REMOVAL OF NUTRIENTS IN WASTEWATER TREATMENT VIA MICROALGAE AND BIOFUEL/BIOMASS PRODUCTION FOR ENVIRONMENTAL SUSTAINABILITY IN VIETNAM, (RENEWABLE)

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Introduction and context

The Vietnamese economy has grown rapidly over the last 25 years and is considered as one of the fast-growing economies in Asia. Their economic development largely relies on natural resources (agriculture, fisheries and forestry), placing stress on the environment as a result of deforestation, overfishing, water pollution, salinization and acidification of soils. The key environmental issues that the country has to face today are: the global climate change, the degradation of the main environment components (forest, biodiversity, water and air) and the problem of solid waste. The fourth Assessment Report of IPCC indicated that the impact of climate change will seriously affect developing countries, in which Vietnam with its exceptionally long coastline is cited as one of the top countries vulnerable to climate change leading to serious floods, frequency and intensity of tropical cyclones, and sea level rise impacting particularly agricultural regions of Mekong and Red river deltas[1]. Vietnam is relatively rich in water resources but the discharge of untreated wastewater released from both domestic and industrial activities into the river network has caused serious pollution problems such as eutrophication of surface water in many urban centers areas and agricultural regions. For domestic water, although 60% of households dispose of wastewater through a public sewage system, much of this went to the drainage system with only 10% of the water treated. Aquaculture and seafood processing are highly developed in Vietnam. The country has no fewer than 1000 food processing corporations and thousands of fish/shrimp-farming. Wastewaters from this type of industrial activities are characterized by a high content of ammoniacal nitrogen that can affect the aquatic environment if they are directly released in rivers. Fish and shrimp farms are generally located in the vicinity of coastal regions and often directly connected to the sea or deltas (e.g. Mekong delta). The Vietnamese coastline is over 3,200 km long, offering great potential for marine fisheries to play an important role in Vietnam's emergent market economy. More than 400,000 people work directly in capture fisheries, and over two million people in support industries and related services. The raw materials for processed fish products come mainly from the southern part of the country, which accounts for 70% of total export value. Around 60% of factories are located in the south, mainly in coastal areas. The untreated wastewaters, rich in nutrients, are directly released into rivers but also into the sea and costal water. Low incomes, use of rudimentary techniques and the lack of information about the development of state-of-the-art technologies mean that, currently, only 4% of the overall companies operating in the fields are equipped with a wastewater treatment system. When installed, the treatment is mainly based on activated sludge and is poorly operated.

In this context, the RENEWABLE research project (ARES-CCD, PRD project 2016-2020) aims to contribute to the prevention of coastal surface and groundwater pollution from aquaculture farming in Vietnam by reducing its pollution load with the use of microalgae wastewater treatment approach. The biomass produced is a source of possible renewable energy for biofuel production and animal feedstuff production.

The objectives of the project

The RENEWABLE project started in May 2016 and is focused on wastewaters from shrimp aquaculture and more specifically on wastewater from intensive shrimp farming aquaculture in the Ninh Thuan province. This province situated in South-central region of Vietnam has been selected to install a field pilot. The province has many valuable assets to achieve the objectives of the RENEWABLE project. An advantageous climate (average temperature stable around 27°C), driest region of Vietnam and excellent sunlight intensity, all conditions favorable for microalgae production. It is one of four biggest fishing grounds of the country, with 50000-60000 tons of seafood produced each year. Moreover, Ninh Thuan waters have constant salinity and a rather clean environment, ideal conditions for high quality seed for shrimps. They produce and provide most of the seed shrimp (24 billions post-larvae of shrimps and prawns in 2014) for all the country. Aside the climate and the favorable environment, the RENEWABLE project will have support from the regional government (DOST, Department of Sciences and Technology) of the province. They are participating as partner in the project.
Intensive shrimp production farms in Ninh Thuan province encompass several open ponds (from 5 to 10) working in closed systems. The size of a pond is about 1000 m^3. The bottom of the pond is covered with a waterproof cover. The production cycle from larvae to shrimp harvesting takes about 3 months. At the end of a cycle, the untreated wastewater is completely discharged in river or coastal water/soil and the empty pond is cleaned before being re-used. Frequently (several times a week), about 20% of the total amount of water is replaced in the pond during the 3 months cycle. Saline water directly pumped from the sea, after pretreatment, is used to refill the open pond.

