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Ocean Acidification as Physical Indicator for Climate Change

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Abstract

Atmospheric carbon dioxide concentration is expected to exceed 500 parts per million and global temperatures to rise by at least 2°C by 2050 to 2100, values that significantly exceed those of at least the past 420,000 years during which most extant marine organisms evolved. Under conditions expected in the 21st century, global warming and ocean acidification will have a huge concern.

Keywords: Ocean Acidification, Climate Change, Seawater pH, Material Strengthening

1. Introduction

Covering about 70 percent of the Earth's surface, the world's oceans have a two-way relationship with weather and climate. The oceans influence the weather on local to global scales, while changes in climate can fundamentally alter many properties of the oceans [1]. However, climate change is acknowledged by many as one of the greatest challenges of the twenty-first century, a challenge that potentially poses an existential threat to the lives and livelihoods of millions of people in different societies around the world.

Moreover, The ocean has long taken the brunt of the impacts of human-made global warming. As the planet's greatest carbon sink, the ocean absorbs excess heat and energy released from rising greenhouse gas emissions trapped in the Earth's ecosystem. Today, the ocean has absorbed about 90 percent of the heat generated by rising emissions. Furthermore, As excessive heat and energy warms the ocean, the change in temperature leads to unparalleled cascading effects, including ice-melting, sea-level rise, marine heatwaves, as consequences of ocean acidification, which eventually will lead to a kind of disorder in ocean circulation.

In less than fifteen years ocean acidification has emerged as a key research priority for marine science and its implementation. And has recently begun to gain visibility in political agendas. Even though the history of anthropogenic ocean acidification as a research topic is brief, ocean acidification was triggered [2], like global warming, by the industrial revolution more than 200 years ago. Since 1800, the oceans have absorbed about one-third of the carbon dioxide produced by man. Without this moderating capacity of the oceans, atmospheric levels of carbon dioxide would have been considerably higher and, consequently, the effect on Earth's climate more pronounced. As ocean acidification continues at a rate that is

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probably unprecedented in the history of Earth, our The number of papers on ocean acidification increased considerably after 2004. With a total number of more than 300 papers (figure 1). However, Ocean acidification is a new field of research which has implications for a very large number of scientific and socio-economic sub-disciplines [2]

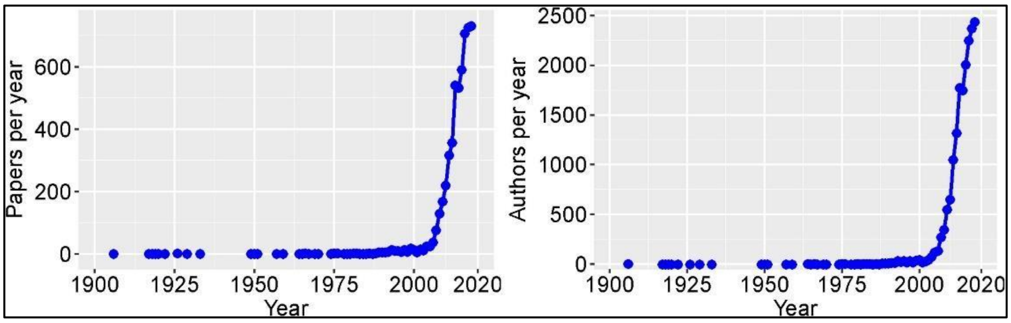

Fig. 1. shows the progress in publishing papers related to ocean acidification.

Despite the impressive development of this field in the past few years, both in terms of research initiatives and publications, only a few consequences are known with a high level of confidence (e.g. chemistry), whereas many (e.g. the biological and biogeochemical responses, and the impact on socio-economics) are known with only a moderate level of confidence.

The goal of this paper is to review somehow all aspects of ocean acidification research and concepts, in term of summarizing the current understanding as well as the usage of ocean acidification as climate change indicator.

