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Alternatives for reducing the environmental impact of an ammonia production plant adjacent to a coastal lagoon in the southeastern Gulf of California

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A B S T R A C T

There is an increasing demand for N-fertilizers and the manufacture of N-products worldwide. In Mexico, ammonia production is being promoted by the government, but this development is associated with several environmental impacts. This study examines the causes, effects and mitigation alternatives related to the installation and operation of an ammonia production plant adjacent to a coastal lagoon. A multiplicity of causes (and effects) was identified: water suction (elimination of plankton and larvae), effluent discharge (thermal contamination, salinization, and the effects of chlorine), and the conversion of wetlands (loss of habitat and nursery areas, biodiversity, fishery benefits, retention of contaminants, coastal stabilization, carbon storage and aesthetic value). At present, it is estimated that wetlands (9146 ha mangroves + 22,641 ha others) in the Ohuira-Topolobampo lagoon sustain the production of 3000 t live weight of seafood catches per year, implying that the conversion of 126 ha of wetlands could represent for fishermen a catch reduction of 11.9–41.3 t of shellfish per year and a decrease in the annual retention load of up 0.52 kg Cd, 41.0 kg Cu, 0.40 kg Hg, 280 kg Pb, 88.2 t P and 75.6 t N by wetland sediments. To mitigate the environmental effects associated with the installation and operation of the plant, the following is recommended: (i) afforestation of an equivalent area (126 ha), (ii) installation of an exclusion system for fauna to avoid the incidental capture of plankton and larvae, (iii) the use of cooling towers, and (iv) the selection of an appropriate discharge point for the effluent. A list of fauna and flora of the lagoon, as well as environmental services that could be compromised and affected by the operation of the ammonia production plant, is presented. This study is the first to analyze and document such effects and mitigation options related to land conversion and water management, providing useful information for decision makers.

1. Introduction

With worldwide ammonia production estimated at 172×10^6 t (as N) (FAO, 2015), ammonia is one of the most abundantly synthesized industrial chemicals in the world (Bicer et al., 2016), and its production is used mostly (80%) for worldwide agriculture

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because it is the source of nitrogen for all N-containing fertilizers. The rest is used for the manufacture of several products (nitric acid, dyes, explosives, nylon and other polyamides, medicines, and cleaning products) and as a refrigerant. Conversely, ammonia is being considered for use as a sustainable fuel; it can be used in all types of combustion engines, gas turbines, burners and directly in fuel cells, which is a very important advantage compared with other types of fuel (Bicer et al., 2016). As occurs with other economic activities, the installation and operation of an ammonia production plant (APP) implies several environmental effects related to (i) losses of coastal habitats (grass and herbaceous vegetation, mangroves, etc.); (ii) water management (water suction and discharge of effluents), and; (iii) greenhouse gas emissions (CO_2, N_2O, CH_4), which, except for the last item, have not been documented in the scientific literature. Typical losses of functions related to the damage of coastal habitats include a variety of impacts such as the reduction of fisheries and carbon storage, elimination of waterfowl refuges and migratory stop-over sites, decline of aesthetic value, interception of land-derived nutrients, and decreasing stabilization of the coastline (Valiela, 2006).

In the coming years, it is expected that the majority of ammonia consumption will be in Asia because of industrial and fertilizers, where China's consumption is estimated to have grown by 6% per year. This growth and agricultural demand in Latin America and Africa indicate that over the next years, the production of fertilizers could further increase. The total ammonia production capacity is expected to rise to 201×10^6 t in 2018. The main additions to this capacity could occur in Asia, Africa, North America and Latin America (FAO, 2015).

Currently, the majority (66–80%) of fertilizers used in Mexico are imported. From this perspective, the Mexican federal government has proposed to increase domestic fertilizer production to meet 80% of the demand, which could reduce the agricultural supply costs necessitated by increasing food production. Therefore, the APP project constitutes an alternative way to increase fertilizer production in Mexico. Sinaloa state (SE Gulf of California) has a vast agricultural area (1.25 million ha) that requires fertilizer application. The economic value of the agricultural products from Sinaloa represents 15% of the total agriculture production value in Mexico. Therefore, a local plant with the capacity to produce 770,000 t of ammonia per year could ensure the supply of N-containing fertilizer.

