

Algae and the Circular Economy: regulatory challenges

This **SCOPE Newsletter** summarises the webinar organised by <u>ESPP</u>, with EABA (<u>European Algae Biomass Association</u>) on regulatory questions around valorisation of nutrients and other materials from waste-derived algae.

The webinar, on 22nd March 2021, brought together over 400 participants online (700 registrants had access to meeting networking) including a number of European Commission services (ENV, GROW, MARE, SANTE, RTD, EASME, JRC).

Presentations and very active discussion in the chat (both <u>here</u>) identified and illustrated regulatory questions around valorisation of algae and plants grown using various secondary resources from: municipal wastewater, green waste, eutrophication remediation, cement industry offgas (CO2 capture), aquaculture, manure digestate, dairy processing Questions raised included waste status of algae, contaminants and safety, use in animal feed or fish feed, use in Organic Farming, human food, biofuels ...

This SCOPE Newsletter summarises this webinar (presentations, discussions, chat) and aims to clarify from this a number of specific regulatory questions and opportunities.

ESPP will then work with companies and with other concerned organisations to develop and promote proposals to address these questions.

Event page: slides, Chat transcript: www.phosphorusplatform.eu/algae2021

Full recordings of webinar sessions on ESPP's YouTube channel https://www.youtube.com/channel/UCMid-39AIMT-3pzjoY58qiQ

Webinar participants additionally received the full list of participants with emails for networking.

Definitions and links

EABA (European Algae Biomass Association) https://www.eaba-association.org/en

Definition of algae: EN 17399 (March 2020) defines "algae" as the functional group of organisms consisting of microalgae, macroalgae, cyanobacteria and Labyrinthulomycetes. https://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:2278882&cs=1F20FCBCD6123B309AAB0F52C8CDEF169CEN/TC454

CEN/TC 454 (Technical Committee) "Algae and algae products" https://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:2278882& cs=1F20FCBCD6123B309AAB0F52C8CDEF169

Feed = animal feed, aquaculture feed, pet food.*Food* = generally used to mean human food products.



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Summary and proposals for action

Secondary nutrients: key to the future

Operations presented at this webinar show that algae (or other aquatic biomass) systems can combine wastewater treatment, CO₂ capture and low-grade heat use with production of valuable materials and of renewable energy.

Algae production sustainability can be improved if "fed" with waste inputs, and the use of secondary nutrients will be a key to large-scale algae production (e.g. for bioplastics or biofuels), just as it is for terrestrial agriculture.

Need for regulatory clarification

However, this synergy of waste treatment and production of algae / algae-derived products, raises questions on **product safety for different applications (contaminants, pathogens ...)** and on the regulatory status: "from waste to product".

Many questions on regulation were raised during this webinar, both in the presentations and by participants via the Chat, based on operating experience. Questions concerned the specific regulatory frameworks for use of waste-grown algae (and of materials processed from them such as fatty acids, proteins ...) in different sectors: human food, animal feed, fertilising products ...

regulatory status of algae grown using different secondary inputs: municipal or industrial wastewater nutrients, manures and animal by-products, food waste, biomass, digestates from these, offgas nitrogen, CO₂, secondary heat ... and of algae collected from environment remediation,

regulatory status after processing of materials from such waste-derived algae,

Specific regulations for the different end-uses of the algae / algae products,

Standards: important for market acceptance

Organic Farming: which algae-derived materials can be used in Organic Farming, e.g. as fertilisers or bio-stimulants, animal or aquaculture feed, food additives?

Overviews of questions on safety and regulatory status are provided in the matrix developed by Suez (see workshop slides) and below on <u>this page</u>.

Actions needed

EU Algae Initiative:

- promote the **algae Circular Economy**: use of secondary input materials to feed algae production where appropriate and safe (synergy with wastewater and nutrient removal, CO₂ capture, ammonia offgases), use of algae for surface water remediation, recycling of residual nutrients when algae are processed or used for energy production,

- *develop markets* for algae products, facilitate valorisation of wastegrown algae.

ESPP input to the public consultation (Jan. 2021) here.

D EU Fertilising Products Regulation:

- clarify status of waste-grown algae in CMC1,
- review the exclusion of cyanobacteria in CMC2,
- clarify consequences of trace presence of cyanobacteria (FAQ),
- evaluate algae for CMC7 (biostimulants).

ESPP will follow-up in the EU Fertilisers Expert Group.

CEN standards (CEN/TC 454):

 develop specific standards where appropriate for algae products where waste is used as an input: quality / safety (contaminant limits), traceability, downstream information,

- develop standards for algae use in wastewater treatment: phosphorus and nitrogen removal, net carbon capture,

- develop standards for algae for fertilising products (with CEN/TCs 455 and 260).

ESPP has engaged dialogue with CEN/TC 454.

End-of-Waste:

- clarify if or when algae grown in or using waste inputs are classified as "waste" or as "products",

- include waste-grown algae in the priority streams for development of EU End-of-Waste Criteria.

Joint letter signed by ESPP, EABA and a number of organisations and companies, April 2021 <u>here</u>.

Crisk assessment, Life Cycle Assessment

- carry out risk assessments of different waste-fed algae / algae product value chains (contaminants, pathogens ...),

- develop data and methodologies for overall carbon balance, nutrient balance, LCA, of algae use for waste treatment, including processing and end-use: see work underway in CEN/TC 454. **Propose inclusion in Horizon Europe**.

Animal Feed Regulation:

- clarify interpretation of art. 6(1) Annex III exclusions. ESPP is in dialogue with the European Commission DG SANTE.

Organic Farming:

- identify and propose addition of specific algae or algae products for given uses.

Ludwig Hermann, ESPP President and Jean-Paul Cadaret, President of EABA (European Algal Biomass Association)

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Use of algae in different sectors (in Europe)

Use in human foods

The Novel Food Regulation (EU) <u>2018/2283</u> is applicable. Novel Food is defined as food that had not been consumed to a significant degree by humans in the EU before 15 May 1997 (entry into force of the first Novel Food Regulation). Before placing a Novel Food on the market, it must be authorised by the European Commission as per art. 10 of this Regulation (unless it is already in the authorised list).

EU Novel Food Regulation: https://ec.europa.eu/food/safety/novel_food_en

See also the CEN Standards work underway on specifications for algae for food & feed applications CEN/TR 17599 (March 2021) below.

Use in animal feed and aquaculture feed

Specific limits for contaminants are applicable to materials used in animal feed or aquaculture feed. There is a legal basis to also set pathogen limits (in EU Regulation 183/2005 on Feed Hygiene), but to date this is only applicable for certain feed materials derived from Animal By-Products (in the Animal By-Products Regulation 142/2011).

However, the Animal Feed Regulation 767/2009 (art. 6(1) and Annex III \$5) excludes "All waste obtained from the various phases of the treatment of the urban, domestic and industrial waste water ... irrespective of any further processing" and also "Faeces, urine... irrespective of any form of treatment or admixture". ESPP has engaged discussion with the European Commission (DG SANTE) on clarification and interpretation of these exclusions, including for materials derived from algae grown in e.g. sewage or manure digestate.

Feed Additives Regulation (EU) 1831/2003

https://ec.europa.eu/food/safety/animal-feed/feed-additives/legislation-feedadditives_en

Animal Feed Regulations EC 767/2009 https://ec.europa.eu/food/safety/animal-feed_en

See also the CEN Standards work underway on specifications for algae for food & feed applications CEN/TR 17599 (March 2021) below.

Use in fertilising products

The new EU Fertilising Products Regulation 2019/1009 (FPR) is fully applicable as of 16 July 2022 and covers mineral and organic fertilisers, soil improvers, biostimulants ... However, national fertiliser regulations will continue in Member States. Algae and algae-derived materials will therefore be allowed to be used in fertilising products either in CE-marked products (under the EU Regulation) or in products authorised under national legislation (for national markets).

