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# Scale-up of a clean hydrogen production system through the hydrolysis of sodium borohydride for off-grid applications

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ABSTRACT

Hydrogen is considered a promising energy vector with the potential to replace fossil fuels, and sodium borohydride serves as an effective energy carrier capable of releasing hydrogen ($H_2$) for off-grid applications. However, the hydrolysis of sodium borohydride has only matured at laboratory-scale. Therefore, the scale-up of a laboratory reactor was designed and manufactured to study the effect of larger H2 production. For that, the effect of inhibitor NaOH concentration and water quality were studied. Experiments using 3 wt% NaOH showed overall better performance than those using 1 wt%. Additionally, experiments using tap water — scarcely reported in the literature — demonstrated performance equal to or better than that achieved with distilled water. These results are indicative of a possible significant reduction in the $H_2$ production cost through this method.

## 1. Introduction

Hydrogen ($H_2$) is currently considered a key energy vector in the ongoing decarbonization process It has the highest known gravimetric energy density, approximately three times greater than that of diesel or gasoline. However, as it is not naturally available in molecular form ($H_2$), it must be produced and stored [1]. To be considered green, $H_2$ must be obtained through the electrolysis of water using renewable electricity, i.e., obtained from renewable energy sources, such as the wind and the sun [2]. As a result, grid electricity is required, of which only about 39 % is sourced from renewables on average [3], but also makes this process less-practical for off-grid applications, such as in the maritime sector and in remote off-grid locations. Moreover, electrolysis requires the use of pure water and $H_2$ produced is generally transferred as gas to tanks at high-pressures or in liquid state at cryogenic temperatures, which requires safety handling measures.

As an alternative, chemical hydrides — particularly sodium borohydride ($NaBH_4$) — have a high hydrogen content (10.7 wt %, in theory [4–9]) and can release it through the hydrolysis reaction at ambient to moderate temperature and at considerably lower pressures, as observed in Equation (1).

$$NaBH_4(s) + (x+2)H_2O(l) \rightarrow NaBO_2 \cdot xH_2O(aq) + 4H_2(g) + heat \quad (1)$$

In Equation (1), $x$ represents the excess of water used. Sodium metaborate ($NaBO_2$) is formed as by-product, which retains 2 water molecules, therefore excess of water is requested to promote the $H_2$ yield and rate to acceptable levels. Through this reaction, $H_2$ is obtained pure, clean, can be used in a fuel cell to generate electric energy and can also be simultaneously stored, making it well-suitable for off-grid applications, such as in the maritime small-size transportation – a sector that has been behind in the decarbonization process due to the lack of clean solutions [10,11].

In 2007, a no-go recommendation was reported for this $H_2$ carrier for on-board vehicles storage [12]. Since then, the majority of reports have been focused on the catalytic activity of this technology and few on the regeneration of $NaBH_4$ from the by-product – the main drawback [13–16]. Nevertheless, significant progress has been made since and an $H_2$ system has been defined by the authors to allow this technology to reach laboratory maturity level: two reactors - a cylindrical reactor with interior conical bottom [5] and an egg-shaped one with optimized water valorization [7]; a more than 300-time reusable Ni–Ru catalyst [6]; studies on the best parameters to promote the $H_2$ formation

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