practice, which is demonstrated under market competitive/commercial conditions. The legal frames for biochar industrialization already existing in the EU since decade long time on all Member State Level (all based on EU regulations) while the EU MS28 law harmonized legalization is already in final stage, hopefully in 2016/2017. Therefore TRL9 research for economical, market competitive and EU/MS Authority permitted/legalized production and productive commercial demonstration could be the prime and priority future challenge for the plant based biochar research cases for the interest and benefits for the users, including SME farmers.

2) **ABC Animal Bone bioChar**: this type of biochar is made of food grade animal bones and characterized by as high as 92% mineral carbon and 8% carbon content only. This is a full value recovered organic Phosphorus fertilizer with high calcium content. ABC is recovered organic fertilizer and growing media and horticultural used in as low as 200-1000 kg/ha doses, in average 300 kg/ha. Another specific application is the adsorbent use.

Industrial scale bone char has been produced in Europe and successfully field applied since 1870 for both in the agricultural and adsorbent sectors that resulted development of extensive knowledge base and experience about productions and applications in different climatic and soil conditions. However the over century old bone char production technologies cannot be applied anymore, as do not meet the 21st century European industrial and environmental norms and standards. In 2002 the Terra Humana Ltd. started a new generation ABC specific phosphorus recovery technology and product systematic development with combined science and industrial engineering efforts under large scale EU FP5, FP6, FP7 and CIP Ecoinnovation RTD projects.

Advanced S&T developed to manage Knowledge-Gap solutions. This 14 years development series successfully completed at TRL8 (system complete and qualified) maturity by the end of 2015,

[1] International Biochar Initiative http://www.biochar-international.org
[2] http://digital.csic.es/bitstream/10261/93245/4/ Biochars_soils.pdf

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including development of EU biochar standardization and law harmonization policy support elements. As ABC is a result of the Terra Humana Ltd. company innovation and RTD with specific and confidential know-how, only few open access publications published.

In next TRL9 research for economical, market competitive and EU/MS Authority permitted/legalized production and productive commercial demonstration is the prime challenge in the ABC biochar research case for the interest and benefits for the users, including SME farmers.

The 2016/2017 targeted economical throughput production capacity of the replication model is 6500 t/y (that equivalent with 4000 t/y output), which is further expandable to 20,800 t/y nominal capacity (that equivalent with 12,500 t/y output).

1.5. How can we define the industrial scale pyrolysis system?

The European REACH regulation EC1907/2006 system is defining pyrolysis system and products as chemically modified substances, therefore REACH is providing clear and transparent scenario for manufacturing, import, placing on the market and use under 1 t/y research capacity and above 1 t/y industrial – commercial capacity. The 1 t/y capacity limit will enter in force by 2018, while in 2016 the limit is already as low as 10 t/year. To build and operate laboratory pyrolysis systems below <1 t/y capacity is rather common activity at basic research units. This laboratory construction and operation is not challenging technologically at all but expensive in cost. As the laboratory conditions <TRL6 are far away to mimic industrial scale up conditions and not containing critical industrial scale elements, therefore the laboratory pyrolysis output information and experience are basic scientific that requires further industrial scale ups to get true value and implementation oriented results.

1.6. What is the “TRL” Technology Readiness Level maturity road map to convert science into market competitive industrial practice?

The use of Technology Readiness Levels (TRLs) as a measurement of the maturity level of particular technologies is a new development in Horizon 2020. This measurement system provides a common understanding of technology status and addresses the entire innovation chain. By evaluating a technology project against the parameters for each Technology Readiness Level (see below), one can assign a TRL rating to the project based on its stage of progress. There are nine technology readiness levels; TRL 1 being the lowest and TRL 9 the highest.

Technology Readiness Levels (TRL)[3] are a method of estimating **technology maturity** of Critical Technology Elements of a program during the acquisition process, and used as an objective driven tool for decision making on R&D investments at EU level. TRLs are determined during a Technology Readiness Assessment that examines program concepts, technology requirements, and demonstrated technology capabilities. TRLs are based on a scale from 1 to 9 with 9 being the most mature technology. The use of TRLs enables consistent, uniform, discussions of technical maturity across different types of technology.

[3] Commission Decision C(2014)4995

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TRL 1-9 scientific research programme road map to convert science into market competitive industrial practice:

TRL	Technology Readiness Level	Description	Supporting information
1	Basic principles observed	**Basic scientific research**	Published research with references, IPR considerations.
2	Technology concept formulated		
3	Experimental proof of concept		
4	Technology validated in lab		
5	Technology validated in industrially relevant environment	**Pilot plant demonstration**	Test evaluation protocols
6	Technology demonstrated in industrially relevant environment		
7	System prototype demonstration in operational environment	**Field demonstration**	"Product like" test evaluation protocols, risk/cost-benefit analyses, market evaluations, manuals, unique selling point / business plan developments
8	System complete and qualified, full industrial engineering		
9	System proven in operational environment with competitive manufacturing	**Industrial replication model for full production**	Market competitive production/commercial demo, BAT/BREF documentation.

1.7. What are the tentatively and approx. estimated "TRL" risk and industrial implementation factor profiles for RTD objective driven scale up of pyrolysis systems and biochar products?

TRL	Technology Readiness Level	Scale up approx. estimated risk factor %	Scale up implementation factor %
1	Basic principles observed	Basic scientific research **Technical: 100% risk** **Commercial: 100% risk**	**Technical: <10%** (pre-concept) **Commercial: 0%**
2	Technology concept formulated		
3	Experimental proof of concept		
4	Technology validated in lab		
5	Technology validated	Pilot plant demo **Technical: 70 -95 % risk** **Commercial: 100% risk**	**Technical: <30%** (concept) **Commercial: 0%**
6	Technology demonstrated		
7	System prototype demonstration	Field demo **Technical: 20-25 % risk** **Commercial: 50-70 % risk**	**Technical: <80%** ("product like") **Commercial:<20%**
8	System complete and qualified		
9	**System proven with competitive manufacturing** **END OF THE RESEARCH**	First replication model **Technical: 2-10 % risk** **Commercial: 5-20 % risk**	**Technical: <95%** (proven demo) **Commercial:<90%**
	COMMERCIAL PRODUCTION	Technical: 1-5 % risk Commercial: 3-10 % risk	**Technical: <98%** **Commercial:<98%**

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Up until the end of 2015 most pyrolysis systems and biochar products in the EU are extensively and sufficiently scientific researched at low TRL 1-5. Therefore, the 2020 challenge is to make pyrolysis/biochar science to achieve results and to convert science into market competitive industrial practice. There is an increased pressure on the environmental and climate protection, resource conversions and recycling with proven demonstrated industrial results. Therefore the "*time to market*" from low TRLs towards high TRL direction needs to be shortened and speed up for the pyrolysis and biochar cases.

Low TRL means **high** technical, economical and commercial **risks during scale up**, while high TRL means eliminated – or at least minimized and controlled - technical, economical and commercial risks. **Low TRL** means **low** technical, economical and commercial **scale up implementation factor** during scale up, while high TRL means high technical, economical and commercial implementation factor.

Therefore, it is critically important to make complex, comprehensive and coherent integration aspects already from the beginning of the low TRL scientific research programme, and having a master plan or at least a vision for targeted high TRL scale up steps.

These coherently integrated aspects and considerations through all the TRL maturity phases including

- ✓ application oriented scientific understanding,
- ✓ efficient industrial technology with scale up engineering,
- ✓ commercial product objective driven outputs,
- ✓ sustainable economy of all elements according to market competitive conditions,
- ✓ environmental and climate protection aspects,
- ✓ EU/MS regulations and mandatory Authority permits and
- ✓ user oriented market competitive product systems.

At the end, **the TRL9 is the only true value technical, economical and commercial proven demonstrated research level for all united efforts to convert science into market competitive and legalized industrial practice where the elevated risks are truly identified, eliminated and/or minimized during the scale up process, - while the Knowledge Gap solution is proven demonstrated.**

1.8. How much is challenging to operate modern pyrolysis systems in the 21st century?

PLANT BASED BIOCHAR COMMERCIAL PROCESSING: making plant based biochar products in **small scale** (few hundred tons/year) **is technically not much challenging**, but usually not economical in the temperate climatic zone countries with high overall costs. However, the environmental challenge of these small units is still high, because of the high yield production of pyrolysis oils that are toxic substances.

At higher industrial scale (for which the economical throughput is estimated from approx. 6500 t/y under European conditions) **the plant based biochar is already a complex technological, environmental, economical and commercial challenge,** as this in fact is already a chemical factory that is operational around 450°C material core temperature. Plant based biochar processing and technology units are not enough qualified and not applicable for animal bone processing that require different and far higher technology processing level than plant based biochar units.

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ANIMAL BONE BASED BIOCHAR COMMERCIAL PROCESSING: processing of animal bone and achieve high quality bone char product is technologically **highly challenging in all scale and all configurations**. The modern processing of animal bone – that meets all the advanced 2020 EU industrial and environmental norms and standards - require **complex and advanced high end technology** with material core temperature up to <850°C and specific product post formulation conditions.

CHAPTER 2: Permitting and legal issues

2.1. Does it require any EU/Member State Authority permit to install/operate a pyrolysis plant?

YES, in Europe there is mandatory requirement to get permit from the MS Authorities according to EU regulations to install/operate a pyrolysis plant for commercial production of all and any types of biochar and usually ten advising Authorities involved in this mandatory permit process. The REACH regulation is also defining mandatory certificate for manufacturing of commercial biochar above 1 t/y capacity.

2.2. Does it require any EU/Member State Authority permit to use biochar?

YES, there is mandatory requirement to get permit from the MS Authorities to commercialize and commercial use biochar (both plant based and animal bone biochar) in agriculture in any production ranges in the EU, which is having three mandatory elements:

1) **Mandatory MS Authority permit** to commercial use biochar, valid in the applicant MS only with possibility for **Mutual Recognition (Reg. EC 764/2008)** in EU28. As soon as the revision of the EC 2003/2003 Fertilizer Regulation proposed to include biochar (as expected in 2018/2020), than this EU regulation will be valid in all EU28 Member States (EC Biochar). In case the MS defined stricter standard than the EC Biochar, than this upgraded standard will be valid and applied.
2) **"REACH" certification** (Registration, Evaluation, Authorisation and Restriction of Chemicals[4]) is mandatory for import, manufacturing, placing on the market and use of biochar above 1 t/y capacity (1 t/y is valid from 2018 but in 2016 the mandatory certification limit is already above 10 t/y). "REACH" certification is a complex eco toxicological investigation measured according to GLP (Good Laboratory Practice) and is highly challenging both technically and from cost point of view as well.
3) **"EPR" Extended Producer Responsibility** certificate.