For detail of conditions under which algae can be used in CEmarked fertilising products under the FPR, see Theodora Nikolakopoulou's presentation summarised <u>below</u>.

A key question is whether algae grown in wastewater, or with waste input (e.g. offgas CO_2 or ammonia) are considered to be a "*waste*" or to "*have ceased to be waste*", because this will define whether or not such algae, and any materials derived

from or extracted from them, can be used in EU fertilisers under CMC1 of 2019/1009.

EU Fertilising Products Regulation (FRP) 2019/1009 https://ec.europa.eu/growth/sectors/chemicals/specificchemicals_en

European Commission FAQ (Frequently Asked Questions) for this regulation <u>https://ec.europa.eu/docsroom/documents/44284</u>

Use in Organic Farming

The EU Organic Farming Regulation 2018/848 specifies that non-GMO micro-organisms are accepted in plant production (Annex II, part I), and indicates environmental provisions for production of algae (Annex II, part II).

However, clarification is needed concerning the use of algae in animal feed for Organic Farming livestock and the use of algae-derived products in fertilisers, soil improvers or biostimulants for Organic Farming.

EU Organic Farming legislation: <u>https://ec.europa.eu/info/food-farming-fisheries/farming/organic-farming/legislation_en</u>

Proposed update of Annexes of 2018/848 fixing the list of products and substances authorized for use in Organic production (public consultation April 2021) <u>https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12377-Agriculture-List-of-products-and-substances-authorised-in-organic-production</u>

Use in energy and industry

Under Mandate M547, work is underway to define EU Standards (CEN) for use of algae and algae products in:

- Cosmetics (technical report CEN/TR 17611)
- Pharmaceuticals (technical report CEN/TR 17612)
- Chemical and biofuel applications (no report to date)

The Technical Reports on use in pharmaceuticals and cosmetics state "In all the growth phase, nutrient supply typically in the form of fertilizers - is also highly required; this burden could be mitigated by using wastewater but, at the current stage of development, high-quality production seems to be incompatible with this nutrient source." ESPP intends to question this conclusion.

CEN standards and technical reports can be purchased here at significantly lower prices than via some other Member States <u>www.evs.ee</u>

CEN/TC 454 Technical Committee "Algae and algae products" https://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:2278882& cs=1F20FCBCD6123B309AAB0F52C8CDEF169_

REACH registration

This is not required for mechanically-processed algae, but is necessary for extracts, concentrates or chemically-processed materials from algae.

See ECHA REACH "Guidance for Annex V Exemptions from the obligation to register" <u>here</u>.

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Algae for the future

Waste treatment and Circular Economy

Ludwig Hermann, Proman and ESPP President, launched the webinar by underlining that phosphorus recycling will be important for the sustainability of largescale production of algae, e.g. for bioplastics or energy: both use of nutrients from waste streams to feed algae growth, and recycling of phosphorus from algae processing.

Already in 2012, the US National Academy of Sciences concluded that to produce biofuels to cover 5% of US transport would increase P consumption by 20-50% and N by 40 - 110% if nutrients were not recycled (see ESPP Scope Newsletter $n^{\circ}90$).

Algae production can ensure synergy between wastewater treatment and nutrient removal, carbon capture and use of waste heat, and production of valuable materials and biomass energy. But only if regulatory questions are clarified (especially relating to waste-status of inputs used to "feed" algae) and only if safety, quality and user confidence in final products ensured, by appropriate regulation and standards.

Environmental benefits and economic potential

Vitor Verdelho Vieira, General Manager, <u>EABA</u> (European Algal Biomass Association) set the scene with an overview of waste-related algae production, state of development and potential product markets.

Europe has a long tradition in algae knowledge development and innovation with European companies in the forefront of practical applications of algae for novel foods and feeds, biofuels and chemicals, specialty bioproducts and environmental services.

An important opportunity for algae technologies is in **purification of wastewater streams, enabling recovery of nutrients and production of valuable biomass** "fed" by waste (secondary nutrients and carbon).

Operational full-scale examples include **Aqualia**, with 4 x 0.52 ha microalgae raceway ponds near Cádiz, Spain (see presentation below) and **CLEARAS** <u>www.clearaswater.com</u> tubular glass algae PBR (photobioreactor) at Village of Roberts (Wisconsin, USA)





The **CLEARAS Village of Roberts** installation (photos) currently in the commission phase (expected to be fully operational summer 2021) will treat 0.15 MGD (570 m³/day) of secondary sewage works effluent (1 800 population) using 39 500 linear feet (12 000 m) of indoor PBR glass tubing. The objective is to reduce influent 4 mgP_{total}/l to the discharge consent level of 0.04 mgP_{total}/l (6-month average) without chemical dosing.

CLEARAS has several other algae PBR nutrient removal installations in the construction or design phase: South Davis, Utah (23 000 m³/day, which <u>will be</u> the largest indoor algae installation in the world with 550 m³ of PBR), Mondovi, Wisconsin (1 100 m³/day) and Waupun, Wisconsin (8 100 m³/day).

Science reviews show that there is a wide range of examples, with different algae cultivation systems, showing effectiveness for recovery of inorganic nutrients from wastewaters, including sewage, food and beverage industry or other wastewaters.

Cai, Park & Li, Nutrient recovery from wastewater streams by microalgae: Status and prospects, 2013 <u>https://doi.org/10.1016/j.rser.2012.11.030</u>

Abdel-Raouf, Al-Homaidan & Ibraheem, Microalgae and wastewater treatment, 2012 <u>https://doi.org/10.1016/j.sjbs.2012.04.005</u>

Amenorfenyo et al., Microalgae brewery wastewater treatment: potentials, benefits and the challenges, 2019 https://dx.doi.org/10.3390%2Fijerph16111910

EABA underlines that algae systems offer important benefits in wastewater treatment (see <u>www.eu-sabana.eu</u>):

- instead of dissipating nitrogen and carbon from wastewater to the atmosphere (with resulting CO₂ and other greenhouse emissions), nutrients and carbon are recovered in biomass: up to 10 tN/ha/year, 2 tP/ha/year and 50 tC/ha/year.
- low energy consumption, below 0.5 kWh/m³.
- technology can be adapted to different wastes, for nutrients concentrations varying from 10 to 10 000 mg/l.
- low P and N discharge levels can be achieved, e.g. down to 1 mgP/l.
- revenue is possible from produced algal biomass, recovered nutrients, and valorisation of various materials from algae.
- technologies are robust and can be operated automatically, so are also adapted to installation in smaller settlements.

EABA (European Algal Biomass Association) brings together several hundred members engaged in algae production and algal biomass valorisation, including companies, R&D and national algae. See: https://www.eaba-association.org/en_and https://algaeworkshops.org



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Joshua Fenton Cabell, <u>NIBIO</u>, Norway, outlined the potential for algae production in Norway, in particular with some 9 000 tonnes of phosphorus currently lost each year from aquaculture to the sea.

Norway has abundant hydroelectricity and waste heat. A challenge is lack of sunlight in winter.

Most aquaculture phosphorus emissions today in Norway are from open pens at sea, where adult fish are raised. However, technology development now makes possible production in closed pens at sea or on land, where nutrient recycling is feasible. Current discharge regulations tend to limit only suspended solids and organic carbon, but future developments may also limit nutrient discharges.

Norway largely follows EU regulations, but also has national regulations. Algae are not animals and not plants. Use of wastes in animal feed is generally excluded, but it is not clear whether algae grown in wastewater are considered to be waste.

In any case, the final product must be shown to be safe for the intended use.

EU Algae Initiative

Maris Stulgis, European Commission, DG MARE, outlined the development of the EU's <u>Algae Initiative</u> "Blue bioeconomy - towards a strong and sustainable EU algae sector".