2. Material and methods

The ocean acidification indicator is based on long-term period records from thousands of buoy monitoring stations throughout our oceans. The indicator is particularly crucial since identification can have wide-ranging variation [3]. However, The increase in pH of seawater is a result of change on the chemistry of seawater and marine ecosystems, which will eventually lead to more socioeconomic concerns. In Figure 2 shows that over the spam of four decades the concentration ofCO2 in ppm have a remarkable role in changing the chemistry bonds of seawater which led to impactand decrease the value of pH to be more acidic “the values of pH is variant from spot to another”.

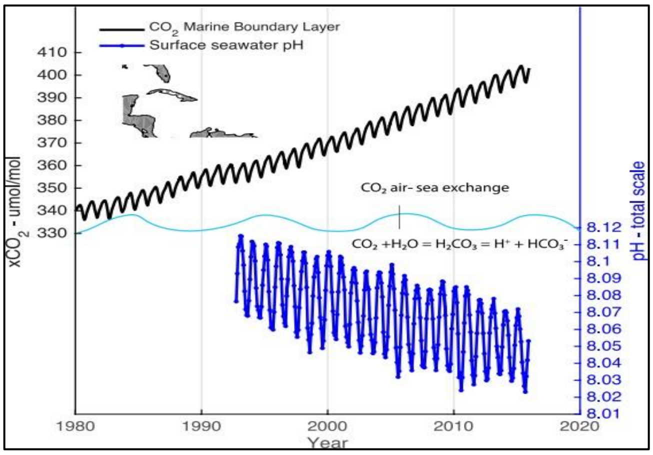

Fig. 2. pH over the spam of 4 decades by monitoring the CO2 concentration in ppm .

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3. Discussion

The mean pH of the ocean's surface has decreased by about 0.1 unit (from approximately 8.2 to 8.1) since the beginning of the industrial revolution, representing a rate of change exceeding any known have occurred for at least hundreds of thousands of years. Figure 2 indicates that if emissions continue on their current trajectory pH may drop by another 0.3 units by the end of the century. Even under optimistic scenarios. Unfortunately, mean ocean surface pH is expected to drop below 7.9 pH [3].

After all, I'm looking forward to discuss two significant factors that can impact the ocean directly aswell as they will increase our current understating in reasons behind why ocean acidification might be a physical indicator for our climate change concerns. Somehow these two factors are linked andcoherent each other, as following:

3.1 Effects of Ocean Acidification on the Chemistry of Seawater

As atmospheric carbon dioxide (CO2) increases and dissolves into the ocean, it modifies the chemistry of seawater. However, the principal processes that control the acid-base chemistry of seawater and the cycling of carbon in the ocean are variant. In addition, one of these principal weak acids and bases that can exchange hydrogen ion in seawater and which it is the only responsible for controlling its pH due to Inorganic carbon dissolved in the ocean occurs in two principal forms: dissolved carbon dioxide (CO2) and producing bicarbonate ion(HCO3). Moreover, CO2 dissolved in seawater acts as an acid and provides hydrogen ions (H+) to any added base to form bicarbonate [2]:

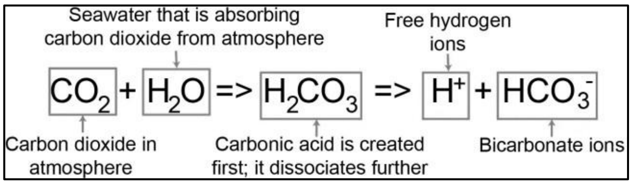

Fig. 3. Chemical reaction emphasizes the change on the chemistry of seawaterdue to CO2 absorption.

As seen in the reactions above, bicarbonate can act as an acid or a base (i.e., donate or accept hydrogen ions) depending on conditions. Under present-day conditions, these reactions buffer the pH of surface seawater at a slightly basic value of about 8.1 (above the neutral value around 7.0). At this pH, the total dissolved inorganic carbon (~ 2 mM) consists of approximately 9% CO2, 90% HCO3 and 1% others (Figure 4) [3].