2.3.What are the criteria for production of biochar in the EU?

The **carbon negative biochar application** conditions must meets the European Union and Member State criteria regulations and policy together, including elements such as

[4] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006R1907-20150601&from=EN

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- **FIT FOR USE**: the biochar is commonly used for specific agricultural and environmental purposes;
- **LEGALIZED**: Authority permitted, fulfils all the technical requirements for the specific purposes, meets the existing legislation and standards applicable to biochar in the temperate climatic zone countries;
- **SAFE**: the use of the biochar will not lead to overall adverse environmental or human health impacts and market demand exists.

2.4. Are voluntarily biochar certificates providing legal right to use biochar in the EU?

No, voluntarily biochar certificates do not have any technical/legal effects and validity in the EU. In this context only the mandatory, EU/MS regulations based and Authority issued official permits providing the technical and legal frames for the lawful use of all and any types of biochar in the EU.

2.5. What are the aims of the revision of the EC 2003/2003 Fertilisers Regulation?

Related to the Circular Economy Package:

The Fertilisers Regulation revision aims at establishing a regulatory framework enabling production of fertilisers from recovered bio-wastes and other secondary raw materials. This would boost domestic sourcing of plant nutrients which are essential for a sustainable European agriculture, including the critical raw material phosphorus. [5]

Related to the Internal Market Strategy:

The initiative supports the aim to create a deeper and fairer internal market with a strengthened industrial base, by removing existing barriers to free movement of certain innovative fertilisers and facilitating the market surveillance by Member States. The Fertilisers Regulation revision aims at addressing a well-known barrier to free movement on the internal market. [6]

2.6. What is the political context of the revision of the EC 2003/2003 Fertiliser Regulations?

The initiative supports the Commission's agenda for jobs, growth and investment, by providing the right regulatory environment for investment in the real economy. In particular, the initiative will make an important and concrete contribution to the Commission's fulfilment of its commitment to submit a new, more ambitious Circular Economy Package by the end of 2015. It will create a level playing field for all fertiliser materials and facilitate recourse to domestic, secondary raw materials. [7]

[5] Roadmap to the Revision of the Fertilisers Regulation (EC) No 2003/2003, http://ec.europa.eu/smart-regulation/roadmaps/docs/2012_grow_001_fertilisers_en.pdf

[6] Roadmap to the Revision of the Fertilisers Regulation (EC) No 2003/2003, http://ec.europa.eu/smart-regulation/roadmaps/docs/2012_grow_001_fertilisers_en.pdf

[7] Roadmap to the Revision of the Fertilisers Regulation (EC) No 2003/2003, http://ec.europa.eu/smart-regulation/roadmaps/docs/2012_grow_001_fertilisers_en.pdf

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2.7. What are the main problems which the revision of the EC 2003/2003 Fertilisers Regulation will address?

1. **DIFFICULTIES ACCESSING THE INTERNAL MARKET: Innovative fertilisers**, often containing nutrients or organic matter recovered and recycled from bio-waste or other secondary raw materials in line with the circular economy model **have difficulties accessing the internal market due to the existence of diverging national rules and standards**. The Fertilisers Regulation ensures free movement on the internal market of a class of harmonised inorganic products belonging to one of the product-types which have been approved by the Commission in comitology and are included in one of the Annexes to the Regulation. Such products are eligible to be labelled 'EC fertilisers'. The playing field in the competition between those fertilisers sourced from domestic organic or secondary raw material in line with the circular economy model and those produced in line with a linear economy model is tilted in favour of the latter. **Around 50 % of the fertilisers currently on the market, however, are left out of the scope of the Regulation.** This is true for a **few inorganic fertilisers and for all fertilisers produced from organic materials**, such as animal or other agricultural by-products, or recovered bio-waste from the food chain. [8]
2. **PHOSPHATE ROCK IS CRITICAL RAW MATERIAL. The problem is aggravated by the fact that one of the main fertiliser constituents is phosphate rock, which has been identified by the Commission as a critical raw material.** For phosphate fertilisers, the EU is currently highly dependent on import of phosphate rock mined outside of the EU (more than 90% of the phosphate fertilizers used in the EU are imported, mainly from Morocco, Tunisia and Russia). This while domestic waste (in particular sewage sludge) contains large amounts of phosphorus, which – if recovered in line with a circular economy model – could potentially cover about 20-30% of EU's demand of phosphate fertilisers. [9]
3. **The Fertilisers Regulation fails to address environmental concerns arising from contamination of soil, and ultimately food**. A **well-recognised issue is the presence of cadmium in inorganic phosphate fertilisers**. In the absence of EU limit values, some Member States have imposed unilateral cadmium limits for EC-fertilisers by virtue of Article 114 TFEU, hence creating a certain market fragmentation also in the harmonised field. The presence of contaminants in those fertilisers which are currently subject to national rules (e.g. fertilisers derived from sewage sludge) poses similar concerns. [10]

2.8. Who will be affected the revision of the EC 2003/2003 Fertilisers Regulation?

1. The initiative will mainly affect those **producers of innovative fertilisers produced from organic or secondary raw materials in line with the circular economy model, who will be able to reach a critical mass through radically facilitated access to the internal market**. Such producers will benefit from the initiative in particular in those Member States which are not providing a sufficiently large home market for new types of fertilisers.

[8] Roadmap to the Revision of the Fertilisers Regulation (EC) No 2003/2003, http://ec.europa.eu/smart-regulation/roadmaps/docs/2012_grow_001_fertilisers_en.pdf
[9] Roadmap to the Revision of the Fertilisers Regulation (EC) No 2003/2003, http://ec.europa.eu/smart-regulation/roadmaps/docs/2012_grow_001_fertilisers_en.pdf
[10] Roadmap to the Revision of the Fertilisers Regulation (EC) No 2003/2003, http://ec.europa.eu/smart-regulation/roadmaps/docs/2012_grow_001_fertilisers_en.pdf

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2. Private and public recovery operators
3. National authorities: decreased workload when national registration or authorisation systems for fertilisers are fully or partially replaced by EU-wide control mechanisms
4. Farmers and other fertiliser users: increase in the product variety
5. General public: will be better protected from contamination of soil, water and food. [11]

2.9. How the REFERTIL project contributed to the revision of the EC 2003/2003 Fertilisers Regulation?

The REFERTIL project (EU contract no 289785, official web: http://www.refertil.info) has been specifically selected by the EU Commission **to develop key science, technology, legal and full harmonization elements and standards for the EC 2003/2003 Fertilisers Regulation revision in the cases of biochar and Phosphorus recovery.** As core element this policy support work is based on the pyrolysis and biochar specialized Terra Humana Ltd +30 years and multi approached biochar specific experience and knowledge.

The REFERTIL consortium has been reviewed the respective EU directives, regulations and also the relevant MS national legislations. Several workshop meetings have been organized with the EU Commission representatives in 2012-2015 for joint considerations and also wide range of European biochar science and technology groups have been consulted for knowledge and experience exchange in this new and complex biochar case. REFERTIL provided a strong policy support for the EU Commission in revision of the Fertiliser Regulation for inclusion of biochar - as safe organic fertiliser and soil additive:

- Uniting all the knowledge and experience generated during the REFERTIL project time.
- **DEVELOPMENT of S&T knowledge:** REFERTIL biochar applied scientific research, industrial engineering, legal and economical aspects under market based commercial conditions.
- **Biochar legal aspect overview** and evaluation.
- **Biochar economics sustainability** evaluation under market based commercial conditions.
- **Setting up quality and safety criteria** for biochar (plant based, bone based, waste derived):
    - Includes mandatory elements with limit values
    - Declaration based elements for self validation
    - Includes risk assessment (soil and groundwater)
- Development of harmonized and standardized analytical measurements for determination of the physic-chemical properties, potentially toxic element content and organic pollutants in the biochar materials.
- Regular meeting with the Commission, public consultation with international biochar vendors and stakeholders.

[11] Roadmap to the Revision of the Fertilisers Regulation (EC) No 2003/2003, http://ec.europa.eu/smart-regulation/roadmaps/docs/2012_grow_001_fertilisers_en.pdf

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Refertil harmonized and standardized biochar analytical measurements:

All measurements and analytics made by the REFERTIL have been accredited (Wessling Laboratories http://de.wessling-group.com/de/). Wessling is also the first and presently the only accredited laboratory in Europe who received international accreditation for biochar specific measurements. The main results of the accreditation work:

- Determination of quality & safety performance of biochar, internationally accredited methods and standards are needed.
- The accreditation of the analytical activities related to the REFERTIL project was an important step.
- Supporting the legal standardization and mandatory permit process of biochar industrial production.
- Most of the standards selected for biochar qualification were chosen from among currently valid CEN/ISO standards.
- Biochar is a new product, for a number of parameters it was necessary to adopt soil or waste analytical methods, which were validated to assess their analytical performance.
- The Environmental Testing Laboratory of WESSLING Hungary Ltd. is the first laboratory in Europe who obtained accredited status, under Wessling-NAT-1-1398/2012 (2014.10.08) for comprehensive analyses of biochar samples. **According to the Mutual Recognition Agreements[12] [13], activities of NAT and organizations accredited by NAT are recognized internationally by all other signatories. According to Regulation EC 765/2008, authorities of the member states of the European Union are obligated to accept the results of organizations accredited by NAT.**

The REFERTIL also demonstrated official and **accredited biochar Authority permit cases** according to the EU regulations, for large industrial pyrolysis installation, operations, manufacturing and applications for commercial purposes, such as:

- ✓ **Industrial scale pyrolysis plant installation and operation permit** number: FES/01/0851-33/2015 (Issuing Authority Industrial Safety Inspection and ten other advising Authorities).
- ✓ **ABC Anima Bone bioChar product horticultural application permit** number: 02.4/102-2/2015 (original biochar permit 02.5/67/7/2009 issued in 2009 after four years efficiency and safety tests and CLP upgraded in 2015).

The REFERTIL EC 2003/2003 Fertilisers Regulation revision biochar and Phosphorus recovery cases standardization and EU28 law harmonization policy support is available on the following website: http://refertil.info/biochar-policy

[12] Multilateral Agreement of the European Cooperation for Accreditation (EA MLA) in the areas of analysis, calibration, control, product certification, management system certification and person certification.