The wastewater generated by this activity has high loads of organic and nutrients. The average BOD_5 generally ranges from 20 to 500 mg/L (COD = 100-1000 mg/L). In addition, the wastewater contains high levels of suspended solids and is rich in nutrients. Another important aspect of the wastewater discharged here is its high salinity (Na^+, Cl^-, SO_4^{2-}), caused by the seawater used by these farms. Saline wastewater has adverse effects to biological processes. High salt levels cause bacterial cells to dehydrate due to osmotic pressure. Saline wastewater discharge can pollute groundwater and the surrounding lands used for agriculture. Due to massive aquaculture development, lack of planning, rudimentary technology and use of many types of improper chemicals cause negative impacts on aquatic environment such as organic contaminants, pathogenic organisms, toxins (ammonia, nitrite, hydrogen sulfide)… Concentration of many pollutants in wastewater from shrimp/fish farming exceed effluent standard maximum limits. In addition, the use of antibiotics, if they are recirculated, could become either harmful for the fishes but also for microalgae itself when implementing algae wastewater treatment. Indeed, the risk of inhibition of algal growth is likely.
Farmers and authorities are aware of the pollution generated by this economical activity and they are interested in treating wastewater reasonably in a sustainable manner. However, an important work of awareness raising, education and training is needed. From discussion with stakeholders, it's very important that if wastewater problem caused by shrimp production is Ninh Thuan is solved, that experience can be widely applied in Mekong Delta to reduce environmental degradation and ensure international environmental standards for shrimp products.

Response strategies and preliminary results

The global objectives of our project are to contribute to improve surface water and coastal water quality in the broader frame of environmental protection and sustainability in Vietnam and to sustain

the livelihood of aquaculture farmers. The intended effect consists to ensure that the feasibility of the reduction of the pollution load of aquaculture wastewater discharged in coastal areas by using microalgae, a fit for purpose-valorization technology for saline shrimp farming wastewater treatment. Second, the valorization potential of the biomass produced through biofuel from saline shrimp farming wastewater treatment and analysis of the remaining biomass after oil extraction for other valorization process like animal feed production (high protein content)[2,3,4,5,6]. A socio-economical evaluation of the complete integrated approach will be performed; a handbook (technical, practical and economical data) will be provided to the stakeholders in order to prepare feasibility scale-up studies in the defined sectors. The last part of the project is dedicated to dissemination of knowledge and know-how acquisition to regional government and aquaculture farmers. Farmers, people using water from river and local authorities have been clearly identified as the end beneficiaries of the RENEWABLE project. The stakeholders involved in the project are the aquaculture farmers (hatcheries, fish and shrimp) but also the industry of animal feedstuff and biofuel.

To achieve the outcomes, the project requires a scientific consortium based on complementary skills between the North and the South partners. We paid attention to select partners in order to ensure that all the required skills will be covered in Belgium and in Vietnam. Industrial and governmental partners are also included to strengthen our group. We organized the budget in such a way that all the partners make financial efforts to give the opportunity to financially support two Vietnamese PhD students. One PhD thesis is oriented towards characterization of Vietnamese microalgae strains with a strong emphasis in analytical chemistry and genetics. The second thesis is linked to chemical engineering, the set-up of the pilots and simulation approaches to optimize the operating conditions. In addition, an investment cost has been foreseen for our South partners to install laboratory instruments for basic water and microalgae characterization and two pilots: one lab pilot at IUH University and one field pilot on site at the research center of fisheries at Ninh Thuan province.

Sets of Vietnamese microalgal species have been tested and are under a full characterization at ULg (genomics, lipidomics, metabolomics). Preliminary results showed very encouraging data at laboratory scale from shrimp ponds regarding inorganic/organic content removal. For instance, a strain selected (*Chlorella vulgaris microalgae*) was able to eliminate more than 80% COD, 75% N-NH4+; 80% TKN and 66% TP. This clearly indicates the potential of microalgae for aquaculture wastewater treatment[7].

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