The objective is to increase the sustainable production, safe consumption and innovative use of algae and algae-based products. The Initiative will contribute to the EU Green Deal and carbon transition objectives. The EU Farm-to-Fork Strategy "will ... set out well-targeted support for the algae industry, as algae should become an important source of alternative protein for a sustainable food system and global food security".

Nearly 80 inputs to the public consultation on the Roadmap for this initiative in January 2021 were largely positive. An Impact Assessment study will be carried out in 2021, including further public and stakeholder consultations.

The Initiative is expected to be published by mid-2022 as a European Commission communication accompanied with an action plan.

ESPP input on the EU Algae Initiative

ESPP's input to the Algae Initiative Roadmap consultation (<u>18/1/2021</u>) underlined that the proposal did not take into account the important potential for recycling of secondary nutrients and CO_2 to feed algae (Circular Economy), that is combining algal production with wastewater and/or offgas cleaning.

ESPP referenced a number of full-scale installations and R&D projects showing that algae production is effective for wastewater treatment, enabling recycling of nutrients and production of valuable materials.

ESPP's input noted that use of secondary nutrients (waste inputs) to feed algae production, and recycling of phosphorus when algae are used for biofuel or energy production, are essential to support large development of algal production, without unsustainable consumption of nutrients/energy.

The European Commission reacted positively to this input, requesting further information, and now participating actively in this webinar.

Feeding algae with waste resources

Algae for sewage P-removal

Pete Vale, Severn Trent Water UK and <u>UKWIR</u> (UK Water Industry Research) presented the <u>I-PHYC</u> (Industrial Phycology) microalgae bioreactor for tertiary nutrient removal in municipal wastewater treatment.

The system claims phosphorus removal down to below 0.1 mgP/l, or even 0.02 mgP/l, as well as removing ammonia, for a residence time of 8 - 12 hours. Using algae means avoiding adding chemicals (iron or aluminium phosphorus coagulants) and makes a (limited) contribution to water companies' net-zero carbon objectives, with up to 10 tCO₂/year per 1000 p.e. capture by the algae. **Produced algal biomass can be used** in pigment or bioplastics manufacture, animal feed or possibly extracts for cosmetics.







Photo: Weston-super-Mare wwtp, Wessex Water, UK. Demonstration-scale I-PHYC algae system in operation.



Photo: Broadwindsor wwtp, South West Water, UK. Above: the black tanks are the I-PHYC algae system, the concrete ponds are sludge holding tanks (not related to the algae process). Below: the I-PHYC tanks use artificial light within the tanks, varying as a function of requirements.

In the UK, one I-PHYC system is operating at demonstration scale (Weston-super-Mare, Wessex Water) with one soon to be commissioned at full-scale (<u>Broadwindsor</u> 480 p.e., South West Water. Two more are planned for small WWTPs in Severn Trent.

The algae system achieved 50 - 75% orthophosphate removal, 75 - 100 ammonia removal and successful recovery of the algal biomass. After solid-liquid separation (sedimentation with sodium hydroxide) the algal biomass had 4 - 6% dry matter content, which was increased to 90% by heat drying.

Ania Escudero, Glasgow Caledonian University (GCU), Scotland, summarised results from tests in the <u>Phos4You</u> (Interreg NWE) project using microalgae to treat primary-settled municipal sewage.



A 500 litre microalgae photo bio reactor (PBR), designed by Greenskill Environmental Technology Ltd., was operated for 6 months at the Wastewater Development Centre in Bo'ness (managed by Scottish Water Horizon).

The recovered algal biomass showed 6% N, 0.9%P and >15% organic carbon (all as % dm). Levels of pathogens and heavy metals were low, but copper was around 520 mg/kg.dm. Pot trial ecotoxicity and analysis of pharmaceuticals are underway.

The algal biomass could be used in organic or organo-mineral fertilisers or organic soil improvers under the new EU Fertilising Products Regulation, via CMC2 (plant parts, on condition that sodium hydroxide was not used for processing), if copper limits were compatible.

It should be proposed also to add the microalga used (Chlamydomonas) to the positive list of CMC7, if biostimulant properties are confirmed.

Frank Rogalla, FCC Aqualia, Spain, presented fullscale development of algae-to-energy from municipal wastewater and CO_2 in the <u>www.all-gas.eu</u> (EU FP7) and <u>www.eu-sabana.eu</u> (EU Horizon2020) projects.

Following successful testing at 32 m^2 , 500 m^2 and $3 000 \text{ m}^2$ scales, four $5 200 \text{ m}^2$ outdoor microalgae raceway ponds are now operating since 2017 at Chiclana, near Cádiz, Spain. This system is fed screened raw municipal wastewater to remove phosphorus, nitrogen and COD. The algae raceway system replaces conventional activated sludge treatment, enabling water reuse for agricultural irrigation (sunlight in the algae raceway ensures natural disinfection). The algae produced are harvested by flotation and used to produce methane, used to fuel CNG vehicles (compressed natural gas). The resulting digestate is a bio-fertiliser.

In the SABANA project, full-scale microalgae raceways are under construction in Spain at Mérida ($26\ 000\ m^2$) and Hellin ($10\ 500\ m^2$), treating municipal sewage. Fertiliser, biostimulant and aquaculture feed products are being developed from the microalgae.

The full-scale experience shows that microalgae are effective in removing nutrients and purifying wastewater, that the overall energy balance is positive through methane production, and that the nutrients can be recycled in fertilising products.

Around 1 ha of algae raceway, in Spain's climate, can treat sewage from 5 000 p.e. (person equivalent) to tertiary standards, and move a fleet of 20 CNG vehicles.

Analysis in the <u>All-Gas</u> project shows that algae to methane changes net electricity use of 0.5 kwh/m³ in conventional wastewater treatment to net production of 2 kwh biomethane/m³, eliminating the carbon footprint and achieving a EROI around 4.

See: <u>https://www.youtube.com/watch?v=9a5p4crkxq4</u>



Photo: microalgae raceway Chiclana, Spain



Algae treatment of various waste streams

Floris Schoeters, Radius - Thomas More, indicated questions raised by the Circular Flanders project, using poultry house cleaning water (rich in N and P) to cultivate microalgae in a photobioreactor (photo below) in order to use the algae in chicken feed.



Questions include:

- Can this poultry housing cleaning water be used to grow algae? Is it classified as "manure"? If yes, what parameters need to be monitored at the algae bioreactor inflow?
- What is the status of the wastewater after the algae bioreactor treatment (N and P largely removed)? What parameters need to be monitored for outflow into the sewerage network?
- What is the regulatory status of these wastewater-grown algae? Can they be used in animal feed? In other applications? What quality parameters (nutrients, pathogens, contaminants ...) need to be monitored? Should these parameters be monitored in the raw algal biomass, or in the final product (dried) ?

Claudio Fuentes Grünewald, Swansea University UK outlined the <u>ALG-AD</u> (Interreg) project, using microalgae to remove excess N and P in digestate, then enzyme hydrolysis to produce functional proteins and fatty acids for use in animal and aquaculture feed.

Three demonstration scale pilot algae photobioreactors (PBRs) are in operation, treating digestates from household food waste and farm wastes (inc. Cat3 animal by-products) in Plymouth UK (Langage, 7 m³ PBR), pig manure digestate in Brittany (Cooperl, Lamballe, 2.5 m³ PBR) and plant biomass digestate in Ghent (Innolab, Oostkamp, 1 m³ horizontal PBR and 2m³ vertical PBR).





Photo above: ALG-AD, Scenedesmus autotrophic PBR

Up to 70% protein content of dry algal biomass is achieved, with good results for extraction of proteins and fatty acids. Levels of pathogens and contaminants are very low. Tests are underway using the resulting products in feed for piglets and fish.

In the absence of a specific regulatory framework for production of algae and use in animal feed, it is assumed that use of digestate of Cat3 ABPS (including manure and agricultural waste) can be used as inputs if and only if the anaerobic digester is achieving an Animal By-Product End Point.