[13] Mutual Recognition Arrangement of the International Laboratory Accreditation Cooperation (ILAC MRA) in the areas of analysis and calibration.

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2.10. What are the REFERTIL recommended maximum allowable limit key values for biochar?

REFERTIL recommended Biochar parameters (Notice)	ORGANIC P-FERTILISER	SOIL IMPROVER
Potential toxic elements (mg/kg)		
As	10	10
Cd	1.5	1.5
Cr	100	100
Cu	200	200
Pb	120	120
Hg	1	1
Ni	50	50
Zn	600	600
Organic pollutants		
PAH_{16} (Notice)	6	6
PCB 7	0.2	0.2
PCDD/F (ng/kg I-TEQ)	20	20
Particle size distribution	ABC: 1-5mm, 90%	PBC: 1-20 mm, 90%
Bulk density	declaration	declaration
Dry matter content	>80%	>60%
pH	6 - 10	6 - 10
Total Organic C	declaration	20%
N and K total	declaration	declaration
Total P (P_2O_5)	>25%	declaration
Total Ca, Mg	declaration	declaration
Germination inhibition assay	No inhibition	No inhibition
Phytotoxicity	No phytotoxicity	No phytotoxicity
Agronomic efficiency	Should be proved	Should be proved

Notice: all proposed parameters are maximum allowable limits on EU level, which in justified environmental cases may be MS amended to lower limits. PAHs are key performance indicators. In some MS PAH_{19} one mg/kg is permitted only since long time as maximum limit for soil improver. Biochar producer's extended responsibility and liability for product safety to be applied.

Cadmium is a challenging element and there are discussions about the range of maximum allowable limit from 1 mg/kg to other higher limits.

Chapter 6 of this FAQ is providing more information on the risk of biochar use (see page 32).

2.11. What is the EU Circular Economy Package?

The Commission adopted an ambitious new Circular Economy Package to stimulate Europe's transition towards a circular economy which will boost global competitiveness, foster sustainable economic growth and generate new jobs. [14]

The Circular Economy Package consists of an **EU Action Plan for the Circular Economy**[15] that establishes a concrete and ambitious programme of action, with measures covering the whole cycle: from production and consumption to waste management and the market for secondary raw materials. The proposed actions will contribute to **"closing the loop" of product lifecycles through greater recycling and re-use, and bring benefits for both the environment and the economy**. The Circular economy offers an opportunity to reinvent our economy, making it more sustainable and competitive. This will bring benefits for European businesses, industries, and

[14] http://europa.eu/rapid/press-release_IP-15-6203_en.htm

[15] Closing the loop - An EU Action plan for the Circular Economy, http://ec.europa.eu/priorities/jobs-growth-investment/circular-economy/docs/communication-action-plan-for-circular-economy_en.pdf

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citizens alike. With this new plan to make Europe's economy cleaner and more competitive, the Commission is delivering ambitious measures to cut resource use, reduce waste and boost recycling.[16]

Important element of the EU Circular Economy Strategy is boosting the market for secondary raw material (= from waste to resources).

Recycled nutrients are a distinct and important category of secondary raw materials, for which the development of quality standards is necessary. They are present in organic waste material, for example, and can be returned to soils as fertilisers. Their sustainable use in agriculture reduces the need for mineral-based fertilisers, the production of which has negative environmental impacts, and depends on imports of phosphate rock, a limited resource. In order to address this situation, the Commission will propose a revision of the EU regulation on fertilisers. This will involve new measures to facilitate the EU wide recognition of organic and waste-based fertilisers, thus stimulating the sustainable development of an EU-wide market.

In order to address this situation, the **Commission will propose a revision of the EU regulation on fertilisers.** This will involve new measures to facilitate the EU wide recognition of organic and waste-based fertilisers, thus stimulating the sustainable development of an EU-wide market. [17]

Important element of the EU Circular Economy Strategy is a revised regulation on fertilisers, to facilitate the recognition of organic and waste-based fertilisers in the single market and support the role of bio-nutrients.

[16] http://ec.europa.eu/environment/circular-economy/index_en.htm
[17] Closing the loop - An EU Action plan for the Circular Economy, http://ec.europa.eu/priorities/jobs-growth-investment/circular-economy/docs/communication-action-plan-for-circular-economy_en.pdf

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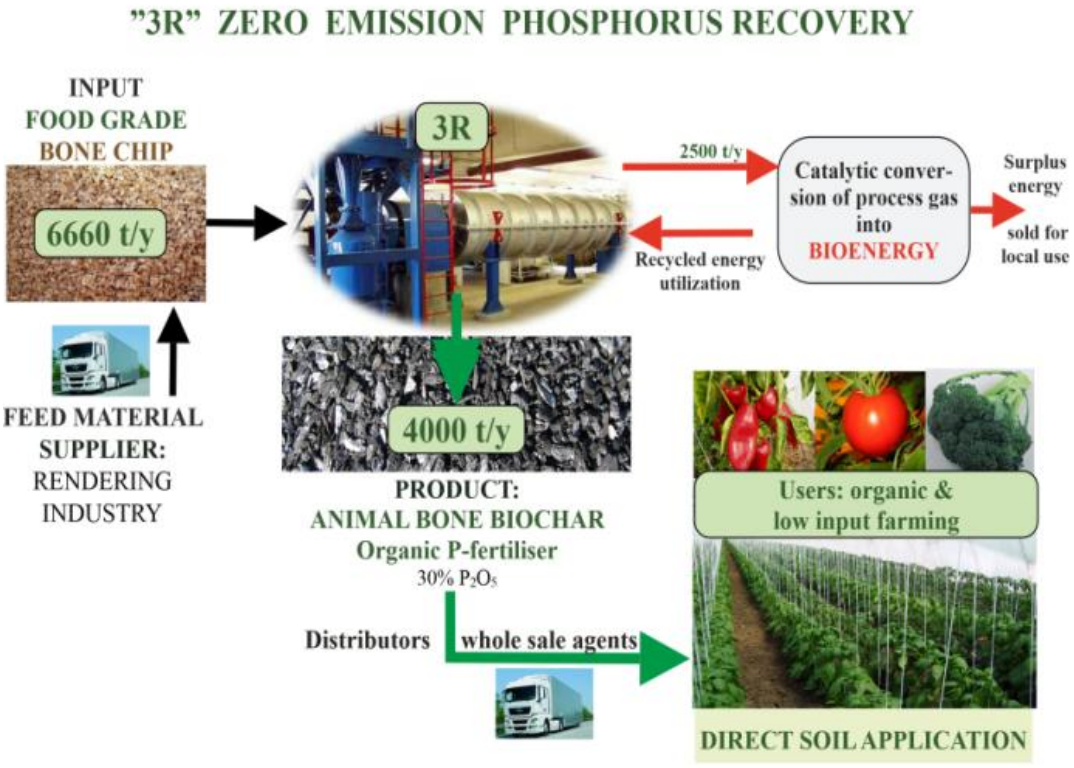
CHAPTER 3: The 3R zero emission pyrolysis process

3.1. What is the concept of 3R Zero Emission Carbon Refinery and Phosphorus Recovery processing?

The "3R" Recycle–Reduce-Reuse Zero Emission Carbon Refinery and Phosphorus Recovery processing is a mimic of the Nature that emits no any waste products that pollutes the environment or disrupts the climate, in which process all and any materials and energy are recycled and reused into useful products.



The Nature cannot afford to waste materials and/or waste of energy, while it always finds the most efficient material and energy recycling, recovery and reuse conversion pattern during the ever ongoing bio-geo-chemical cycles. In order to mimic the Nature, the 3R bio-geo-chemical process - where it is possible, necessary and/or advantageous - coherently integrates the carbon, phosphorus and nitrogen related cycles, such as:

- ✓ **Carbon Recycling and Refining**, thermal processing by carbonization for recycling of carbon for wide range of natural and carbon negative product applications.
- ✓ **Carbon Bio-formulation**, biotech formulation of carbon for efficient bio and plant availability of NPK nutrient uptake process support.
- ✓ **Phosphorus recovery from animal by products**, including NPK-C and micronutrient formulations.
- ✓ **Carbon Bio-energy**, chemical processing of pyrolysis gases and oils for liquid fuel bio-energy production.

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3.2. What are the sustainability criteria of 3R process?

The feed materials of the 3R do not compete with human food, animal feed and plant nutrient supply. The inputs are always low grade non food by-products or waste streams generated by human activities, and not from primer or secondary agricultural land use that are related to food production. The high feed flexibility provides high added value and wide range of different types of output products together with wide range of market demanded application possibilities targeted in the rapidly developing natural soil fertilization agro market, green energy and environmental adsorbent business.

3.3. What is the 3R pyrolysis?

The 3R is knowledge for resource added value conversion and recovery.

The 3R **R**ecycle-**R**euse-**R**educe is a **zero emission low temperature carbonization (pyrolysis) – reductive thermal decomposition processing**. The 3R slow pyrolysis process is based on a horizontally arranged indirectly heated rotary kiln designed for reductive thermal decomposition of plant and/or animal origin biomasses between 450 °C (842 °F) - 850 °C (1562 °F) material core temperature ranges in vacuum (absence of oxygen).

The system works with zero emission, comprehensive recycling and reuse of all process materials and gases. The target of the 3R Zero Emission Pyrolysis Process is the added value upgrading/valorisation of agro/food industrial organic by-products into safe and high value soil amendment and nutrition products.

Pyrolysis of biomass substances produces solid residue rich in carbon content “biochar” and separated volatile crude pyrolysis gas which may be condensed into liquid crude oil and non condensable gases. After catalytic conversion of crude pyrolysis liquid and/or gas products, synthetic fuel and transport quality bio-oil produced. The 3R pyrolysis is safer, better, faster, more economical and environmental friendly than any other solutions.

The 3R system is also integrated into the novel agro biotechnological – solid state fermentation and formulation, and syngas/synthetic biofuel processing units.

The 3R is an engineered full scale industrial design, that development has been completed by the end of 2015.

3.4. What is the 2016 status of the 3R Technology?

The status of the 3R technology is ready-for-commercialization, e.g. post development, industrially proven and field demonstrated and clearly achieved full scale industrial phase; with comprehensive fully scaled up engineering design and approved Authority permits. The 3R technology is original solution, protected by comprehensive and very specific industrial engineering design know-how, which is well documented and prepared for technology transfer during replication phase.

