Wastewater treatment using microalgae enables phosphorous and nitrogen removal in darkness

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Removal of nitrogen and phosphorous from urban waste waters using a simpler and more inexpensive system based on microalgae was the starting point of the research conducted by several UCA scientists of the TEP-181:Tecnología del Medio Ambiente research group, member of Campus de Excelencia Internacional del Mar (CEI.Mar). Led by

Professor José Antonio Perales Vargas-Machuca, a team of experts have developed a new wastewater system for nutrient removal from waste water based on photobiotreatment with microalgae, a process that allows removal of nutrients in darkness.

Urban waste waters have high concentrations of nitrogen and phosphorous that must be removed before discharge into rivers or areas nearby natural parks, in order to avoid problems of eutrophication with consequent degradation of environmental quality. Currently, many efficient procedures exist for removing these nutrients but they usually present drawbacks in terms of cost-effectiveness, complexity of operation, waste generation (sludge) and/or high energy consumption.

In order to overcome these problems, various scientists have focused on treating waste waters by using microalgae; an aspect that UCA researchers have also addressed in their research. Therefore, Professor Perales Vargas-Machuca's team has focussed on photobiotreatment of waste waters by using microalgae, a biotechnological process that needs light in order to take place. "This technology, which involves removal of nutrients from waste waters, has two main disadvantages: land area occupied by reactors and separation of the biomass from the culture medium," Professor José Antonio Perales explains.

"Microalgae basically need nitrogen, phosphorous, water and light. The first three elements are present in urban waste waters, but in order to obtain sufficient energy, the reactors must be exposed to sunlight like solar panels. Reactors must not be too deep because light would not reach microalgae. This limitation regarding light path should be taken into account when it comes to reducing the land area these photo-bioreactors would need," says Perales Vargas-Machuca. The shorter the light path, the greater the concentration of microalgae obtained in the culture medium. However, if a reactor whose light path is too short (shallow) is used, and then the problem would be the excessive area of land needed. Therefore, the most common photo-bioreactors used are reactors with longer light paths. "The advantage of these reactors is their low cost, but lower biomass is achieved, which entails another problem: harvesting."

Harvesting or separation is the process through which the solid elements (algae biomass) are separated from the liquid phase. This technique "involves high energy consumption and is only profitable when the objective is to obtain value-added products from biomass such as carotenoids and xantophile (both organic pigments) but not when we seek to treat waste waters," as UCA researchers claim.

However, the team of researchers started to fit together the pieces of the jigsaw, and while cultivating algae during their experiment, they observed that "microalgae, as any other organism, use part of what they assimilate to grow and store the rest. In the case of nitrogen and phosphorous, which are contaminating nutrients present in waste waters, the microalgae accumulate the nutrients internally in such a way that their assimilation commences before the growth phase. Microalgae consume all the nitrogen and phosphorous until the nutrients disappear from the waste waters, and because microalgae start to grow before the growth of biomass takes place, this explains why microalgae are internally saturated with these elements. Microalgae grow later at the expense of these reserves,"says the UCA Professor who led the research.

With this idea in mind, the researchers conducted various experiments and found out that microalgae assimilated nitrogen and phosphorous in darkness too. "Light was needed for algae to grow but not to assimilate the nutrients, so we can take advantage of this capacity in reactors without having the depth limitation (no light). Therefore, we partially overcame the problem of space required with photo-bioreactors."

The next step was separation or harvesting; that is to say, separating already treated water and keeping a high concentration of microalgae in the photo-bioreactor in which they would grow at the expense of their reserves in a way that they could be used again in order to perform a continuous treatment process. In this way, "we can choose whether to obtain a small amount of biomass with high nitrogen and phosphorous content or a large amount of biomass with low nutrient concentration depending on the objective of the process, whether it is wastewater treatment or biomass production. This problem can be overcome using membrane separation technology and all this without interrupting the process in the night phase."

According to José Antonio Perales, "the system we have designed can work on a continuous basis in darkness and in daylight, whereas conventional systems can only grow algae under illumination. All the algae we produced during the luminous phase (daylight) with waste water assimilate nitrogen and phosphorous and grow at the expense of their nutrient reservoir, whereas in the darkness phase (night) algae only purify waste water by assimilating nutrients but without growing in the dark."

The patent, developed by researches Jesús Ruiz, Pablo Álvarez, Zouhayr Arbib, Carmen Garrido and Jesús Barragán, apart from Perales, is the start of the road that will take José Antonio Perales' team to the development of a prototype that will run on a continuous basis. "To date we have only experimental evidence that the process can perform successfully, but we need to test within a reasonable time frame using a prototype that is ran continuously. Once operating variables under controlled laboratory conditions are adjusted, we will assemble the system in the laboratory's outdoor facilities to test the system's stability taking into account seasonal daylight changes, temperature and other variables and comparing it with conventional photo-bioreactors."

The study is the result of two research projects: 'Use of mocroalage for nutrient removal from waste waters and biofuel production', under the Spanish National Plan, and 'Feasibility study on the use of microalgae for wastewater treatment: CO_2 biofixation and biofuel production', a scientific excellence study supported by the Junta de Andalucía (Regional Government of Andalucia).

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