Photos below: Water2Return algae production



Robert Reinhardt, <u>AlgEn</u> (Algae Technology Centre), Slovenia, outlined experience testing algae to treat wastewater and then produce fertilisers and biostimulants in the <u>Water2Return</u> project (Horizon2020).

The project is based on more than 6 years of operational experience in other projects (<u>AlgaeBiogas</u>, <u>Saltgae</u>). A demonstration scale algal raceway pond is part of the complex water treatment line of slaughter-house wastewater, **treating some 50 m³/day of effluent**.

The harvested algal biomass has been processed to produce a biostimulant, shown to be effective in pot trials and currently in large scale field tests.

The resulting biostimulant product can only be eligible for use in CE-marked fertilisers under the EU Fertilising Products Regulation, under CMC2, if the algal biomass is only mechanically processed and dried. Also, CMC2 excludes cyanobacteria, and clarification is needed as to whether this refers to accidental presence, because these will to some extent grow spontaneously in algal production ponds.

However, algae derived from dairy wastewater processing have been approved for use in food products in Italy.

Photo below: AlgaeBiogas - Saltgae algae production



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Silvio Mangini, Archimede Ricerche, presented experience in the <u>Saltgae</u> project (Algae to treat saline wastewater, Horizon2020) operating a multistage combined photobioreactor plus 0.5 ha algae raceway pond (24 m³/day inflow) treating dairy processing at Camporosso, Italy, and a 0.5 m³ PBR plus 163 m³ raceway pilot treating aquaculture discharge at Arava, Israel.

These pilots show that N and P can be effectively reduced in the wastewater, and *Spirulina* algae can be produced, year round (in covered installations).



Algae CO₂ capture

Frédérique Ferey, <u>LafargeHolcim</u>, provided an overview of perspectives for using microalgae for CO_2 capture in the cement industry, and their subsequent uses.

The cement industry contributes around 6-9% of global CO₂ emissions. Biological conversion of CO₂ using microalgae is today a confirmed element of the industry's portfolio for CO₂ reduction (see Global Cement and Concrete Association GCCA here). The challenge is considerable: capture of just 1% of LafargeHolcim's net CO₂ emissions would produce over 500 000 t/y of micro-algae (fresh weight) and with current raceway technology would require around 540 km² (a 23 x 23 km square). This would mean significant opportunities for production of e.g. biofuels, bioplastics or animal feeds.

An advantage of using algae for CO₂ capture is that flue gases can be fed directly to the algae, without need for scrubbing/cleaning or concentration.

Lafarge has engaged R&D since 2006, with a number of different microalgae species in ponds, tubular photobioreactors and columns, in France, Spain, Austria, India and Sri Lanka, with biomass valorisation in methanisation or biofuels. At present, however, trials are suspended because there is no available downstream market.



Catherine Legrand, <u>Algoland</u> / Linnæus University, Sweden, summarised results of carbon capture trials carried out with Cementa AB (HeidelbergCement Group) and with other installations.



Pilot scale trials were carried out for five years feeding microalgae bioreactors (photo: M.Olofsson below) with fluegas from a powerplant (CO_2) after particle filtration only (not scrubbed). Natural algal communities from the Baltic Sea were used, dominated with *Mychonastes* and *Monoraphidium* sp. dominating.

Nutrients were sourced from different waste streams (municipal wastewater treatment plant, dairy water, process water from a papermill) and compared to synthetic growth medium.

Except in winter, 40 - 60% of CO₂ input was recovered in biomass and >70% of the biomass was high value materials (lipids, proteins, carbohydrates).

Carbon consumption (CO_2 reduction loss) in processing the algae to pellets for animal feed was only around 5%, partly because forestry-origin bioenergy was used for pelletising/drying.

Analysis showed that the biomass was conform to requirements for biofuels, fertilisers and animal feeds, with no significant heavy metals. Tests with hens showed that they liked the algal biomass mixed into their feed, no contamination of eggs and satisfaction of consumers with the eggs (panel tests). The egg yolks were very yellow because of carotenoids in the algae, so attractive to consumers.

Regulatory questions raised concern definitions and safety standards for algae biomass fed with waste streams. This is important to facilitate use of secondary nutrients, secondary water and offgases in algae production, to avoid consumption of virgin resources.

Another challenge is the need to train cross-disciplinary technology designers and operators, with competence in waste management, industrial processes, wastewater and biological processes.

Harvesting algae from nature

Eutrophication remediation

Gang Pan, Nottingham Trent University UK, explained the potential for harvesting algal blooms in eutrophic waters, in order to reduce water nutrients and restore water quality, and to valorise the biomass and nutrients.

Harmful algal blooms concentrate phosphorus in eutrophied surface waters into algal biomass, which can be harvested by flocculating and filtration using floating installations. This removes both excess nutrients and biomass from the water body, so reducing the eutrophication problem and the risk of anoxia.



The harvested biomass can be used to produce fertilisers, energy (methane, biofuels) or biochar soil improvers.

Dr. Pan emphasises the need to move innovation from research to full-scale implementation, an international funding approach to make technology development cost-effective, and at the same time development of appropriate industrial value chains for products.

Valorising beached seaweed

Pi Nyvall Collén, <u>Olmix Group</u>, Brittany, France, presented the companies activities valorising seaweed and the technical and regulatory challenges.



Large quantities of non-attached seaweeds are deposited on Brittany's beaches by tides (red algae, brown algae and green ulves algae). The seaweed biomass has high value potential. Harvesting from beaches has little impact on seaweed biodiversity, and reduces the nuisances resulting from accumulation and decomposition of seaweed on beaches.

The regulatory context is complex, because beached seaweed is "waste" and responsibility of the local authority (authorisations for collection, access to the Public Maritime Domaine ...) whereas drifting seaweed is "biomass" and responsibility of the State (subject to fishing licensing).

Valorisation of seaweed requires specific technical and logistic competence, which Olmix has developed. Seaweed is only collected when beaching is posing nuisances to users, and from beaches which have a reliable record of low heavy metal, dioxin and pesticide levels in seaweeds. Beached seaweed must be collected within 24 hours and stabilised within 48 hours, for example. Seaweed must then be washed, for which efficient and non-destructive methods have been developed, and foreign materials removed, conditioned, stored and transported.

Olmix' value products from seaweed include animal care (e.g. feed additive mixes to improve feed digestion or immunity), plant care (soil improvers and bio-stimulants) and human care (para-pharmaceuticals, food processing aids).

Not just algae ...

Duckweed for wastewater treatment

Paul Fourounjian, ILA (<u>International Lemna</u> <u>Association</u>), summarised experience and potential of using duckweed for wastewater nutrient removal and then valorisation.

Duckweed (*Lemnaceae*) is a family of small, surface growing, freshwater plants, found naturally in Europe and worldwide, which can be cultivated on shallow ponds, thereby purifying water and converting wastewater nutrients to easily harvested biomass. In year-long pilot scale trials13 to 38 tdm/ha/y were harvested in subtropical climates. Protein content can be around 40% dm.

Harvested duckweed biomass (depending on substrate regulatory and quality conditions) can be used to make bread or meat-substitute food products, soy replacement in chicken, pig, cattle and fish feed, or in energy production.

Duckweed growth can degrade hormones, reduce pharmaceuticals and remove pathogens from wastewater. Heavy metals and microplastics can be captured in the duckweed, which is beneficial for water treatment if the duckweed is then used for energy production, but requires surveillance for other uses.

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Duckweek pond – photo courtesy Paul Skillicorn

Duckweed cover of water has been shown to reduce evaporation (total water loss) by a third.

Duckweed can be grown in anoxic waste waters, because it uses oxygen from the air, and can restore some dissolved oxygen.