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The 3R **technological solution has already been successfully true industrial value real life and long termed tested 2004 – 2015. The 3R refined carbon products successfully real life field tested in several EU countries and in Israel**. The prototype system has been "industrial product like", including all components and elements of scale up, therefore no potential technical reasons are expected that it will not work in larger scales. Thus, the technological risk is limited to almost zero, e.g. to same as for any commercial solutions. However, still need a push from proven prototype to industrialization level.

3.5. What economical industrial process throughput capacities are available for the 3R pyrolysis technology?

The **nominal capacity** of the standard 3R system (or the average capacity) for single rotary kiln installation is from the economical 2.6 tons/hour or 20,800 tons/year throughput capacity with 8000 h/year operation (depending on the input moisture content), which is ~80% utilization of the system.

Depending on the feed material characteristics and the objectives for the economical added value product valorisation 5 tons/hour or 40,000 tons/year, 15 tons/hour or 120,000 tons/year and 15 tons/hour or 240,000 tons/year throughput capacities are also available. Individual industrial projects require project specific considerations where input and output quantities may vary.

3.6. What is the basic economy in full scale 3R Phosphorus recovery production?

It is calculated that the EXW (EX Works whole sale, e.g. the ABC is ready for pickup at production place and all other transportation costs and risks are assumed by the buyer) production costs of mineral fertilisers are 1.8 – 2.4 €/kg P, while the end-user price to farmers being around 2 times higher after marketing and distribution costs. It is calculated that the EXW production costs of the ABC innovative and recovered Phosphorus fertilizer is approx. 2.1 – 2.4 €/kg P (before marketing and distribution costs).

3.7. Which are the key milestones of the RTD & implementation of the 3R industrial pyrolysis system?

		
PILOT **1990-1995**	**FIELD DEMO** **2004-2015**	**FULL INDUSTRIAL** **2016**
3R pyrolysis technology pilot plant	3R pyrolysis technology field demo plant	Full industrial TRL9 plant with 20,800 t/y throughput capacity

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Operational field: from applied science to economical scale up industrialization for commercial applications. Road map to 3R development:

TRL 1	basic principles observed (**1983**)
TRL 2	technology concept formulated (**1985**)
TRL 3	experimental proof of concept (**1985**)
TRL 4	technology validated in lab (**1990-1995**), pilot operations
TRL 5	technology validated in relevant environment (**2002-2005**) EU FP5 NNE5/3636/2001
TRL 6	technology demo in relevant environment (**2005-2009**) EU FP6 Food-CT-2005-514082 and EU CIP ECOINNOVATION ECO/08/238984 **(2009-2011)**
TRL 7	system prototype demo in op. environment **(2011-2014)** EUFP7 REFERTIL 289785
TRL 8	system complete and qualified (**2015**) EUFP7 REFERTIL 289785
TRL 9	actual system proven in operational environment (industrial/commercial replication model 20,800 t/y throughput BAT/BREF - P recovery plant **(2016**)

3.8. What kind of energy supply is needed for the 3R system?

The 3R is an energy self sustaining pyrolysis system with comprehensive energy recycling during standard performance. During **thermal heat up process two versions are available** (selection depends on the project conditions)

- **Electrical heating**: 2 units of onsite “isle mode” 1 MWe rated capacity (refurbished recommended) biooil driven gensets installed, total 2 MWe, with nominal output 1,4 MWe at 70% utilization. The gensets operated for 16 hr start and heat up, than for production of 725 kWh electric consumption and 675 kWh to grid connection for sale (5,000 MWe).
- **Oil/gas fired system**: bio-oil or gas fired heating up procedure.

In all cases the 3R is energy self sustaining.

3.9. Does the 3R technology and products providing environmentally safe solution?

Yes, the 3R technology and products are fully safe and sustainable solutions. The 3R process total safe output natural products made for any open ecological soil or environmental applications. The full life cycle of 3R technology and product starting from feed material supply via processing to formulation into a product for open ecological application is certified for environmental sustainability and meets all major international, industrial and environmental norms/standards, especially of the targeted markets in the EU, USA, Canada, Australia and Japan.

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3.10. Is the 3R technology officially Authority permitted?

YES, both the 3R pyrolysis technology and 3R bone based biochar product (recovered Phosphorus fertiliser) is fully permitted by EU MS Authorities under the strict EU regulations.

- ✓ **Industrial scale pyrolysis plant installation and operation permit number**: **FES/01/0851-33/2015** (Issuing Authority Industrial Safety Inspection and ten other advising Authorities).

- ✓ **ABC Anima Bone bioChar product horticultural application permit number**: **02.4/102-2/2015** (original biochar permit **02.5/67/7/2009** issued in 2009 after four years efficiency and safety tests and CLP upgraded in 2015 by National Food Chain Safety Office, Directorate for Plant Protection, Soil Conservation and Agri Environment).

3.11. Who owns the IPR of the 3R?

The 3R pyrolysis technology, process, industrial design and product formulations are original solutions; which are developed, invented and designed by Edward Someus. The sole owner of the 3R IPR is the sole inventor, developer and the 3R technology industrial engineering designer Edward Someus.

3.12. What are the key competitive advantages of the 3R technology over other pyrolysis options?

Many known pyrolysis options are alternative modifications for incinerator or gasification options which are generally experienced not to be functional in industrial scale. Since 1980's several multinational companies set up traditional system modified thermal treatment programs with different gasification and reductive processing design, but mostly failed. The 3R recognition has been that advanced and efficient pyrolysis designs must be managed for the reductive thermal processing only and experiences cannot be overtaken from other types of thermal processing units. The 3R is

1. not a modified traditional thermal treatment design, but rather an comprehensive original solution that is specifically objective driven developed for high efficient and high temperature indirect heat transfer and maintenance of true reductive thermal processing conditions in vacuum,
2. although the 3R complex and advanced design, it does not to contain exotic technical solutions and materials,
3. is a zero emission solution for primary designed applications, where all and any material streams are recycled and reused, same as done by the nature,
4. auxiliary installations are also specifically objective driven developed and designed for the pyrolysis conditions, and
5. having feed flexibility, continuous and automated throughput.

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3.13. Is 3R an European Union Commission project?

Yes, this is an official and high priority project financial supported by the European Union in Brussels since 2002 executed under the European Commission Directorate General (DG) Energy and Transport, DG Agriculture, DG RTD and CIP Ecoinnovation programmes. For the EU27 compost and biochar standardization (EC2003/2003 Fertilizer Regulation revision biochar case) works info is available at http://www.refertil.info .

CHAPTER 4: The feed materials for the 3R technology

4.1. Which types of feed materials are processed by the 3R and what are the major application areas of the 3R technology?

BIOMASS to RECOVERED ORGANIC PHOSPHORUS FERTILIZER:

- ✓ Category 3 and 2 bone meal (all types) animal by-product: **phosphate recovery** from food grade animal bone.
- ✓ Sea food by-products (fish bone, calcareous shell of molluscs, crust shells of crustaceans).

BIOMASS to SOIL IMPROVER:

- ✓ Plant based agricultural and forest industrial by-product material streams.
- ✓ Any other by-product and waste material streams.

BIOMASS to ADSORBENT: Specific and high quality activated carbons and adsorbents, such as ABC Animal Bone Char and coconut shell activated carbon based adsorbents, including virgin products and regenerations.

BROWNCOAL to ANTRACITE Clean Coal: Conversion of high moisture and Sulphur **content brown coal into anthracite type clan coal** and liquid fuel.

BIOMASS to LIQUID BIOFUELS:

- ✓ Category 3 and 2 MBM meat and bone meal / PAP processed animal protein (all types).
- ✓ Category 1 animal rendered SRM products (all types).

4.2. What are the animal by-product categories?

- **Category 3 FOOD GRADE:** parts of animals that have been passed fit for human consumption in a slaughterhouse but which are not intended for consumption. Category 3 material also includes former foodstuffs (waste from food factories and retail premises such as butchers and supermarkets). Catering waste, including domestic kitchen waste is category 3 material.
- **Category 2 INDUSTRIAL GRADE:** rendering waste includes fallen stock, animal manure and digestive content, also default status of any animal by-product not defined as either category 1 or category 3 materials.

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- **Category 1 specified risk material,** including pet, zoo, circus and experimental animals. Wild animals may be classified as category 1 material when they are suspected of carrying a disease communicable to humans or animals.

4.3. What is MBM?

Meat and Bone Meal is a product of the animal waste rendering industry. It is typically about 50% protein, 35% ash, 8-12% fat, and 4-7% moisture. MBM is no longer allowed in feed for ruminant animals.

4.4. What is PAP?

Processed animal protein is defined in Animal By-product Regulation, Regulation (EU) No 142/2011[18] as animal protein derived entirely from Category 3 material, which has been treated in accordance with Section 1 of Chapter II of Annex X (including blood meal and fishmeal). PAP not intended for human consumption, including mixtures and products other than pet food containing such protein:

- Must come from an approved country,
- Must come from an approved/registered plant,
- Must be accompanied by an animal health certificate.

4.5. Can all kind of animal livestock bones (eg. pigs, poultry, sheep, goat, horse etc.) be converted into bone meal that is needed for the 3R technology?

All types of animal bones can be converted into bone meal that is needed for the 3R pyrolysis technology input. Mainly standard **food grade category 3 pig and cattle bones are used**. Mainly mammal and avian bones utilized for producing high quality bone char for natural phosphate (with >30% P_2O_5) and mineral recycling. Different bone characteristics will be reflected in the bone char performance; for instance, sheep, horse and goat bones are denser, whereas the avian bones are more porous and lighter.

[18] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:054:0001:0254:EN:PDF

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CHAPTER 5: The 3R refined carbon and recovered organic fertiliser products

5.1. What is biochar?

Biochar is **plant or animal biomass origin stabile carbon based carboniferous material** for Authority permitted open ecological soil enhancement use and eco-safe carbon negative applications in the agricultural and forestry sectors. The high mineral content **animal bone based bioc**har (ABC Animal Bone bioChar) is **organic P/Ca fertiliz**er at 200-1000 kg/ha dose rate and **growing media** in the horticultural sector. The high carbon content **plant based biochar is soil improver** usually at approx. 5000-20000 kg/ha dose rate for water/nutrient retention and carbon sequestration applications, but providing no fertilizer effects with economical importance. For both biochar types there is a long list of additional beneficial effects.