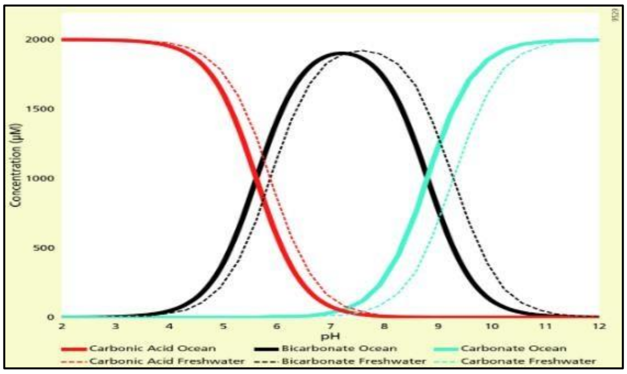

Fig. 4. Typical concentrations of the major weak acids and weak bases in seawater as afunction of pH.

For long-term chemical impact, we can divide the seawater into two projections firstly horizontal (Projections for Surface Waters) and vertical projections (Projections for Deeper Waters). In term of horizontal aspect, it is noticeable to determine the pH variation of surface seawater because the relationship between atmospheric CO2 and seawater carbonate chemistry is well understood, it

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is a simple matter to calculate the variations in average pH and inorganic carbon species concentrations in the surface waters of the open ocean based on the known variations in atmospheric CO2 over long spam of period for instance over the past 150 years.

While the CO2 concentration in the surface ocean tracks the increasing values in the atmosphere, the penetration of that CO2 into deep water depends on the slow vertical mixing of the water column and the transport of water masses in the complex wind-driven circulation and overturning of the oceans. About half of the anthropogenic CO2 is now found in the upper 400 meters, while the other half has penetrated to deeper water, as illustrated in Figure 6. This slow penetration of CO2 into the deep ocean is reflected in a slower decrease in pH at depth than at the surface [3].

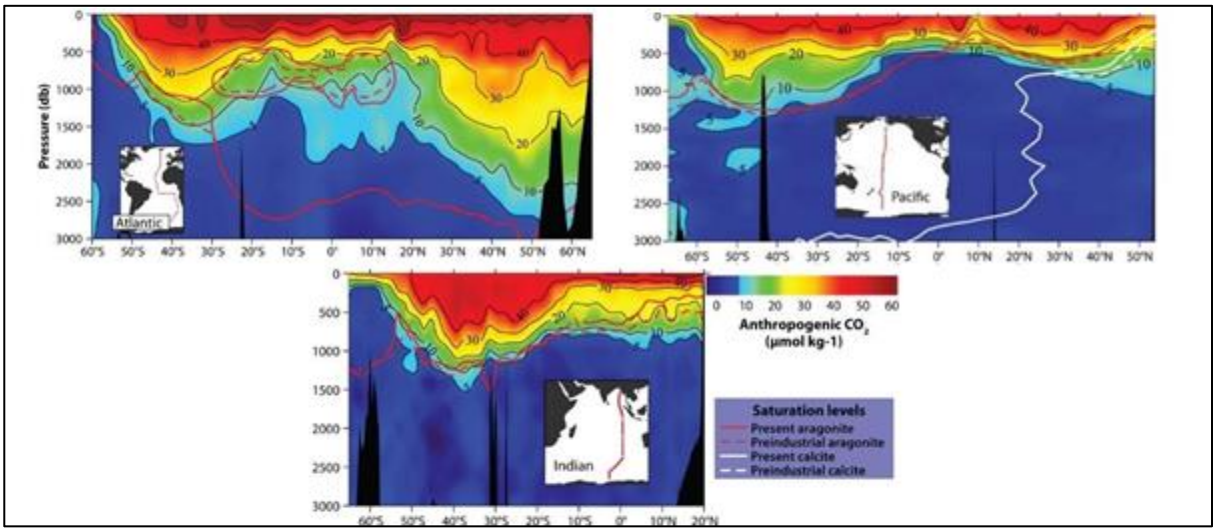

Fig. 6. Vertical distributions of anthropogenic CO2 concentrations (μmol kg^{-1}) throughoutIndian, Pacific and Atlantic oceans.