Reindert Devlamynck, Inagro, Belgium, summarised trials growing duckweed to treat pig manure in Flanders and regulatory questions around valorisation of the resulting protein-rich materials in animal feed.



After biological treatment of pig manure, the liquid fraction (diluted) is used to grow duckweed in a 140 m^2 surface area pilot-scale pond (corresponding to c. 49 m³/year biological treatment effluent). Nearly 4 t protein/ha/year was produced.

This is significantly higher than e.g. soy fields in North and South America (1.4 t protein/ha/year.)

In a continuous test it was found that As, Cd, and Pb were well below the feed standards of EC directive 2002/32/EC (on undesirable substances in animal feed). Further work is needed to verify levels of possible organic contaminants, such as veterinary pharmaceuticals, pathogens. However, current treatment system can also be optimised. The question here is, which processing steps are effective, and which are required? For example, washing, bleaching, acid treatment of the biomass? Or by digesting the manure or a heat treatment to reduce potential pathogens?

Inagro is interested to investigate using this pilot site, with other partners, in order to provide data to support definition of regulations on manure-grown duckweed to produce animal feed.

Regulatory and safety questions

Risk assessment: contaminants and pathogens

Giuliana D'Imporzano, University of Milan, summarised conclusions of the risk assessment of microalgae grown in wastewaters and manure slurries, in the EU Horizon2020 <u>SABANA</u> project.

In this project, demonstration photobioreactors from 100 l to 100 m^3 and a full scale 5 ha open raceway pond system are being constructed and tested at IFAPA near Almeria, Spain. Algae products are being produced and tested, including field trials as biostimulants and fertilisers, and testing as aquaculture feed.



Analysis showed that after cultivation of the freshwater microalga *Scenedesmus almeriensis* or the seawater microalga *Nannochloropsis gaditana* pathogen levels in pig slurry were reduced (absent in outlet for E. coli and Salmonella). The algal biomass itself showed pathogen levels generally compatible with use in animal feed, except for levels of *Clostridia* spores in some cases.

Pathogen removal seems to be related to high oxygen concentration in the medium and photochemical oxidation (solar UV) in the algae system.

Tests with *Chlorella vulgaris* in pig slurry showed uptake of heavy metals by the algae, in particular copper and zinc. In this case, cadmium levels in the algae were below EU limits for animal feed.

Tests using freshwater algae consortia showed high levels of degradation of pharmaceuticals and pesticides in microalgae growth, with 41 out of 52 substances tested showing >70% degradation. Levels in the biomass produced were low for



most pharmaceuticals, but with some showing uptake by the algae biomass (e.g. Citalopram, 24 μ g/g, Pentoxifyllin 0.06 μ g/g in algal biomass grown in wastewaters).

Field trials and trials as aquafeed show that microalgae biomass, produced using wastes such as wastewater or manure, is not toxic and provide positive effects as a plant growth promoter and in enhancement of fish health.

In discussion: degradation of organic contaminants in algal systems, such as pharmaceuticals and pesticides, is caused by light (UV) and high oxygen levels (from photosynthesis), resulting in photo-oxidation.

Suez regulatory & safety questions

Pierre-Olivier Descamps, Suez and CarbonWorks (Suez- Fermentalg joint venture for microalgae carbon capture, see <u>here</u>) presented a detailed matrix developed by specialists in Suez' different activities, suggesting possible regulatory status and safety concerns for different products produced from microalgae, depending on the different wastes / secondary materials used as inputs to feed the microalgae.

This matrix of regulatory/safety questions for inputs to algal production and algae applications can be seen in Suez' slides on the webinar <u>webpage</u>.

ESPP, with FEFAC and other webinar participants, have developed a simplified matrix, below on page 13.

For any algae production system, be it for CO_2 capture or for wastewater treatment or both, Suez needs clarity on the waste status or otherwise, not only of the algae biomass produced (and materials extracted from it) but also of the different inputs (CO_2 , secondary nutrients, secondary water ...).

For example, what is the waste status of CO_2 from biogas from anaerobic digesters? Does this depend on the input materials to the digester? Or on the gas purification system? What is the waste status of CO_2 which has been captured and then transported (e.g. liquified by pipeline or by truck)?

EU animal & aquaculture feed industry position



The EU feed industry is willing to make use of its wellrecognized capacity to contribute to the circular economy. In this sense, exploring new feed resources such as algae is a permanent objective.

There are many potential applications of algae for feed use, either as biomass or for specific nutrients / active substances.

However, there are a number of prerequisites for a successful feed use of new resources and the most important one is the safety of the product for the animals, for the consumers and also for the environment.

FEFAC, representing the European feed industry, is particularly vigilant when it comes to materials at the boundaries between waste and food/feed products. The General Food Law (EU Regulation 178/2002), which encompasses the feed legislation, provides to food and feed business operators the primary responsibility for the safety of the products they place on the market. In practice, the feed industry has developed and implemented feed safety assurance schemes requiring that a detailed risk profile must be established before it can be commercialized. Such a profile for algae would be useful, especially for those grown on organic wastes.

Input provided after the webinar by: Arnaud Bouxin, Deputy Secretary General, FEFAC.

Matrix of safety questions: waste inputs / algae end-uses										
End-use application of algae / algae-derived products:	Pharma- ceuticals	Cosmetics	Food (human)	Animal & aquaculture Feed. Pet food	Agriculture: fertilisers, biostimulants, soil improvers	Food contact plastics	Other bio- plastics etc.	Biofuels production	Energy via combustion and similar	
Algae grown in wastewaters										
Wastewaters not containing Animal By-Products										
- Industrial wastewater, landfill leachate										
- municipal wastewater (sewage)	<u>Possible contaminants will depend on the wastewater input, on algal culture conditions</u> <u>and on how the algae are processed (extraction, purification):</u> - heavy metals									
- separately collected food waste (bio-waste)										
- food & beverage industry	- dioxins, PAH, VOC - consumer & industrial chemicals - pharmaceuticals & antibiotics - ARGs (antimicrobial resistance genes)									
- green waste / roadside grass										
- agricultural crops / energy crops / biomass										
- aquaculture discharge										
Digestates etc. of the above										
Wastewaters containing Animal By-Products	In addition to possibly some of the above: - pathogens									
- manures										
- slaughterhouse wastewater, other animal by-products										
Digestates etc. of the above										
Algae fed with waste derived secondary materials										
E.g. struvite or other precipitated phosphate salts, hydro-thermal carbonisation residues, carbonates, sulphur compounds	Possible contaminants will depend on the original waste stream and on the recovery process							ery process		
Algae fed with offgases										
CO_2 , NO_x , from waste treatment, sewage treatment, manure processing, anaerobic digestion, cement production, industry/petrochemicals,	Possible contaminants as above: will depend on origin of gas (waste being treated or industrial process) and on the gas collection and cleaning processes installed									
Algae collected from environmental remediation										
Beach deposited seaweed, canal vegetation removal, eutrophication remediation (algal bloom removal)	Possible contaminants will depend on levels of environmental pollution.									

Marcella Fernandes de Souza, Ghent University, Belgium identified regulatory questions raised by the EU Interreg <u>Grassification</u> project and <u>Grass2Algae</u> (Flanders), using grass juices to feed microalgae.

These projects are testing various valorisation pathways for grass clippings (from roadsides or farms) including methanisation, production of fibres and use of the liquid fraction (after pressing) to feed algae production.



Grass2Algae will verify the safety and quality of the algae grown, e.g. for pesticides and pathogens if the grass was fertilised with manure. Monitoring already has shown that grass growing along roadsides has low levels of heavy metals, so not expected to be of concern.

Regulatory questions include

- roadside grass clippings have waste status, does this mean that the algae produced and materials extracted from them also have waste status?
- the possibility to use offgas CO₂ from biogas production to feed the algae? waste status of this offgas?
- use of non-indigenous algae species?
- conditions for discharge of the outflow water from the algae production?
- criteria for use of the algae in animal feed, human food products or other applications?

