ATLANTIS-pH

Biological and Chemical Mitigation of Ocean Acidification through Controlled Cyanobacteria Cultivation and Alkalinity Enhancement

ABSTRACT

Ocean acidification represents one of the most critical and irreversible consequences of anthropogenic carbon dioxide emissions. Since the pre-industrial era, the average pH of surface oceans has decreased by approximately 0.1 units, corresponding to an increase of nearly 30% in hydrogen ion concentration. This chemical shift threatens marine biodiversity, disrupts carbonate chemistry, and compromises ecosystem services essential to human civilisation.

This paper proposes ATLANTIS-pH, a scientifically conservative pilot system combining controlled biological carbon fixation using cyanobacteria or microalgae with monitored alkalinity enhancement. The project aims to evaluate whether localized mitigation of acidification can be achieved safely, measurably, and scalably under strict Monitoring, Reporting, and Verification (MRV) principles.

KEYWORDS

Ocean Acidification, Cyanobacteria, Microalgae, Carbon Dioxide Removal, Marine Alkalinity Enhancement, Blue Carbon, MRV

1. INTRODUCTION

The world's oceans absorb approximately one quarter to one third of anthropogenic CO_2 emissions annually. While this process moderates atmospheric warming, it fundamentally alters seawater carbonate chemistry. Dissolved carbon dioxide reacts with seawater to form carbonic acid, reducing carbonate ion availability and lowering pH.

Unlike climate warming, which manifests primarily through temperature change, ocean acidification is a chemical transformation — silent, persistent, and largely irreversible on human timescales. Emission reduction alone may be insufficient to prevent ecological thresholds, motivating complementary mitigation approaches.

2. CHEMICAL BASIS OF OCEAN ACIDIFICATION

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons 2H^+ + CO_3^{2-}$$

Increased atmospheric CO_2 shifts equilibrium toward higher hydrogen ion concentration, decreasing pH and carbonate saturation states essential for calcifying organisms.

3. RATIONALE FOR AN INTEGRATED STRATEGY

Biological fixation alone is transient without biomass removal. Alkalinity enhancement alone alters buffering capacity but does not permanently remove carbon. ATLANTIS-pH integrates both mechanisms to address root cause and chemical consequence simultaneously.

4. BIOLOGICAL COMPONENT

Selected non-toxigenic cyanobacteria and microalgae are cultivated exclusively in closed photobioreactor systems. Candidate genera include Synechococcus, Chlorella and Nannochloropsis.

5. SYSTEM ARCHITECTURE

The pilot consists of:
- Seawater intake and filtration
- Closed photobioreactors
- Biomass harvesting
- Optional alkalinity dosing chamber
- Controlled discharge

6. BIOMASS REMOVAL

Harvested biomass undergoes drying and conversion to biochar or anaerobic digestion, ensuring durable carbon sequestration.

7. ALKALINITY ENHANCEMENT

Micro-scale alkalinity increase is achieved through controlled dissolution of alkaline minerals within an isolated mixing chamber prior to discharge.

8. MONITORING, REPORTING AND VERIFICATION

Continuous monitoring includes:
- pH
- Temperature
- Salinity
- Dissolved oxygen
- Fluorescence

Laboratory analysis includes TA, DIC, nutrients and chlorophyll-a. Net carbon removal is calculated conservatively.

9. EXPERIMENTAL DESIGN

12-month pilot:
Phase I – Engineering validation
Phase II – Biological operation
Phase III – Biomass harvesting
Phase IV – Alkalinity trials
Phase V – Reporting

10. CONCLUSION

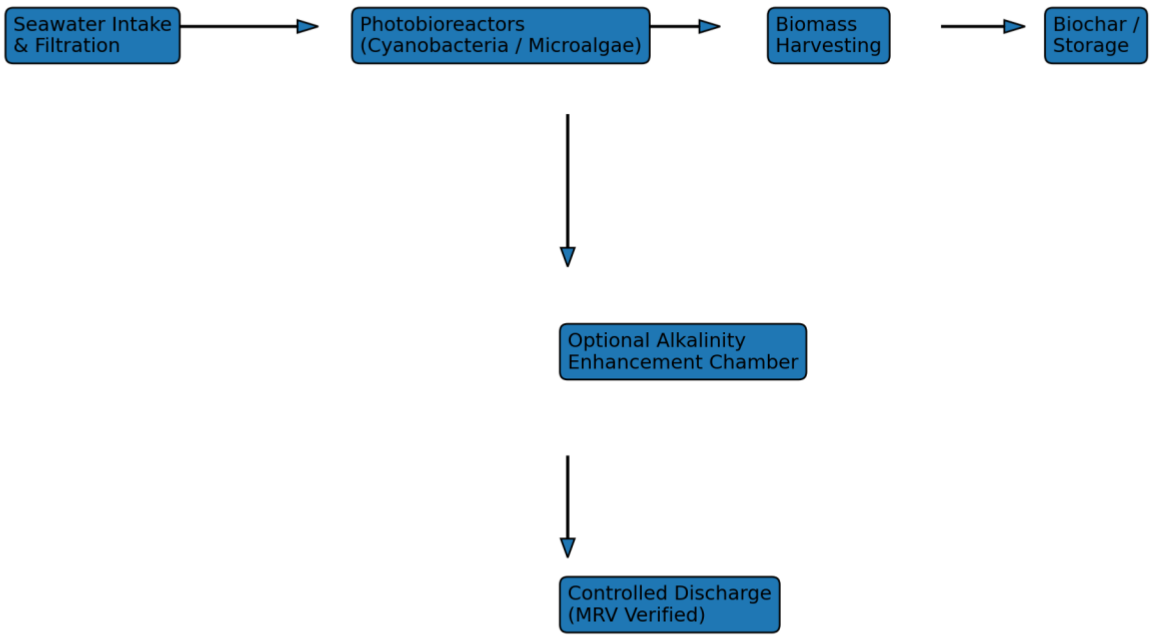
ATLANTIS-pH proposes a cautious, scientifically grounded approach to explore mitigation of ocean acidification through controlled biological systems and chemical buffering restoration. The project emphasizes reversibility, transparency, and ecological responsibility.

AUTHOR

Francisco Gonçalves
Independent Researcher
Portugal

Figures

Figure 1 – Conceptual architecture of the ATLANTIS-pH pilot system.



The diagram illustrates the controlled seawater intake, closed photobioreactor operation, biomass harvesting and sequestration pathway, optional alkalinity enhancement chamber, and monitored discharge under MRV protocols.