Legal notice: Biochar soil applications are irreversible; therefore commercial biochar key players such as industrial producers, market distributors for placing product on the market and users having high legal, economical and social responsibilities with joint and several liability for their activities. In this context, beyond the mandatory EU/MS permits, operational and use licenses the **preventive and precautionary principle** (connected to international, EU and Member State legislations) **and its instruments are to be fully implemented** as well.

5.2. What is the Plant Based Biochar (PBC)?

Plant based biochar: this type of biochar is made of plant material residuals and characterized by high carbon content, usually at 90% level, and used as soil improver with 5 – 20 t/ha doses, in average 10 t/ha in wide range of agricultural cultivations. Plant based biochar does not have fertilizer direct value with economical importance, but rather having water and nutrient retention effects, sequester carbon in the soil; improving crop yields, nutrient cycling and immobilize trace metals.

5.3. What is the ABC Animal Bone bioChar?

ABC Animal Bone bioChar: this type of biochar is made of food grade animal bones and characterized by as high as 92% mineral carbon and 8% carbon content only. This is a full value recovered organic Phosphorus fertilizer with high calcium and content. ABC is horticultural organic recovered fertilizer and growing media used in as low as 200-1000 kg/ha doses, in average 300 kg/ha. Another specific application is the adsorbent use.

5.4. What is not biochar?

1) Biochar is **NOT a fine ground charcoal and/or any energetic carbon**, and/or
2) biochar is **NOT labile carbon** material, such as HTC hydrochar, that application is rapidly promoting GHG developments, and/or
3) the pyrolysis – **biochar production - process is not EU/MS Government Authority permitted, labelled** and controlled operation**, meet quality** to be put into open ecological soil environment above 1 t/y capacity, and/or

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4) the **biochar material open ecological soil environment industrial scale application is not EU/MS Government Authority permitted** and controlled operation 1 t/y capacity, and/or

5) the **pyrolysis manufacturing process is not towards zero emission performance**, the pyrolysis process is **not energy self sustaining**, and/or

6) made from input **feed material that is not from recently living organisms** and containing potentially toxic elements and/or priority hazardous organic substances that may result exceeding allowable limits according to the MS/EU regulations (IMPORTANT: when plant based biochar is used in dose many tons/ha, than the inputs of the possible exotox substances are multiplied as well) and/or

7) made from input feed material, that is originating **from primer and secondary land use products**, and/or the feed material use is competing with human and/or animal food supply and/or food crop plant production nutrient supply, and/or

8) the overall life cycle of the process (input material, process, biochar use) is **having more negative environmental impact than total benefit**, and/or

9) the product is **not labelled with EPR extended producer responsibility** certificate, and/or

10) the **output biochar product economical value and free market valorisation is not based on common market demands** and commercialization process, e.g. biochar economical valorisation may not be based grants and/or subsidies.

5.5. How to produce 3R BIOCHAR products?

The **3R biochar refined carbon and recovered organic fertiliser are made by 3R slow pyrolysis advanced zero emission production technology.**

Stabile carbon biochar is produced under 450°C – 850°C reductive thermal processing negative pressure conditions with zero emission or near zero mission environmental performance. Biochar – as chemically modified substance - industrial production or import above 1 t/year capacity requires comprehensive environmental and industrial safety Authority permits and EU REACH registration by 1 June 2018. All biochar productions and soil applications in industrial scale require accredited MS Government Authority permit in the EU and the temperate climatic zone countries as well.

The 3R biochar technology has been specifically developed for the temperate climatic zone countries production and applications in the EU, Australia, Japan and the USA. All biochar productions and applications in industrial scale require accredited Authority permit in the temperate climatic zone countries.

5.6. What is the difference between ABC and PROTECTOR products?

ABC is a non-formulated Animal Bone bioChar while PROCTECTOR product is a formulated ABC substance which means that beneficial natural soil microorganisms and/ot other substances are entrapped on the internal and external surface of the ABC carrier. Different types of specific 3R biochar and mineral carrier composites are available depending on the input material and carbonisation process.

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5.7. What nutrients are in the ABC/ PROTECTOR recovered organic fertiliser product?

The specific animal bone char based biochar / PROTECTOR contains high amount of recovered Phosphorus (P_2O_5 >30%) and Ca (27%) available for plants, which allows efficient, environmentally safe and natural renewable phosphorus supply. Beside the highly available phosphorus content the animal bone charcoal also contains important trace elements and other nutrients. NPK-C formulated PROTECTOR is a standards product of the Terra Humana Ltd.

5.8. For which climatic conditions and soils has the 3R Biochar application been developed?

The 3R Biochar has been specifically developed and tested for **temperate climatic zone applications** (in each hemisphere, the temperate zone is found between 60 and 30 degrees latitude), practically the EU, USA, Australia and Japan targeted. The technology can be flexibly used for different soil conditions, especially for degraded soil conditions.

5.9. What are the different application areas of the biochar products?

1. **Plant based biochar (SOIL IMPROVER and GROWING MEDIA):** >90% w/w **high carbon content** plant origin **micro and meso porous** (1 nm – 50 nm) **carboniferous product,** with high water holding and nutrient retention capacity and C sequestration, but low soil fertilization effects. **The stabile carbon based biochar** is providing high efficient carbon sequestration to avoid global warming caused by climate change. Usual application rate is 5 t/ha – 20 t/ha, depending on the case by case scenario and economy.

2. **Animal bone based biochar ABC – animal bone char (Recovered ORGANIC P FERTILIZER and GROWING MEDIA):** <20% w/w **low carbon** and **high calcium phosphate / apatite mineral** content **macro porous** (50 nm – 63,000 nm) NPK-C biochar full value organic Phosphorus fertilizer, with trade name **Animal Bone Charcoal "ABC" product**. This macro porous structure of bone char offers the microbes a protected niche when introduced into soil

   The ABC is made of food grade (category 3) bone meal by pyrolysis thermal process. The specific 3R biochar effects are natural slow release fertilization, plant growth promotion, improving soil retention of nutrients and water, improved cation exchange capacity, while decreasing and/or fully substituting the use of chemo-synthetic substances in low input and organic agriculture. ABC is improving soil fertility, enhancing soil microbiological life and biodiversity, restoring soil natural balance in different climatic conditions and at different soil types, especially at degraded soils.

   The specific 3R biochar can be an important tool to increase food security and cropland diversity in areas with severely depleted soils, scarce organic resources, and inadequate water and eco-friendly fertilizer supplies, whereas important application element is the drought tolerant food crop cultivation system.

   The 3R animal bone char based biochar application doses variating from 200 kg/ha to 1000 kg/ha and safely used in any open ecological soil environment.

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The 'ABC', can also be used as a carrier for formulated biological control agents or other beneficial microorganisms, meanwhile delivering P and Ca for plant growth.

5.10. Has the 3R Bone charcoal been field demonstrated?

YES, highly impressive results were obtained during the efficiency trials carried out in several countries between 2005-2015 under different climatic, soil and ecological conditions in several EU countries.

Animal Bone bioChar (ABC) showed a very good fertilization effect on crops, while plant based biochar had few effects on yields and results vary according to soil type.

For validation of the PROTECTOR effects several open field and green house cultivation tests have been executed in Germany, Netherlands, Israel, Italy and Hungary. Applied doses was 400 – 1000 kg/ha.

- HEALTHY PLANT in NURSERY: Already in the seedling period was realized >20 mm size differences benefit for the PROTECTOR products in greenhouse nursery. Stronger plant at nursery stage provides life time positive effect for plant growth.
- FIRST HARVEST GREEN HOUSE YIELD INCREASE: >300% related to the non-treated control PROTECTOR treatments resulted earliness concerning yield results at the first harvest.
- SECOND HARVEST GREEN HOUSE YIELD INCREASE: >50% increased plant yield and quality after PROTECTOR treatment in several greenhouse vegetables cultivation.
- OPEN FIELD YIELD INCREASE: extra surplus yield 2.5-5 tonnes/hectare. Significantly increased plant yield and quality after the PROTECTOR treatment in open field cultivation with several vegetables test plant, such as tomato, green pepper, broccoli and Chinese cabbage.
- FRUIT QUALITY IMPROVEMENTS: the >10% increased mineral and nutrient content resulted highly improved fruit quality, better taste and extended fruit storage performance. On the basis of extended soil analysis PROTECTOR treatment favourably influenced the soil structure and increased plant available soluble macro and micro nutrient content of soil.
- RESTORATION OF NATURAL BALANCE OF SOIL and IMPROVEMENT of PLANT NATURAL RESISTANCE: PROTECTOR treatment favourably influenced the soil structure, increased P_2O_5 availability by >20% and increased the plant available soluble macro and micro nutrient content of soil. The treatment enhanced the plant natural bio-control ability.

5.11. What are the advantageous effects of application of ABC recovered organic P-fertiliser product?

- Providing 10-30% yield incensement. The more efficient P utilization >10% decreasing the overall quantity of fertiliser need.
- **Low cost price organic nutrients**: ABC is a cost effective €975/ton alternative of the mineral fertiliser. 10-30% lowers price range calculated on the plant available-utilizable P_2O_5 value.
- Improving soil fertility and restoring soil natural balance in different climatic conditions and at different soil types, especially at degraded soils,

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- Substituting intensive farming agricultural chemicals and chemo-synthetic fertilizers by recovered organic fertiliser.
- Improving bio-security and food safety while removing biological threats,
- Improving plant drought tolerance and cultivation water security,
- Combating weeds,
- Providing C negative applications to avoid global warming caused by climate change.
- Decreasing food production costs for low input and organic farmed horticultural food crops, while offering options to more Consumers for affordable priced safe food.

5.12. How the 3R output products are improving the food safety?

The 3R bone char (apatite mineral based, with >30% P_2O_5) - made from category 3 food grade bones - is a **pure natural and fully safe product**, aiming restoration of soil natural balance. The 3R bone char does not containing Cadmium or Uranium contamination and does not containing any chemosynthetic substances or potentially toxic chemicals as well.

P rock fertilizers are also apatite mineral based, but in many cases originating from the by-products of the Uranium enrichment operations. 80% of the human Cadmium and related heavy metal intake is from the agri use of rock phosphate. There is a rapid P crisis under development worldwide.

5.13. How does biochar offer a novel approach to over farming and damage to soil as a result of increasingly intensive agricultural production?