Wolfgang Trunk, European Commission, DG SANTE, (in the Chat) indicated that regulatory questions concerning the manufacturing and use of algae for animal feed and human food are harmonised across the EU. Thus, there are no differences between Member States. He suggested to submit questions to the European Commission, DG SANTE, who will provide a comprehensive answer.

Rommie van der Weide, Wageningen Research ACRRES,

(in the Chat) indicated that algae species must be on a positive list for use in animal feed, see chapter 3 of "Opportunities for micro algae as ingredient in animal diets", <u>October 2016 (may</u> not be fully up to date today).



EU Fertilising Products Regulation 2019/1009

Theodora Nikolakopoulou, European Commission DG GROW, explained under what conditions algaebased materials can be included in EU fertilising products (CE-marked), as of application of the new Fertilising Products Regulation 2019/1009 in July 2022.

EU Fertilising Products Regulation 2019/1009 https://ec.europa.eu/growth/sectors/chemicals/specific-chemicals_en

This Regulation lays down criteria in accordance with which a waste material can cease to be waste if it is contained in a compliant EU fertilising product. This requires that the material be conform to the specifications for materials to be included in fertilising products (CMCs = Component Material Categories, Annex II) and that the fertilising product itself be conform to a Product Function Category (PFC, Annex I) and to labelling and conformity assessment obligations (Annexes III and IV).

Algae and algae-derived materials can be included in different CMCs, subject to specified conditions and limitations being met:

- Current CMCs:
 - "Virgin material substances and mixtures (CMC 1)", but waste/waste origin excluded
 - "Plant, plant parts, plant extracts (CMC 2)", includes algae (micro- and macro-) but excludes cyanobacteria and excludes any chemical or heat treatment*
- as input materials for production of:
 - "Compost (CMC 3)"
 - "Digestate (CMC 4 & 5)"
- Possibly in "By-products" (CMC 11), however criteria are currently being developed for this CMC and will probably not cover algae-based by-products
- For future CMCs, expected to be adopted soon (STRUBIAS), as input materials for production of:
 - Thermal oxidation materials and derivates (CMC 13)
 - Pyrolysis and gasification materials (CMC 14)

* The European Commission is currently considering an amendment to allow heat treatment at up to 100°C for fiberisation processes.

A question was raised as to whether algae grown using manure as a substrate might in future be included in CMC10 (Animal By-Products and Derived Products).

Another question concerned the possible trace presence of cyanobacteria in an algal culture of another species: would this exclude from CMC2? On the one hand, an EU Fertilising Product must consist solely of materials which are CMCs, "accidental" presence of non-CMC materials is not allowed. On the other hand, the Commission's Frequently Asked Questions indicate "materials present in the final composition of an EU fertilising product cannot be 100% pure. Thus, irrespectively of the actual industrial process followed, a fertilising product is expected to contain detectable traces of impurities". However, it is not clear that this FAQ statement

applies to materials which are explicitly excluded (in this case, cyanobacteria). The European Commission will look into clarifying this.

Leon Fock, <u>Eurofema</u> (European Organic Fertilizers Manufacturers Association) outlined the questions posed by user industry about waste-derived algae:

- Absence of standards, to date, for algae for fertilising products (see below work underway in CEN/TC 454)
- Quality and safety: heavy metals? Pathogens?
- As for other waste-derived materials, maximum residue limits for food and feed after use on crops: the new EU Fertilising Products Regulation limits may not be strict enough to guarantee this
- Again not specific to algae: agronomic effectiveness: are marketing claims supported by evidence? Some Member States already prohibit some claims.
- Carbon footprint: algae production fixes CO₂, but what is the net carbon footprint after processing of the algae (e.g. drying), transport, manufacture and use of a fertilising product? (Note: see answer from Catherine Legrand)

José Maria Gomez, Biomasa Peninsular, presented the company's development of microalgae cultivation in wastewater to produce fertilising products. He outlined regulatory aspects relevant to valorisation of wastederived algae, in particular nutrient recycling.



Photo: Twin Layer in LIFE TL_BIOFER Project.

A twin-layer microalgae biofilm pilot (photo), inflow 6 000 litres/day, was operated for 2 years near Cordoba, Spain (EU TL-Biofer LIFE project, see ESPP <u>eNews n°31</u>), fed with secondary sewage works effluent. The algae were processed by lyophilisation and were formulated using water dilution, extraction and solid blends to produce bio-based fertilisers/biostimulants, showing low heavy metals and no detectable pathogens, and with excellent results in lab and agronomic pot trials.

Algae-based amino-acid biostimulants were produced at <u>URBIOFIN</u> (BBI-JI) project by enzymatic hydrolysis. Field trials are underway in 2021

Key legal questions identified concern not only "waste" status and possible eligibility for use in fertilisers (both addressed in other presentations) but also:

- lack of clarity or exclusion of waste-grown algae and products produced from them in the EU Fertilising Products Regulation (FPR):
 - Are these excluded from CMC1 as "waste origin"?
 - In principle, could be eligible for CMC2 if mechanical processing only, quality requirements and End-of-Waste provisions (see Articles 6 and 19 of FPR). Enzymatic hydrolysis and other non-mechanical processes are excluded.
 - Questions around cyanobacteria exclusion in CMC 2.
 - Algae not to date included in CMC7
 - By-products from algae production not today considered in CMC11
- No harmonised EN standards exist for bio-based fertilisers and biostimulants, nor for algae based products (estimated in 2024). Standardisation mandate M/547 on algae and algae-based products or intermediate. Already existing CEN Technical Committees:
 - CEN/TC 454: algae and algae products,
 - CEN/TC 455: plant biostimulants and agricultural micro-organisms,
 - CEN/TC 260: fertilisers and liming materials.
- **REACH** registration requirement or not? and difficulty/cost if registration is required for algae-derived organic materials.
- eligibility for use in **Organic Farming 2018/848**, as fertilisers, biostimulants, animal feed or in food processing?
- regulatory situation where **algae production involves several "waste" inputs:** offgas nitrogen, CO₂, wastewater nutrients, secondary heat ...?

Photo: algae production raceway, Zaragoza, courtesy of <u>URBIOFIN</u> - University of Valladolid



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CEN/TC 454 standards for algae

A general principle is that standards for final products (e.g. food or cosmetics) should treat materials derived from algae in the same way as materials derived from other crops or plants.

However, if wastes are used as the medium for algae production (e.g. wastewater) or otherwise input into algae production (e.g. offgases), then specific standards may be needed to address quality and safety (possible contaminants or pathogens, depending on the waste stream), information and traceability.

CEN standards for algae are under development, following the European Commission mandate M547 (<u>March 2016</u>) and <u>should cover</u>:

- Terms and definitions for algae and algae products. This is published as CEN standard **EN 17399** (March 2020)
- Classification of algae, products and processes. No publication to date.
- Algae processing. No publication to date.
- Specifications for food & feed applications. Technical report **CEN/TR 17599** (March 2021).
- Specifications for non-food/feed applications. Two technical reports to date: **CEN/TR 17611 cosmetics** (January 2021) and **CEN/TR 17612 pharmaceuticals** (January 2021). Work is understood to be underway on "chemical and biofuel applications" (no publication to date).
- Product test methods and sampling. No publication to date.

The above CEN standards and technical reports can be purchased here <u>www.evs.ee</u>

CEN/TC 454 (Technical Committee "Algae and algae products") https://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:2278882& cs=1F20FCBCD6123B309AAB0F52C8CDEF169_

It is noted that this CEN work underway under Mandate M547 covers use of algae to produce fertilisers, soil improvers and biostimulants under "chemicals and fuels".