An illustration of the time lag between surface and deep ocean acidification is shown in Figure 7, according to simple calculations, under scenario of CO2 emissions, we can determine that it will take about 500 years longer for a 0.3 unit decrease to occur in deep waters compared to surface waters. However, in some regions where the vertical movement of water is relatively fast, the time scale for deep penetration of anthropogenic CO2 will be on the order of decades instead of centuries [3].

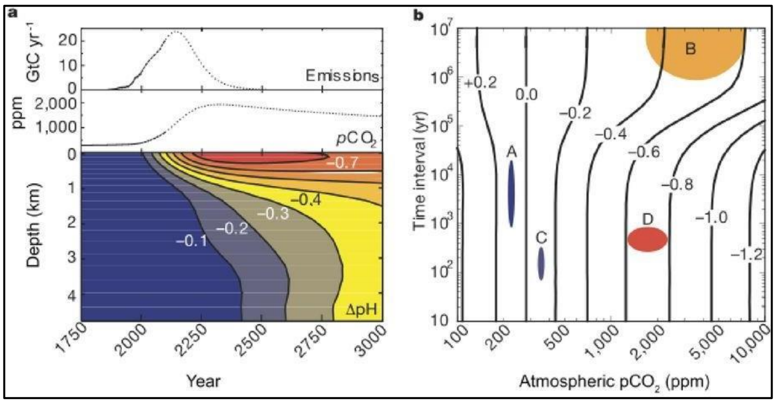

Fig. 7. the time lag between surface and deep ocean acidification under scenario of CO2 emissions

Last but not the least, Recent studies have shown that ocean acidification can affect the physical properties of seawater. At low-frequencies, sound transmission in the ocean is attenuated by volume changes related to acid-base equilibrium of some chemical species. Change in the proportions

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of such systems, notably the boric acid and borate ion acid-base pair, may thus result in a "noisier ocean".

3.2 Effects of Ocean Acidification on off-shore industrial infrastructure

The structural form of ocean structures is unique and expensive by design, installation, commissioning, and operability. Legislation calls for periodic certification of offshore structures. Alternatively, one could rely on the structures to be so well-designed and built with no serious failure develops during working life of that structure. Unfortunately, weather conditions and marine growth become more severe than initially predicted values. Acidified seawater has been underestimated in few design cases. Moreover, fatigue and corrosion are still debatable subjects due to that.

Nowadays high-budget and long-term projects in mid of our ocean such as offshore drilling systems platforms "oil rigs" or even those facilities located in the shoreline such as harbors or ports and sea terminals must be followed by restricted regulations and criteria during the planning and construction stages in term of maintenance and development purposes in the future. However, their infrastructure should be more sustained and anti-corrosion as well as resisting the all-extreme circumstances whether from external or internal factors.

From mechanical perspective, strengthening of materials to avoid even a slight possibility of corrosion whether steel or concrete corrosion is significantly important and all the doubts must be put in concern. Mostly in the stage of research and development-DR " the primer step of large projects" the mechanical studies must be presented by collecting symbols from implementation areas and then examine all parameters.

These parameters are variant from compound to another, but the major parameters of seawater that influence the corrosion rate are pH status, salinity, dissolved oxygen, and temperature, but approximately all materials and compounds are directly impacted by acidic matters and minimizing the strengthening and resistance of material. Furthermore, in our analytic study we will sub-divided these materials into two fundamental material compounds that can be found in all cases of oceanicand coastal constructions which they are steel and deep-sea concrete. as following:

3.2.1 Steel corrosion:

Steel is a common material used for marine construction. It is also one of the widely used materialsin ocean structures. It is classified in several ways to make it suitable for particular set of applications in the ocean environment. However, Classification of steel based on strength is intrinsic in the design codes. Depending on the component of the member and type of load combinations including the loads of seawater pH over long spam of time.

Steel is grouped according to the strength level and welding characteristics. Using steel for ocean structures requires the use of low hydrogen for welding process as well as high-strength steel with specified minimum yield strength (SMYS) greater than 360 MPa. Unfortunately, steel corrosion in some cases can be occurred in sudden high-distributed pH coastal and ocean spots due to high concentration of CO2 absorbed which led to unstable acidic environment. Furthermore, several researchers have already investigated the corrosion behavior "in sub-tropical regions" of some kind of steels such as mild steel "carbon steel" considering the parameter of pH seawater [4].