Intensive farming practice and human activities have disturbed the natural cycles of nitrogen and phosphorus. Intensive agriculture relies on continual inputs of mined, non-renewable phosphorus critical raw material and energy –intensive nitrogen supply. It is estimated that human activity has doubled the global amount of reactive nitrogen in circulation; while tripled the amount of phosphorus since the industrial revolution. The mineral phosphate industry and use of chemosynthetic mineral fertilisers causing several environmental damages, including cadmium build up in soil, GHG emission, fluorine emission and Phosphorus run-off in subsurface water base. There is strong need for increased sustainability and closing the nutrient loop in agriculture with the creation of a virtuous cycle between urban and rural areas. In this context, reducing the use of mineral fertilisers in agriculture is important, that can be achieved by recovering nutrients such as Phosphorus from organic by-products and biowaste.
The ABC animal bone based biochar or "bone char" is free from toxic elements and having approx. 30 % P_2O_5 content. This high recovered Phosphorus content makes it suitable for application as a slow release natural fertiliser for substituting the mineral phosphate fertilisers. Moreover the compost and biochar products are re-fertilizing the depleted agricultural soils, improving drought tolerant farm methods and addressing the problem of degrading soil quality in Europe.

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5.14. What is the market insight as to what the demand is for 3R products, who buys it?

There is a wide and rapidly expanding green market for the 3R products in large international dimension, for which the main uses including, but not limited:

(1) Horticultural farming soil cultivation productions in **low input and organic farming sectors,** with clear objective to remove toxic chemicals from the food chain production base. Supplier of natural NPK.
(2) Horticultural and forest nursery.
(3) Regeneration of degraded agricultural and natural soil conservation areas.
(4) Enhanced biomass production and energy forest plantation programmes for improved biomass energy production cultivations.
(5) Compost makers for production of enriched compost.
(6) Environmental applications , adsorption industry and water treatment.
(7) Agricultural and environmental biotech industry, solid state fermentation and formulation.
(8) Green energy production, transport biofuel and green electric power.

5.15. If there is no fertilizer use market during the winter, would it require huge inventory amounts tying up a lot of capital? Is the 3R bone char seasonal product?

No, the 3R bone char is a continuous year around application scenario for different alternative use. There are three major applications of the 3R processing products:

- **Bone char-to-agricultural and horticultural farming** to achieve triple soil effect, such as plant growth promotion, biocontrol by-effect and natural fertilization. (based on category 3 food grade bone meal input).
- **Bone char-to-adsorbent**, water treatment and environmental decontamination. Although bone char having <100 m2/g specific surface area only, it is far higher efficient adsorbent of large molecular organics, than any high grade coal or plant based activated carbon. There are many different adsorption scenarios with wide market application possibilities, such as drinking water treatment, effluent treatment, treatment of raw waters in rural locations, removal of colloidal / suspended contaminates, arsenic removal, sugar refinery (since 1870), ion exchange, chemisorption, incorporation of heavy metals and radionuclides, removal of pesticides and THM precursors.
- **MBM/PAP-to-energy**, for production of transport quality bio-fuel (biojetfuel or kerosene) and recycled liquid Nitrogen fertilizer. The installation is same as for bone char, same unit is processing MBM material cat 3-2. (based on category 3 and cat. 2 meat and bone meal / processed animal protein inputs). (Category 1 processing is also possible, but need separated production scenario, due to legal requirements).

The 3R animal waste processing output product markets are extensive, wide range and continuously developing, therefore, there is no seasonality of the bone char production, but rather it is a continuous supply to diverse application channels. The 3R high grade bone char is possessing special characteristics, including total macro porosity, eco-safe performance, >90% calciumphosphate and <10% carbon only.

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CHAPTER 6: Risk of biochar use

6.1. What is the status of the accreditation of the determination of the quality and safety parameters? Is there any organization in Europe whose having accreditation for biochar analysis?

To determine quality & safety performance of biochar, internationally accredited methods and standards are needed. Accreditation of the analytical activities related to the REFERTIL project is an important step to be able to support the research work related to the project with analysis that have a recognized quality management background, in addition to the proper professionalism. It is also an important step to support the legal standardization and mandatory permit process of biochar industrial production, product application and commercialisation, including producers extended responsibility and liability legal issues for the product.

Most of the standards selected for biochar qualification were chosen from among currently valid CEN/ISO standards. As biochar is a new product, for a number of parameters it was necessary to adopt soil or waste analytical methods, which were validated to assess their analytical performance. Validation methods were developed to check the suitability of not entirely standard methods to be used in laboratory practice.

The accreditation procedure was initiated at NAT (National Accreditation Body) after almost two years of continuous work. During this period, WESSLING gained significant experience in this analytical area and maintained the external and internal quality assurance activities as well. **The Environmental Testing Laboratory of WESSLING is the first laboratory in Europe who obtained accredited status, under Wessling-NAT-1-1398/2012 (2014.10.08) for comprehensive analyses of biochar samples.**

According to the mutual recognition agreements[19] [20], activities of NAT and organizations accredited by NAT are recognized internationally by all other signatories. According to Regulation EC 765/2008, authorities of the member states of the European Union are obligated to accept the results of organizations accredited by NAT.

6.2. What are PAHs ?

Polycyclic aromatic hydrocarbons (PAHs) are priority pollutant substances, a group of hydrocarbons many of which are known or suspected carcinogens and their concentrations in the environment are thus of interest. PAHs are toxic, persistent in soil environment and having potential for subsurface water contamination, so it is very important to use only certified, low PAHs concentration biochar in agriculture. Moreover PAHs are included in the list of priority hazardous substances. Directive 2008/105/EC listing PAHs as priority hazardous substance. **In some EU Member States the maximum allowable limit for PAH priority pollutant substances in soil improvers is 1 mg/kg PAH_{19} since 2006.**

[19] Multilateral Agreement of the European Cooperation for Accreditation (EA MLA) in the areas of analysis, calibration, control, product certification, management system certification and person certification.

[20] Mutual Recognition Arrangement of the International Laboratory Accreditation Cooperation (ILAC MRA) in the areas of analysis and calibration.

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6.3. What are the key factors for occurrence of PAHs in biochar?

PAHs can be considered as the key organic pollutants and an indicator of biochar product quality.

The occurrence of PAHs in biochar primarily derive from obsolete, low grade and inefficient pyrolysis condition, but in the plant based biochar cases also from contaminated and/or improper selected feed stocks as well. The plant biochar material may contribute high levels of PAHs to soil when the total PAHs concentration in the biochar product is high and/or when high application doses (such as above 5 tons/ha) are applied to achieve the desired effect requirements. The recommended determination of PAHs components in biochar is CEN/TS 16181:2013 standard with a gas chromathography-mass spectrometry method after carbon disulfide extraction instead of the more traditional hexane, petroleum ether or toluene, because suitable recovery can be achieved even without time-consuming Soxhlet extraction, even in the case of PAHs components with high boiling points.

6.4. What are the recommended methods for PAHs analysis?

There are several type of PAHs depending on the number of connecting benzene rings. To get information about specific PAHs represented in biochar, not only 16 priority PAHs (based on US EPA offer) were measured but the 19 most common components. Quantitative and qualitative there is a large difference between PAH_{16} and PAH_{19}, resulting a far higher environmental risk profile of the PAH_{19}.

6.5. What is the rational from improved limit value for PAHs in biochar?

PAH content of biochar is primarily depending on the carbonisation processing technology design quality and technology performance that are defining the processing conditions. Within the REFERTIL project (www.refertil.info) more than one hundred biochar samples, both PBC and ABC, has been investigated. Both REFERTIL produced biochar samples and samples from several EU producers have been investigated. The results clearly justify that only the high quality biochars contained less than 1 mg/kg PAH_{16}. In this context, it has been demonstrated that the advanced thermodynamics of the modern and high quality engineering designed pyrolysis process performance do not support formation of PAHs and dioxins. During REFERTIL project in the Fertiliser Regulation EC 2003/2003 revision supporting document PAH_{16} maximum allowable limit value was defined as 6 mg/kg, but for environmentally justified reasons Member States can apply more strict rules, as some of them already do. As an example the national regulation in Hungary (36/2006 (V.18.) FVM decree) requires PAH_{19} content under 1 mg/kg for soil improvers since 2006. During the limit value definition it is very important to define how many components are under PAHs. The PAH_{19} concentration can be twice as much as PAH_{16} , because 1- and 2-methylnaphthalenes (measured only under PAH_{19}) are dominant beyond the typical PAH_{16} components in biochar: mostly naphthalene and phenanthere, but in some ABC samples anthracene and phenanthrene are also present. **Polycyclic aromatic hydrocarbons can be considered as the key organic pollutants and an indicator of biochar products quality.**

6.6. What are the risks of other organic pollutant in biochar?

In no any cases have **Polychlorinated dibenzodioxins (PCDDs) and Polychlorinated dibenzofurans PCDFs** been identified as target contamination as these compounds are

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predominantly formed at temperatures exceeding 1000°C while the feed material streams having very low chlorine content. Therefore, the risk of dioxins and furans contamination in biochar products is low. **PCB_7** were not detected in the REFRTIL (www.refertil.info) investigated more than one hundred biochar samples (produced in the REFERTIL material treatability test and received industrial reference biochar samples) derived from traditional biomass feedstocks (agri residues, woody biomass, food industrial by-products) and animal and category 3 by-products.

6.7. What are the risks of the potentially toxic elements?

Certain Potentially Toxic Elements (PTEs) such as Mercury, Cadmium, Nickel, and Lead are included in the list of priority substances. Directive 2008/105/EC listing Cadmium and Mercury are identified as priority hazardous substance.

Measuring PTEs (metals) in biochars is very important, because of the 3x – 5x re-concentration tendency during phase separated processing. This results much higher PTE concentration in solid output products than in original input average. The higher the organic matter content in feedstock, the less the yield of biochar, thus PTE high accumulation occurs especially in PBCs.

The rate of enrichment is depending on the concentration of the given elements in the feedstock stream and on the yield of biochar reached with the given pyrolysis condition. The PTE concentration in the biomass feedstock often determines biochar's safe application rate. All the ABCs and high quality PBCs made from by-products were well below a strict member state regulations and REFERTIL recommended biochar quality and safety parameters.

In the case of pyrolysis of waste material streams with high and/or variating PTE input concentrations there is a high risk that PTEs in final biochar products may reach the recommended safety criteria limits that does not meet the permitted limits and EPR specifications.

Therefore the concentration of PTEs in input material should be regularly monitored. Several organic waste streams are known to generally contain high levels of light and heavy metals, which remain and concentrated in the final biochar product following pyrolysis.

