Microalgae in Waste Water Treatment

Green Gold from Sludge?

There is a significant increase in the global use of renewable energies due to the impending shortage of fossil resources and noticeable effects of global warming. They are one of the key issues in the energy strategies of the future. However, there is also an increasing need to re-evaluate the existing strategies for renewable energies under the aspect of fuel or food production. The use of microalgae might provide a helpful alternative in a developing field of research.

The use of biomass production has risen up to 68 % of the renewable energies and is currently holding a significant share in the renewable energy mix in Germany [12]. A competitive situation concerns the share of arable land available for agricultural food production, as 15 % of the agricultural area of the Federal Republic of Germany is used for biomass production today. Microalgae are offering a sensible alternative, since the yield of oils and biomass is considerably higher than in agricultural crops (fig. 1., according to [2]). They also provide a wide variety of substances of interest to pharmaceutical and food industries.

Several landmark projects mostly using photo-bioreactors for the production of microalgae for a maximum output of closely defined valuable ingredients are existing throughout Germany today. The pilot project in Hamburg Reitbrook (E.ON Concern; Hamburg University) concerns itself with the aspect of photosynthetic CO2 fixation in green microalgae as a contribution to reduce carbon dioxide greenhouse effect. An estimated fixation rate of 400 t/ha reactor area however will not contribute noticeably to a substantial reduction of an amount of approximately 2-27 Mio. t CO2 output per power plant and year.

The microalgae farm in Klötze (Saxony-Anhalt) is currently producing 50 t biomass per year for the subsequent use in cosmetic and food products. The high market value of such products balances the cost intensive production to meet the industrial standards required. It provides an interesting alternative for the biomass production of microalgae on a high input/output level. Further optimization of
Biomass production based on microalgae is provided by Subitec mainly aiming at the production of high value products (Astaxanthine, Eicosapentaenoic acid).

Another approach was followed up in 2006 by a joint project of the Bremen University with industrial partners (Lamotte, Polyplan, Algatec) using feedstock materials as additional C-donators for micro algal growth. The fatty acids produced were meant as fish oil substitutes for food processing and cosmetic industry.

In addition, microalgae are frequently mentioned in the context of biodiesel production, since micro algal populations show an average production of 30% oil content in wet biomass depending on the state and composition of the algal population. This value is far above the oil contents of agricultural plants currently used for biofuel production. However, complex harvesting and processing procedures (pyrolysis and esterification) combined with insufficient production of algal dry mass per liter are limiting factors to this course of action. The costs in biofuel production out of micro algal biomass amount to approx. 50 €/liter presently [12], which is way above a commercially attractive level of production cost.

A cost extensive approach to the production of micro algal biomass is needed to further encourage investigation. One promising alternative seems to be the production of micro algal biomass in communal waste water plants providing a readily available medium for algal growth at almost no cost. This way no additional agricultural areas are used for biomass production. Moreover waste water ingredients such as nitrate, phosphate or residues from food processing industries can be used as nutrients for micro algal growth. Nitrates are mostly denitrified otherwise and lost in the process. Algal biomass production is offering the retrieval of nitrogen by incorporation in the biomass produced.

There are 9.994 communal waste water plants in Germany today, the level of waste water treatment reaches 96% with a total of 9,4 bill. m³/a of treated water [14].
Throughout Germany 80% of the waste water plant treated water is classified as on a "low" or "very low" (BOD 1 and 2) pollution level with the nutrient values of the treated water at 8.3 mg/l for nitrate und 0.8 mg/l for phosphate [15] on average. In comparison to input levels of <25 to >50 mg/l nitrate [13] and ca. 2.5 g phosphate/denizen on a daily basis a recycling mechanism of these nutrients would hold considerable advantages, especially concerning the well known finite nature of the phosphate reserves.

Thus waste water plants are currently testing the use of microalgae worldwide in warm and moderate climate zones. Hammouda et al. [4] showed that micro algal populations (Chlorella, Scenedesmus) were up to 100% effective in removing ammonia, nitrate and phosphate in Egypt. Micro algal cultures of local marine origin were also used effectively in Scotland for waste water treatment [3]. Up to 1 g/l micro algal biomass production in summer and 10-100 mg/l biomass production in spring and fall seasons were documented in stabilization ponds in Sweden [5].

The use of algal biomass as feeding stuff supplement [7] or in fertilizer mixtures [11] is possible and does not require high cost harvesting and processing procedures as necessary in the production of biodiesel out of algal lipids [10]. Further processing of the harvested biomass for biogas production (H2 production, [1]) is a promising alternative as well. A further motive for future application of algal biomass production is the use of CO2 as a promoting agent for culture growth. CO2 emission trade - 1 t of CO2 was traded for 14.70 € at the EEX in Leipzig in September 2008 - will offer an additional financial compensation for the amount of CO2 reduction reached this way. Combined with the availability of waste water as a free available nutritional source for algal biomass production this might provide an additional attractive stimulus for waste water plants even throughout Europe.
Pilot studies at the University of applied Sciences Ostfalia in Wolfenbüttel, Germany (fig. 2.) showed, that local algal species (Chlorella, Scenedesmus) seemed to tolerate communal waste water of different plants, which did not always meet the requirements (C:N:P=106:16:1, Redfield Ratio [9]) for an optimized medium for algal growth. An almost complete decomposition of nutrients such as ammonia, nitrate and nitrite was reached within 10 days. These findings are consistent with observations under naturally varying conditions in a polluted area in Egypt (Lake Burullus) with pH of 7.15-8.5 and varying nutritional values. Here Chlorophyceae held a share of up to 39.9% of the algal species found and microalgae of the Scenedesmus species were predominant with up to 14.4%. Observations in Chlorella cultures in communal waste water back these findings: Lau et al. [6] found a better decomposition of phosphate and nitrate in communal waste water, if the micro algal cultures underwent previous acclimatization of two weeks.

Thus summarized the production of micro algal biomass by waste water plants could prove a useful further alternative in the variety of renewable energy resources. The ready availability of waste water as medium for algal growth as well as low cost harvesting and processing procedures for the biomass produced from feedstock and fertilizer supplement to biogas production are attractive features for further research, especially with respect to the current lively food or fuel discussion. Thus, the step from waste water treatment to a contribution to power supply could prove to be an interesting future option for providers.

References
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Watch a video on Screening Microalgae - Searching for a Diamond in the Muck

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