As a result, they found there is little information on how the effects of ocean acidification on strengthening of steel corrosion. ultimately affecting the structural and functional aspects of steel bonding compounds. However, Indirectly, ocean acidification may affect the productivity and composition of some coastal and oceanic constructions.

3.2.2 Deep-sea concrete corrosion:

Concrete, which has embedded steel, has a high degree of protection against corrosion. As concrete is alkaline in nature, it provides barrier protection to steel reinforcement. Presence of chloride in sufficient quantities in the vicinity of steel

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results in cracking, spalling, and delamination of concrete. Briefly, acidified environment is considered to be serious problems for deterioration of concrete under the change of seawater chemical compound. Dissolved carbon dioxide reacts with seawater to form carbonic acid. This form of final product can interact and decrease the strength of concrete and also facilitate the ingression of aggressive agents into the concrete. which can cause corrosion [5].

To sum up the section, it can be clearly seen that ocean acidification might be also negatively impacted on the industrial aspects as well. To be more precise it can be harmful parameter for causing catastrophes in mid of ocean industries for instance deep ocean pipelines as well as seabed drilling systems that is via corrosion fatigues of those materials used in their construction then lead to leak out the crude oil. In other words, from engineering standing point ocean acidification have been identified as the most challenging causes of catastrophic brittle fracture of drill pipes during drilling operations of deep-sea oil wells in recent decade.

4. Conclusions

From our discussion section we can conclude, compared with other climate change physical indicators, It is important to acknowledge that the data are limited and somewhat contradictory nature. So far, only hundreds of studies have been performed in term of ocean acidification, and of those studies, there is little consistency in the observed responses to ocean acidification, Furthermore, such as these cases we are in need of high accuracy modelling systems with high consistency to be well-known with the final approach. Therefore, Mitigation is one possible response to predicted impacts and anything we do to mitigate climate change today, it will benefit the future of our ocean as well.

Over the last decade, there has been much focus in the ocean science community on studying the potential impacts of ocean acidification. NOAA's Ocean Acidification Program serves to build relationships between scientists, resource managers, policy makers, and the public in order to research and monitor the effects of changing ocean’s compounds economically, ecologically as well as industrially. Last but not the least, Ocean acidification is an emerging field of research, the governments and global organizations have taken initial steps to respond to long-term needs. As a result, it is likely to be challenging and will require multidisciplinary research approaches. As consequences, that’s only can be done via implementing new norms from preparedness to mitigation to response till our recovery.

References

[1] U.S. Environmental Protection Agency, "Climate Change Indicators: Oceans," 2022. [Online]. Available:https://www.indicators/oceans#:~:text =As%20greenhouse%20gases%20trap%20more,climate%20patterns%20around%20the%20world. . [Accessed 3 Aug 2022].

[2] J.-P. G. Lina Hansson, Ocean Acidification, First ed., United States, New York: Oxford University, 2012.

[3] National Research Council, "Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean," National Academies Press - National Academies of Sciences, Washington, D.C., 2010.

[4] Philippe Refait , Anne-Marie Grolleau, Marc Jeannin , Celine Rémazeilles, René Sabot , " Corrosion of Carbon Steel in Marine Environments: Role of the Corrosion Product Layer," *Corrosion and Material Degradation,* Vols. 1, 198–218; doi:10.3390/cmd1010010, no. 5 May 2020, 5 May 2020.

[5] Melissa Melendez, Joseph Salisbury, "Impacts of Ocean Acidification in the Coastal and Marine Impacts of Ocean Acidification in the Coastal and Marine," Commonwealth Marine Economies - National Oceanography Centre (NOC), London-UK, 2017.

[6] Srinivasan Chandrasekaran, Arvind Kumar Jain, "Ocean Structures Construction, Materials, and Operations," in *Materials for Ocean Structure*, Boca Raton Florida, CRC Press, 29 Dec 2016, pp. 129-193.

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