The main objective of this study is to identify mitigation options for reducing the environmental impact of an APP adjacent to a coastal lagoon in the SE Gulf of California. This case study is useful because the study area is representative of subtropical conditions; therefore, improving the installation and operation conditions of an APP in this region has relevant implications for the future development of APPs in tropical and subtropical latitudes. The study is necessary because the installation and operation of an APP in the margin of a coastal lagoon, it is essential to identify and implement realistic and effective mitigation measures. It is important to ensure the sustainability of the lagoon with respect to the environmental services and functions it provides for the fisheries, aquaculture, and the integrity of the biodiversity. In contrast, the justification of whether to install an APP becomes a matter of economic and food security for a country, which merits an exhaustive analysis, but that goes beyond the scope of this study.

2. Methods

2.1. Description of the project

The APP project comprises the construction and operation of a plant for the production of ammonia from natural gas with a capacity of 2200 t day^{-1}, which includes the installation of the production plant and a storage facility, a pipeline duct for the reception of natural gas, and a pipeline for the transportation of ammonia to the terminal in the Topolobampo port for its distribution (CAPSA, 2013). Essentially, the processes of the APP consist of the conversion of natural gas into hydrogen gas. The hydrogen is then combined with nitrogen to produce ammonia and carbon dioxide; the process is initiated with the input of natural gas, water vapor, and air (Fig. 1). The plant is planned to be built in a site adjacent to the Ohuira-Topolobampo (OHT) lagoon (Fig. 2), because of the access to port facilities for ammonia transportation and for importation of natural gas from the El Oro-Topolobampo pipeline.

2.2. Site selection: OHT lagoon

Upon analyzing the different options along the 652 km coast of Sinaloa, it is evident that not many options satisfy the requirements for an ideal APP site, which include low environmental costs, communication and supplies of water and energy. The prerequisite of a nearby port with facilities to transport the product to the rest of the country is a key factor. Sinaloa has only two available ports with such facilities, Mazatlan and Topolobampo. Therefore, the selection of Topolobampo as the site appears to be correct (Fig. 2). Along the south of the Sinaloa coast, there are two coastal sections with a limited number of wetlands, and there are no registered Ramsar sites. However, the problem with such coastal sections is the absence of a port infrastructure. Developing the project in any of these sections means creating a port infrastructure, which implies an additional economic challenge.

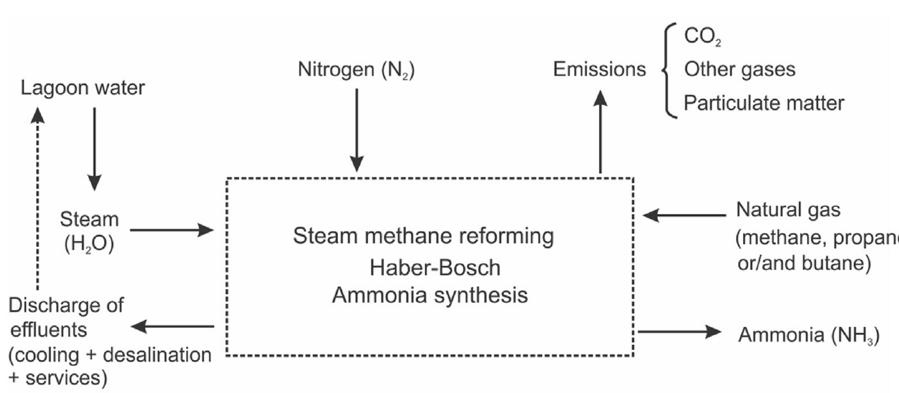

Fig. 1. Schematic diagram of an ammonia production plant that uses nitrogen, natural gas and lagoon water.