Other work underway in CEN should also bring clarifications concerning use of algae and algae-derived products: CEN/TC 411: Bio-based Products, CEN/TC 455: Standards on Plant Biostimulants and Agricultural Micro-organisms, CEN/TC 260: Fertilisers and Liming Materials.

Waste-derived algae not addressed

The CEN Technical Reports on algae for different applications published early 2021 (see above: food & feed. pharmaceuticals, cosmetics) do not address the consideration that algae may be derived from waste inputs. For example, safety or contaminant verification, traceability or customer information requirements could be appropriate if waste is used to feed algae.

Also, the Mandate M547 from the European Commission mentions only specifications for the residue streams from the

algal production process. This mandate does request to define nitrogen and CO_2 uptake.

The Technical Reports on use in pharmaceuticals and cosmetics state (under "Sustainable development of microalgae production", \$8.4 and 6.4 respectively):

"In all the growth phase, nutrient supply - typically in the form of fertilizers - is also highly required; this burden could be mitigated by using wastewater but, at the current stage of development, high-quality production seems to be incompatible with this nutrient source."

ESPP suggests that this paragraph could maybe be revised in the future, if evidence is developed that processes can ensure appropriate quality and safety of waste-fed algae.

This paragraph does not appear in the Technical Report on use for human food and animal feed applications.

ESPP action: waste-derived algae in CEN standards work

ESPP will engage dialogue with CEN/TC (Technical Committee) 454 on algae, and with the European Commission to take into account, where feasible and relevant, waste-derived algae in specifications for algae and algae products for different applications. ESPP will propose, to concerned companies (algae operators, wastewater sector, CO_2 ...) and research experts to develop information on, e.g.:

- how to take into account, in algae standards, the use of different wastes as algae feed streams, and implications for standards for quality and safety (e.g. possible contaminants or pathogens),

- appropriate limitations of wastes used to feed algae for some specific end-uses,

- purification processes, analysis and testing as a function of different waste feeds,

- information to customers and traceability.



End-of-Waste

Caroline Attard, European Commission DG Environment, provided an overview of EU rules on waste and by-products and work underway on "End-of-Waste" under the EU Circular Economy Action Plan.

The classification of a substance or object as a waste or a by-product or whether it has ceased to be waste is made by the producer on a case-by-case basis, taking into account the specific factual circumstances of the case and national Member State procedures and national rules transposing Directive 2008/98/EC on waste, amended by Directive (EU) 2018/851 (WFD).

The WFD provides the definition of "waste" whereby a substance or object is considered as waste if the holder: discards (action or activity), intends to discard (intention) or is required to discard (legal obligation) it (Article 3(1)). It also outlines the rules and conditions against which Member States can establish criteria for by-products and end-of-waste status (Articles 5 and 6 of the WFD).

In order to improve clarity for operators, the Waste Framework Directive enables Member States to define national criteria for By-Products and End-of-Waste (must be notified to the EU) and also the EU to define European criteria.

It should be noted that offgases such as CO2 or ammonia from production processes emitted into the atmosphere are out of the of scope of the Waste Framework Directive (see Article 2 of Directive 2008/98/EC on waste); however they may be, subject to the <u>Industrial Emissions Directive</u> 2010/75/EU. Conversely, **gases from waste recovery** operations (e.g. biogas produced from anaerobic digesters) would need to meet specific End-of-Waste criteria for their use as a product (secondary raw material).

An action of the Circular Economy Action Plan, is to identify candidate waste streams for scoping development of European End-of-Waste criteria. The European Commission launched the work on this action in the second half of 2020.

Candidate waste and material streams will be shortlisted based on criteria such as: existing recovery rates, opportunities for circularity, benefits for human health and the environment, benefits for society, market viability, success rate, scale of shipments across the EU, volume of generated waste. It is expected that the waste streams will be quite precisely delimited, specifying both the origin and characteristics of the waste and specific use destination(s) for recovered material(s). A stakeholder workshop is planned later this year.

Detailed development work will then be carried out for the selected streams, based on the established JRC End-of-Waste methodology.

Waste Framework Directive (consolidated version) <u>https://eur-</u> lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20180705

EC website on waste and recycling https://ec.europa.eu/environment/topics/waste-and-recycling_en Guidance on the interpretation of key provisions of Directive 2008/98/EC on waste (2012) <u>http://waste-prevention.gr/waste/wp-</u> content/uploads/2015/10/2012_Guidance%20interpretation%20Directive%2 098-2008-EC_EN.pdf (Note: this is still largely valid, however note that

certain updates were made in 2018 via Directive (EU) 2018/851)

JRC, End of Waste Criteria, Final Report (2008), https://publications.jrc.ec.europa.eu/repository/handle/JRC53238

Study to assess member states practices on by-product (BP) and end-of waste (EoW) <u>https://op.europa.eu/en/publication-detail/-</u> /publication/beb56eaa-9fc0-11ea-9d2d-01aa75ed71a1/language-en/format-PDF/source-search

Roberta Congestri, <u>AISAM</u> (Italian Association for the Study and Applications of Microalgae), identified questions on how to address the possible waste status of algae:

- Varying safety and contaminant challenges in different input waste streams: sewage, manures, abattoir wastewaters, industrial wastewaters ...
- Distinction between high-value materials from algae (e.g. extracted proteins or cosmetics ingredients) and raw algae biomass
- Need for different criteria depending on the end-use: food, feed, cosmetics, industrial uses, energy/biofuels ...
- Challenges of a "biorefinery" approach which combines a range of input material flows and output products

ESPP action: End-of-Waste

Discussion suggested that it is not today clear whether algae grown and harvested using wastes as inputs (e.g. in nutrient removal and treatment of wastewater, or CO_2 or N-offgas capture) are considered to be wastes or not. On the one hand, they are produced from wastes, but on the other, there is no intention to "discard" them.

This leads however to uncertainty for operators and investors. Participants therefore suggested to work towards End-of-Waste status for waste-derived algae, under certain conditions (input feed, contaminants and safety, quality, specified uses ...). ESPP will:

- coordinate input to DG Environment to suggest that algae, algae derived materials, and more widely other relevant materials recovered from wastewater, should be considered for development of EU End-of-Waste status

- organize with EABA and operators an inventory of existing national regulatory status definitions for waste-derived algae and of national End-of-Waste criteria where these exist.

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Organic Farming

Damiano Gritti, Severino Becagli Società Agricola and EABA, underlined apparent incompatibilities between some of the challenge of the EU Organic Farming Regulation 848/2018 and circularity and valorisation of algae.

For example, in 848/2018:

- art. 6(b) states "Suitability of aquatic medium and sustainable management plan. 1.Operations shall be situated in locations that are not subject to contamination by products or substances not authorised for organic production, or pollutants that would compromise the organic nature of the products". Is this compatible with use of algae harvested in estuaries or onshore waters where some anthropogenic pollution is present?
- Annex II, Part III, point 2.3.2 states "only nutrients of plant or mineral origin authorised pursuant to Article 24 for use in organic production may be used". Is this compatible with **use of wastewater rich in nutrients** needed for algal growth?

Rules on **Organic Farming production of algae** need to be clarified. Can waste-derived nutrients be used to feed the algae?

Can algae cultivated using waste derived medium/nutrients be used in Organic Farming as feed, fertilisers or biostimulants?

Participants raised further questions concerning algae and Organic Farming, including **what processing of the algae is possible** to extract proteins and lipids for animal feeds? Which chemicals can be used?

Conclusions and discussions

Session conclusions:

EU Fertilising products Regulation

Rapporteurs: Marie-Edith Ploteau, Lippeverband and Phos4You (Interreg NWE); Aurore Assaker, Ghent University and Biorefine Cluster Europe.

Use of algae is today a proven technology for treatment of municipal wastewater and biowastes, both in small sewage works and in larger installation, with a number of full-scale installations operating worldwide. Further political support and incentives are needed for roll-out, in order to improve costefficiency and market validation.

