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Feasibility, potential and environmental impacts of ocean alkalinity enhancement for removing CO_2 from the atmosphere and counteracting seawater acidification

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The deployment of carbon dioxide removal (CDR) processes is required, as well as strong and immediate emission reductions, to limit the global temperature increase "well below to 2°C above pre-industrial levels" as required by the Article 2 of the Paris Agreement.

Among the CDR processes, ocean alkalinity enhancement (OAE) allows to remove CO_2 from the atmosphere and simultaneously to counteract the ongoing ocean acidification caused by the increased CO_2 atmospheric concentration. In the framework of the DESARC (DEcreasing Seawater Acidification Removing Carbon) MARESANUS research project, different strategies to produce decarbonized slaked lime (SL), i.e. $Ca(OH)_2$, and to discharge it in the seawater have been evaluated.

The feasibility and the potential of OAE were evaluated at the global scale and at the Mediterranean Sea basin scale. Two different logistic scenarios for the discharge of SL were analyzed: new dedicated ships, and partial load on modified existing dry bulk and container ships. The data on the existing global fleet of vessels and marine routes has been elaborated to assess the potential discharge of SL.

Through the life-cycle assessment methodology, the efficiency of removing CO_2 from the atmosphere was evaluated, as well as other potential environmental impacts connected to SL production and transport. The "cradle-to-grave" approach has been applied to different configurations of the process, that consider both biomass gasification and the use of renewables as a source of energy for limestone calcination, as well as eventual CO_2/H_2 separation and CO_2 storage.

The data collected for the life cycle inventory were mainly obtained from the preliminary design of the process and the scientific literature, as well as from the ecoinvent database. According to the environmental footprint method implemented in SimaPro software, sixteen impact categories for assessing the burdens on the environment and human are evaluated, with a particular focus on Climate change, Land use, and Mineral and metals use.

The results show that for all the analyzed configurations, the process has a potential negative impact on the Climate change category, i.e. there is a benefit for the environment in terms of CO_2

removal from the atmosphere. Since the avoided impacts are related to the source for hydrogen, the type of avoided source has a relevant role and is subjected to a sensitivity analysis.

Finally, the availability of limestone for the large-scale development of ocean alkalinisation have been evaluated, considering in particular the deposits of pure limestone near the coastlines, that could minimize logistic and transportation activities.

Results show that pure carbonate potential resources are of several trillion tons and are not a constraint for the development of global-scale ocean liming. A large part of pure limestone resources is nearby the coastline, in areas with no or low vegetation cover, mainly in North Africa and Iran. Global limestone yearly production is similar to coal, and the required upscaling compared to the current extraction rate is far lower for limestone than for other materials considered for OAE, such as olivine, magnesite and brucite.