CHAPTER 7: Fertiliser – Phosphorus Fertilisation

7.1. What is fertiliser?

Fertilisers are plant nutrients, which can be natural or synthetic products and made of organic or inorganic materials. Fertilizers are added to plant systems in order to supply one or more nutrients required for healthy plant growth. Any material, organic or inorganic, natural or synthetic that supplies plants with the necessary nutrients for plant growth is called fertilizer.

7.2. Why do we need fertilizer?

The soil often does not contain enough nutrients in desirable quantities needed for economical and high yield food crop plant growth.

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7.3. What is the importance of phosphorous mineral fertilisation?

Phosphorous (P) plays several roles in plant metabolism and is one of the essential nutrients required for plant growth and development. It has functions in forming the structure of macromolecules such as nucleic acids and also in energy transfer in metabolic pathways of biosynthesis and degradation. Beside nitrogen, phosphorous is the most abundant nutrient contained in the microbial tissue, accounting for as much as 2% of the dry weight.

Phosphorous is one of the key nutrients because of its relative scarcity and its essential role in all life forms. P is a major constraint on food and fibre production in many parts of the world. Therefore, an **economical supply of P is necessary for a secure production in agriculture and forestry.** Nutrients such as nitrogen and phosphorous are removed from soils during plant growth and need to be replaced.

7.4. What is the conventional/synthetic/inorganic fertilizer?

Synthetic fertilisers are either mined and refined, or manufactured products, containing one or more essential plant nutrients in available or potentially available forms and in commercially valuable amounts without carrying any harmful contaminant above permissible limits. There are concerns about the limits of the harmful contaminants, especially heavy metals, such as Cadmium ad Uranium in P rock. Unfortunately, most of the P rock fertilizer deposits containing over high level of heavy metals, therefore the human Cadmium intake 80% are traced to P rock fertilizer use. Although organic fertilizers are also prepared and used, they are not yet covered by the term fertilizers, largely due to traditional nomenclature (FAO). Inorganic fertilisers are derived from non-living sources and include most of our man-made, commercial fertilisers.

Phosphate rock is mined from sedimentary deposits, with phosphorites being the predominantly mined deposit type. Most phosphate rocks display elevated uranium, thorium, heavy metal, metalloid and rare earth element levels. Although phosphorus is a nutrient, P-fertilizer also contains variable amounts of cadmium (Cd), an intrinsically toxic substance and one of the “heavy metals”. These undesired contaminants are absorbed by the growing crops, will appear in the food, which subsequently leads to intake by the consumers. P-fertilizer is the only mineral fertilizer that suffers from this problem. Synthetic fertilizers are made from chemically treated phosphate rocks**. If safe food production targeted, high Cd/U/heavy metal content P rock fertilizers are not recommended for use as they are highly concentrated and reactive.** When applied on the field they react with calcium, iron, magnesium and aluminium, and thereby quickly form such compounds that make phosphorous unavailable for the plants. They may also react with trace elements, bind them causing deficiencies of micronutrients.

7.5. What is the problem with the quick release fertilisers?

Inorganic fertilizers are typically quick release materials, may contain contaminations, such as from **Phosphate rock Cadmium and Uranium**, a have leach potential compared to organic fertilizers. Because of the lack of carbon, inorganic fertilizers “feed the plant but not the soil.”

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7.6. What is the problem and concern with the intensive agriculture?

Intensive farming is concerned above all with productivity and uses a **high level of inputs** to achieve it. The inputs are usually in the form of chemicals, fertilisers, pesticides and growth-regulators produced by energy intensive industrial processes and additional energy is consumed due to the high levels of mechanisation. Food production systems are partially responsible for elevated levels of green-house gases in the atmosphere due to the heavy reliance on fossil fuels.

Traditional chemosynthetic P fertilizer production is based on chemical processing of high-grade insoluble mineral phosphate ore, which includes an **energy intensive** treatment with sulphuric acid at high temperature. Since natural gas is such a critical resource in fertilizer production, natural gas price fluctuations have a dramatic effect on fertilizer costs. As energy costs continue to rise, and the demand for fertilizers increases, this effect is becoming more pronounced.

7.7. What is the problem with the synthetic phosphorus fertilizers?

Today's agriculture relies on phosphorus fertilizers mostly processed from mined phosphate rock which is a practically non-renewable resource since it takes 10-15 million years to form and currently known reserves are likely to be exhausted in 50-100 years. **Phosphate rock (PR) is a finite, non-renewable natural resource and critical raw material. Geological deposits of different origin are found throughout the world. Currently, few PR deposits are mined.** The rate of production of economically available phosphate reserves will soon reach a peak, followed by a rapid steep decline and subsequent ongoing decline of productivity. Demand for phosphorus fertilizers is expected to increase by 50-100% over the next 50 years due to the increasing population, increasing demand for meat and dairy-based diets and increasing demand for non-food crops like biofuel crops.

The quality of phosphate rock continuously and rapidly declines: the concentration of P_2O_5 in mined phosphate rock decreases and the concentration of associated heavy metals like cadmium increases. The Uranium contamination is a naturally occurring element in the phosphate rock, therefore in many cases the phosphate rock is primarily used for production of Uranium extractions for nuclear power plant fuel, while the phosphate is a by-product for this nuclear industrial operation. The cadmium content of the sedimentary phosphate rock can be very high. This is either considered as a harmful concentration for application in agriculture or expensive and energy intensive to remove. Cadmium can accumulate in soils and plants through repeated fertilizer use. The application of fertilizer on agricultural lands may result in the transfer of cadmium into the food chain.

There is an increasing social and ecological need for recovery, recycling and reuse of the phosphorus resources like harvested biomass, food industrial and animal wastes (food grade bone meal of hog origin) rich in phosphorus into natural Phosphorus fertilizers.

One of the main fertiliser constituents is phosphate rock, which has been identified by the Commission as a critical raw material. For phosphate fertilisers, the EU is currently highly dependent on import of phosphate rock mined outside of the EU (more than 90% of the phosphate fertilisers used in the EU are imported, mainly from Morocco, Tunisia and Russia).[21]

[21] Roadmap - Revision of the Fertilisers Regulation (EC) No 2003/2003, http://ec.europa.eu/smart-regulation/roadmaps/docs/2012_grow_001_fertilisers_en.pdf

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7.8. What is the organic fertiliser?

Organic fertilisers are derived from living or once-living material, including animal wastes, crop residues, compost and numerous other by-products of living organisms. The term organic fertilizer is used to describe **nutrient sources of organic origin either natural or processed**, containing at least 5% of one or a combination of the three primary nutrients (N, P, K). In these sense organic materials of animal origin such as guano, bone meal, fish meal, leather meal, are true organic fertilizers beside the commonly used organic sources of nutrients such as manure, slurry and compost. If the nutrient content is below 5% they are considered as organic amendments.

7.9. What are innovative fertilisers?

Innovative fertilisers defined in the Roadmap - Revision of the Fertilisers Regulation (EC) No 2003/2003 (October 2015) [22] as containing nutrients or organic matter recovered and recycled from biowaste from food change, animal/other agricultural by-products or other secondary raw materials in line with the circular economy model.

7.10. What are the advantages of the slow release innovative fertilisers?

A slower nutrient release **results in more sustained availability of the nutrients**, and a lower "burn and leach" potential as compared to their inorganic counterparts. In addition, organic fertilizers may act as energy source for microorganisms in the soil, which can improve soil structure and plant growth.

7.11. ABC is an innovative fertiliser?

Yes, ABC is innovative and recovered Phosphorus fertilizer that is produced from animal by-products in line with the EU bio nutrient circular Phosphorus economy model.

7.12. What are the main advantages of ABC Phosphorus recovery?

There are multiple benefits to carrying out of ABC Phosphorus recovery; however the core benefit is the high economical added value of the unique and multifunctional product under market competitive conditions for different functional applications. In common words, the Customer pays for the efficient product technical applications, that is the internal benefit and market value, while the external benefits, such as environmental benefits, are bonus to the Consumer. The basic advantages of ABC Phosphorus recovery short listed as following:

1) **high value for money for specific agricultural and adsorbent applications** under market competitive conditions,
2) **high application efficiency** of the ABC product with unique chemical and physical product character,
3) total **safe** product under any environmental, climate and soil conditions,
4) existing and **rapidly growing market demand** for Phosphorus bio-fertilizer with unique character and total safe performance for market competitive price while creating short-term

[22] Roadmap - Revision of the Fertilisers Regulation (EC) No 2003/2003, http://ec.europa.eu/smart-regulation/roadmaps/docs/2012_grow_001_fertilisers_en.pdf

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(1-2 years) economic opportunities for all stakeholders, that is so much important for SME farmers,

5) fully meets the rapidly changing legal environment in the EU and USA that require production and market uptake of the innovative and recovered Phosphorus fertilizer at market competitive cost.

Additional benefits:

- the recovered ABC Phosphorus is a renewable resource and in line with the EU circular economy model,
- providing important environmental benefits,
- monetary value of the environmental benefit,
- reducing the EU dependence on imported P critical raw material that containing Cadmium and Uranium pollutants,
- combining the recovery of other nutrients, most importantly N, K and microelements,
- saving phosphorus stocks, and
- close the regional P-cycle that is shorten delivery and logistical routes and cost.

7.13. How can we replace the finite non-renewable phosphate rock and inorganic phosphorus fertilisers? What are the alternatives of the chemical P-fertilisers?

Struvite is a magnesium ammonium phosphate mineral that is known is several forms, such as urinary stones and precipitated from sewage water. Phosphorus content in wastewater can be reduced by recovering a portion of the phosphorous as a crystalline product called struvite, containing approx. 9.9%Mg, 5.7%N, and 12.6%P and may used as slow release fertilizer. Both struvite and ABC Animal Bone bioChar are proposed to be included in the EC 2003/2003 Fertilizers Regulation revision.

Manure and compost typically have very low NPK content but rich in organic carbon and contain active micro-flora. From manure or compost **very high quantity (20-30 t/ha) is needed for providing sufficient amount of nutrients**. Cu and Zn are used as growth promoters at pharmacological levels, or because wide safety margins are applied, Cu and Zn are often oversupplied in pig diets. Consequently, these elements are highly concentrated in pig manure and accumulate in soil, where they may impose a medium or long-term toxicity risk to plants and micro-organisms.

Soft rock phosphate and natural phosphate is mined from sedimentary deposits, with phosphorites being the predominantly mined deposit type. Some phosphate rocks display elevated **uranium, thorium, heavy metal, metalloid and rare earth element levels** and **also contain variable amounts of cadmium (Cd)**, an intrinsically toxic substance and one of the “heavy metals”, which is also absorbed by growing crops. Therefore these contaminants appear in the food, which subsequently leads to intake by the consumers.