The energy balance is clearly positive when algal biomass goes to methane production. Further investigation of carbon sequestration (use of waste CO_2) should assess the overall carbon balance, taking into account processing and use of algae.

Algal biomass produced from waste treatment algae systems can offer good properties (protein content, biostimulant properties) as well as recovering nutrients and carbon.

Quality is often good for use in animal feed, which provides higher market value than fertilising product use, but poses regulatory and safety questions.

Use of algae in fertilising products, under the new EU Fertilising Products Regulation (FPR), is possible under several different CMCs (see presentation by Theodora Nikolakopoulou, DG GROW). However, a number of questions are raised:

• Are waste-grown algae and materials produced from them eligible under CMC1? This will depend on "waste" status, and this can vary between Member States.

- Algae are eligible under CMC2 (plant materials), but only if not chemically processed (so that some extraction processes are excluded). "Drying" is allowed, but to what temperature? Also, all "cyanobacteria" are currently excluded. What about accidental presence of cyanobacteria? (NOTE: see discussion of cyanobacteria below).
- CMC2 does not exclude "wastes", but it is nonetheless not clear whether algae with "waste" status could be used under CMC2 taking into account article 19 of the FPR.
- Would it be useful to add some microalgae species to the list of species in CMC7? There are currently no algae in this list, whereas inclusion is necessary to allow use in microbial biostimulants PFC6(A). If so, scientific data on agronomic efficacy and safety are necessary.
- Algal biomass can be an input to FPR composts, digestates, ashes/ash derived materials and biochars (CMCs 3, 4, 5, 13, 14) subject to some conditions.

Waste status and other regulatory challenges

Rapporteurs: Thomas Vannecke, Flemish Coordination Centre for Manure Processing (VCM); Renske Verhulst, Netherlands Nutrient Platform.

Algae or duckweed production systems can have different objectives, and often combine several of these:

- producing specific materials or products,
- environmental cleaning (decontamination, eutrophication mitigation),
- wastewater treatment,
- nutrient recovery,
- CO₂ capture.

Safety questions for algae depend both on the origins of waste inputs used to feed the algae (wastewaters, CO₂), and so possible contaminants or pathogens, and on the intended uses of the algae and materials produced.

Questions raised in this session are:

- Legal status of the algae and materials produced from them, of by-products generated in algae processing, and of the liquid discharge from the algae production.
- Need to investigate End-of-Waste status for these different streams: do some Member States already have End-of-Waste status for some streams? Is coordination between Member States feasible for some materials?
- Which safety and contaminant criteria are important: heavy metals? Organic contaminants? Pathogens?
- Where manure is used as an input feed for algae or duckweed production: is an Animal By-Product End Point applicable? Is the resulting biomass considered "processed manure" under the Nitrates Directive?

Other questions raised in discussions

The following questions were also raised, and some answers can be found in the webinar Chat transcript <u>here</u>. These technical questions on algae production were not the objective of this webinar and are not further addressed in this summary.

Are digestates useable to feed algae production?

- solid/liquid separation is generally done, and algae are grown in the liquid fraction, which contains most of the phosphorus

- digestates tend to have dark coloration, which can be an obstacle to algae production (blocking light). This can be addressed by improved solid/liquid separation or microfiltration, or by dilution.

- high ammonia content can be an obstacle

Is artificial light needed for algae reactors?

- LEDs are used with specific wavelengths

How is biofilm formation prevented in algae photobioreactors?

- internal particle circulation can prevent biofilm creation on reactor glass, surfaces, lights. This is well-known and tested technology.

What levels of P and N removal from wastewaters are achieved using algae systems?

If pharmaceuticals and organic contaminants are broken down by algae, do we know what are the metabolic degradation products?

Which algae species are used for wastewater nutrient removal?

- the Phos4You demonstrator (GCU) used *Chlamydomonas acidophila* because it can use nutrients at low light intensity and is tolerant of ammonia.

How do N and P contents vary between different algae species?

What fatty acid contents are found in cultivated algae?

What is the optimal N:P for algae cultivation?

Can discharge water from aquaculture be recycled, after treatment (e.g. by algae) in Organic Farming aquaculture? - in Sweden, 'Organic' fish/aquaculture products must be in flowing, not recycled, water.

Are there "algae brokers" who will buy algae paste or powder and resell on to applications?

- there are some brokers amongst EABA members.

What is the meaning of "bio-fertiliser"?

- this is not defined in the new EU Fertilising Products Regulation,

- "bio-fertiliser" is generally used to mean a fertiliser derived from bio-based materials.

Cyanobacteria

A number of participants raised questions concerning cyanobacteria and their exclusion from CMC2 (plant materials) of the EU Fertilising Products Regulation.

It does not seem justified to exclude all cyanobacteria, in that for example *Spirulina* (photo) is authorised in food applications / dietary supplements (see <u>here</u>).

It is also noted that **Spirulina is authorised in fertilising products in France under NF U 42-001**, see example of a product on the market here (<u>Penn Ar Bed, Proalg Booster</u>)

Photo: Spirulina production, Severino Becagli, Grosseto, Tuscany <u>https://www.severinobecagli.it/en/</u>







Photo: Spirulina for food applications



It also needs to be clarified that accidental presence of cyanobacteria in a cultivation of another species should not be an obstacle, if they do not impact safety.

EABA has proposed to add the word "toxic" to this CMC2 exclusion of cyanobacteria. This proposal is welcomed by a number of participants. However, this requires a clear definition of "toxic". Another proposal suggested during the webinar would be to define a positive list of accepted "safe" cyanobacteria.

In both cases, evidence would be needed to support which cyanobacteria under what conditions can be considered nontoxic, in that production of toxins by cyanobacteria depends on their growing conditions.

Participants note that various lists of toxic algae are available and could be referred. The IOC-UNESCO <u>catalogue</u> of toxic marine microalgae (HAB harmful algal bloom) species includes 42 cyanobacteria species, but also many species from six other taxa.

Theodora Nikolakopoulou, European Commission DG GROW, indicated (in the Chat) that in the absence of an assessment on algal toxicity and of toxic algae species, the EU legislators (Council and Parliament) decided to exclude all cyanobacteria.

Where next?

Pieter de Jong, WETSUS and **Water Europe**, underlined that nutrient recovery from wastewater, and production of specific circular feedstocks (e.g. bioplastics) from WWTP sludge and bio-waste, is now moving from R&D to full-scale implementation.

In addition, during this webinar, examples presented show that algae production combining wastewater treatment and nutrient removal with nutrient recovery and production of specific materials is also rapidly advancing in TRL levels and application size.

A more circular water sector is a global challenge, with developments strongly underway in Europe, the USA and worldwide.

Regulatory questions around waste and product status are an important challenge, and pose risks which can inhibit investment. More widely, **the wastewater sector hopes that recovery of targeted materials from wastewaters will be included in the priority streams for development of EU End-of-Waste status** announced by the European Commission in the Circular Economy Action Plan. He proposes to develop, jointly with operators and experts concerned, and with ESPP, an outline list of relevant materials/uses from wastewaters to propose to the European Commission.

This joint letter requesting that certain materials recovered from wastewaters be considered for priority EU End-of-Waste assessment was sent by ESPP to the European Commission on 3rd May 2021 and is online here <u>www.phosphorusplatform.eu/regulatory</u>

Further organisations are welcome to add their signature: contact info@phosphorusplatform.eu

Ludwig Herman, Proman and **ESPP President**, concluded the webinar by noting the considerable potential for algae production to combine waste treatment, CO_2 recovery and nutrient recycling.

This webinar has contributed to identify the regulatory, standards and safety questions which need to be addressed to enable this. The aim has not been to bring answers, but to define questions and possible actions to address them.

Finally, the key to success is the quality of the final product, be it biomass used directly as fertiliser, or specific materials such as lipids or proteins.



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