Guano is a bird or bat droppings with approx. 8-12 % P content. Guano has accumulated over centuries on small islands on the Pacific Ocean or the coast of Chile and Peru, where it was mined in such large quantities that its deposits are **now severely depleted**. In contrary to phosphate rocks it is a renewable resource, however only over a long period of time; therefore guano in practice is an finite resource. Bats are highly vulnerable to regular disturbance to their roosts,

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therefore most bat guano exploitations are already stopped or underway to be stopped by natural conservation regulations.

Sea-bird guano also contains high level of mineral (As) contamination and **its renewal also takes for a very long time**.

The **organic mineral fertilizers** typically consist of organic materials (peat, meat, meal and composted and humidified cow or chicken manure) mixed with mineral fertilizers (DAP) or natural P source (mostly GAFSA rock phosphate). The problem is the uranium and cadmium impurities.

There are no any other materials known produced by the Nature on Planet Earth with high P_2O_5 content (>30%) than apatite mineral that is having two forms such as mineral phosphate rock and bone char.

7.14. What is the efficiency of the 3R process?

The most important efficiency aspects of the 3R are based on the innovative, advanced and unique technology design and construction that makes possible the very high efferent indirect heat transfer, process safety and zero emission performance. The 3R zero emission or at least towards zero emission concept is the mimic of the Nature, where the term “waste” does no exists, as all materials are circular recycled and reused in a most efficient way. The 3R represents a shift from the traditional industrial model with linear economy but rather 3R is a resource efficient circular economical model where all materials streams are added value valorised and converted into safe and market demanded products and bio-energy. This is a combined economical and environmental interest based sustainable model. As the material and energy processing are fully optimized under the **unique and advanced engineering design high tech** of the 3R, therefore all material streams are recycled and reused, but still the total production is remaining highly cost efficient, when all costs are included, including the environmental and climate protection costs as well.

7.15. Why do we want to avoid using Bone Meal in livestock feed and fertilizers?

Despite animal rendering by-products (bone meal and MBM) are sterile products at the point of production, there is a very **high risk for cross and recontamination during applications**.

The animal and human pathogens are optimized and designed by the Nature for mammal protein environment. Many pathogens (that are rather common on our environment) having dormant phase associated with adverse environmental conditions have arisen when growth, development and activity are temporarily stopped. Therefore many microbes can survive adverse environmental conditions for long time. But when new conditions are introduced into the environment, such as availability of protein nutrients and some moisture at elevated temperature, than pathogens may be active again.

As because animal rendering by-products are mammal protein based, these pathogens may rapidly colonize any crude bone meal and any protein based livestock in the open environment. These human and animal pathogens are prime risk potential that hopped across animal and human species: **most importantly salmonella** but also anthrax; TBC tubercolosis; mouth and foot disease and other infections. There are clear WHO reports on such disease trans-contamination routes related to Bone Meal in livestock feed and fertilizers, used in open ecological environment.

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The Producer Responsibility Principle: Producers having full responsibility for animal by-product disease cross and recontamination cases ("manufacturers of products bear responsibility for the environmental impacts of their products throughout the products life-cycles, including upstream impacts inherent in the selection of materials for the products, impacts from manufacturers, production process itself, and downstream impacts form the use and disposal of the products.

Producers accept their responsibility when they design their products to minimize the lifecycle environmental impacts and when they accept legal, physical or economic responsibility for the environmental impacts that cannot be eliminated by design" [Davis, Gary 1994].

The cross and re-contamination routes of the crude animal bone meal, MBM/PAP:

- While rendered products leave the cooker negative of the bacteria, **recontamination can occur anywhere** along the way to the feed mill or in the feed mill. Renderers take many precautions to prevent recontamination while the meal is in their possession but have little control over their product once it leaves a facility.
- Untreated bone meal and any protein content animal rendering by-products cross and/or re-contaminated which material constitute a significant reservoir of Salmonella contamination. In Europe, during the late 1980s and early 1990s, animal proteins were the most important source of contamination. Human and animal salmonellosis is still causing high economic losses. In humans, the main infection vector is related to poultry product consumption. The US Agriculture Department has reported that animal feeds are the main source of infection in poultry production, and *Salmonella Enteritidis* is the most frequently isolated serotype.
- **Salmonella may be present in animal feeds and/or by cross / recontamination at such low levels that it is difficult to detect, but nevertheless it proves to have a high survival and colonization ability in bone meal or MBM, after introduced in new in-vivo environment.** The control methods for Salmonella in animal feeds depend on the effectiveness of feed decontamination and the prevention of recontamination. Since bone meal materials are an important reservoir of Salmonella, it is of utmost importance to ensure a total decontamination of feeds.

Although, the usual treatment >133°C, 20 minutes, 3 bar thermal treatment, may be enough to sterilize the category 3 bone meal, after the material is leaving the factory the cross and recontamination is a very high risk.

Therefore, added value high temperature pyrolysis processing is providing fully safe and for producer/user juridical fully protected solution for this issue, and also offering far better business opportunity for product valorisation, - which is versus the risky market use of the crude bone meal for any in vivo applications.

7.16. Does the steam processed bone meal provide a safe alternative solution for substitution of the phosphate rock based fertilisers?

NO. Steamed bone meal has a high Phosphorus content, but there is concern as to whether the standard steam treatment (133 ºC/3 bar/20 min) is sufficient for safe microbiological inactivation of MBMs. Furthermore, the raw **bone meal protein content is an optimal culture medium for human and animal pathogen re-infections of public health concern (such as anthrax, salmonella and mouth and food diseases).** In this context, all protein based organic waste streams are potential risk materials for human and animal pathogen infections. **The protein**

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content still resulting very high risk for re - cross and post contamination after sterilizing thermal inactivation, therefore the protein content must be removed by high temperature pyrolysis treatment. The **animal bone char** - produced from food grade animal bone meal by thermal process up to 850 degree Celsius (carbonization) - is total protein free and a full – total environmental and human **safe P rich material.**

7.17. Does the 3R Bone based Biochar product provide a safe alternative for natural phosphorus supply?

YES. The 3R Bone based Biochar product is not only a slow release natural P bio-fertiliser but also has a plant growth promotion and bio-pesticide effects, increases the natural resistance of the plant and helps in the natural restoration of the degraded soil without any negative environmental impact. **There is no any other material with high concentrated P_2O_5 content, as high as 30%, known than formulated bone char that can provide an environmentally fully safe and renewable natural phosphorus source available for the plant.**

7.18. What is 3R Nitrogen Oxide Emission Mitigation and Recycled Nitrogen Fertilizer?

Nitrous oxide is a powerful greenhouse gas, important in climate change, and as well, is stratospheric ozone depleting substance. The human population has grown at an unprecedented rate past decades and this has resulted in many localized significant environmental impacts. Food production is considered as a major source of global nitrous oxide emissions. The nitrogen in wastewater and solid wastes may be a significant fate of much anthropogenic nitrogen. Up until now less attention has been given to human impacts on the global nitrogen cycle, impacts which are quantitatively greater than the impacts on the carbon cycle.

It is likely that much of the Earth's population now relies on anthropogenic nitrogen in its food supplies, resulting anthropogenic nitrogen contained wastes. Carbon dioxide and nitrogen cycles are strongly coupled. Human nitrogen additions are the principle cause for the increase in terrestrial nitrous oxide emission since 1960, and contribute to about one fifth of the current global net carbon uptake. The climatic effects of the anthropogenic nitrogen perturbation from the the greenhouse gases CO_2 and N_2O gases are very substantial. The anthropogenic Nitrogen is the input of man on nature, that is induced or altered by the presence and activity of man (such as fossil fuel combustion and agricultural fertilizer use activities) which makes anthropogenic interference of the global nitrogen cycle, as global fertilizer. Humans have approximately doubled the global rate of N fixation since pre-industrial time up to now. The global-warming potential (GWP) is a relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. The GWP of anthropogenic reactive Nitrogen oxide is 289 over 20 years. It is also considered that 1.6 kg of CO_2 needed per kg of NH_3 production. The 3R recycled Nitrogen process is extracting Nitrogen from the food chain and re-use it again. The recycling of reactive N back to agriculture is reducing the requirement for new reactive N and would also prevent the carbon-based greenhouse gas emissions associated with the manufacture of high energy intensive nitrogenous fertilizers from fossil fuels.

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About Edward Someus

Edward Someus is a senior Swedish environmental engineer (graduated from the University of Lund, Sweden) with +30 years competence and core specialization for pyrolysis science, recycling technology and industrial engineering; carbon refinery and phosphorus recovery processing and market competitive application of carbon/biochar products. The work **method used during the past three decades is to coherently combine applied science; industrial engineering and objective driven innovative carbon refinery technology/product developments together for resource efficient recycling and added value reuse of organic waste streams from agriculture and food industry to implement low carbon circular economy.**

Edward Someus is one of the leading scientist, technology and industrial engineer for **zero emission pyrolysis technology for resource efficient and added value recovery of organic by-products, waste streams and carbon negative product applications.** This pyrolysis development programmes started up during the 80's**.** He works for several EU programmes as coordinator and key technology designer since 2002.

Edward Someus is uniting biochar S&T efforts in more than 10 European counties and operating in Australia as well. Edward Someus is inventor, developer, industrial engineer and sole owner of the 3R zero emission carbon refinery and phosphorus recovery by pyrolysis original solution system. His main interests and competences are related to **CARBON REFINERY** and **PHOSPHORUS RECOVERY** processing, including:

- ✓ **zero emission pyrolysis** system and rotary kiln engineering design in industrial scale,
- ✓ **production of Animal Bone bioChar (ABC) innovative recovered Phosphorus fertilisers from animal by**-products,
- ✓ **refined carbon, biochar and activated carbon processing and applications,**
- ✓ **catalytic conversion** of crude pyrolysis oils to refined bio-oil,
- ✓ **added value carbon bio-refinery** (including solid state fermentation and biotech formulation), and
- ✓ **integrated thermal processing by pyrolysis and biotechnological processing**, where specific biochars are used as carriers for biotechnological soil applications.
- ✓ **clean coal** pre-treatment processing of brown coal for conversion to refined anthracite solid fuel for power plant operations <150 MWe capacity towards zero emission performance.

Basic contacts for further technical and business information

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