Ocean Acidification in a nutshell

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Since its inception, the combustion of fossil fuels with its associated emission of CO_2 (carbon dioxide), has become one of the greatest anthropogenic challenges in the 21st century. The global emissions of CO_2 have steadily increased throughout the last 150 years, of which emissions in 2019 were registered to be approximately 33 gigatons (Gt) [1] [2].
Approximately 50% of CO_2 remains in the atmosphere whilst the remaining 50% is absorbed equally between onshore plants and the ocean [3]. This has given rise to global concern, increasing the awareness of for instance deforestation, and it has led to the implementation of measures to combat the greenhouse effect. However, a related issue often neglected in the public debate is ocean acidification (OA). OA is defined as the reduction of ocean pH and shifts in carbonate speciation, caused by the addition of CO_2 in seawater [1]. In this essay we will emphasize the importance of including OA in the public debate and why it is an important issue.

The process behind OA and its impact on marine life

Acidification is the process where an environment becomes more acidic, in other terms it means that the pH decreases. Besides modifying the atmosphere, CO_2 affects Earth by continually dissolving into the oceans. Here it reacts with H_2O to form carbonic acid (H_2CO_3) (*eq. 1*). As the amount of CO_2 in the atmosphere increases, the ocean absorbs CO_2 to balance the change that disturbs the equilibrium between ocean and atmosphere. Without the oceans, the concentration of CO_2 in the atmosphere would be greater, as would the global warming and climate change [4]. The ocean is, therefore, acting as a buffer for CO_2 emissions. Since H_2CO_3 is a divalent acid, it can dissociate twice and release two hydrogen ions (H^+), first when dissociating into bicarbonate ions (HCO_3^-) then into carbonate ions (CO_3^{2-}).

$$CO_{2(atmospheric)} \leftrightarrows CO_{2(aq)} + H_2O_{(l)} \leftrightarrows H_2CO_{3(aq)} \leftrightarrows HCO_{3(aq)}^- + H_{(aq)}^+ \leftrightarrows CO_3^{2-}{}_{(aq)} + H_{(aq)}^+$$

Equation 1

About 30 % of the anthropogenic emission has diffused into the oceans, through above mentioned direct chemical exchange [5]. Scientists believed the ocean's absorption of CO_2 would have no significant effect on the marine organisms [6]. However, the dissolution of CO_2, have shown an adverse impact on several organisms. Decreasing pH has been shown to negatively affect marine life, such as calcifying organisms. This is due to the carbonic acid reacting with carbonate ions in the water to form bicarbonate. Carbonate ions are what shell-building animals such as corals, mussels, and phytoplankton need to create their calcium carbonate shells and skeletons. Less available carbonate results in the shells becoming thinner and more fragile. Due to enhanced acidic water, calcium carbonate dissolves better allowing the ocean to soak up excess CO_2 due to the lower pH which then dissolves more rock, releasing more carbonate ions. Ultimately increasing the ocean's capacity to absorb CO_2 which dissolves the shells of the marine organisms[z], killing many of which are important for many individuals in the marine ecosystems.

How target 14.3 in UN's SDG agenda interacts with other SDGs

SDG target 14.3 dedicated to the minimization of OA and its impacts, is linked in several ways to other SDGs. Indeed, some could prevent its achievement, others could support its implementation, and finally some could be undermined if OA continue to increase [7].

As mentioned, the rapid increase of the ocean pH value is a result of fossil fuel burning, which releases CO_2 emissions. Humans rely on fossil fuels to maintain their activities such as production of goods and services or transportation. Hence, all the SDGs that would stimulate these practices, and therefore boost the CO_2 emissions, are going against the OA mitigation. This is the case for SDGs 8 and 9, which respectively promote economic growth and investments in infrastructures and industrialization [7]. Both goals aim to increase these polluting human activities, and thus leading to an acceleration of OA.

On the contrary, all SDGs leading to a decrease of CO_2 emissions assist the target 14.3. Developing greener energies with less greenhouse gas production is hence beneficial, as SDG 7 (clean energies) aims to. Furthermore, by taking climate actions to fight against climate change and for marine habitats protection, SDG 13 (climate action) would also support OA mitigation [7].

Moreover, the target 14.3 also entails research about impacts of OA with a focus on education in developing countries. This links OA to the implementation of goal 4 (quality education), whereby it helps to form a global partnership in science; a partnership which includes developing countries. [7]

Lastly, one of the most affected are cold water corals, which are an important habitat for many species that are crucial to the fish industry. Therefore, fish stocks that contribute to the food supply of the world population are endangered, and the key target SDG 2 zero hunger is endangered when OA cannot be minimized. [7]

Who does OA impact?

The ocean holds an important socioeconomic value, being a big source for income and food. A rise in OA might have detrimental effects on the ocean and the users of it. Users of the ocean can be stakeholders like fishermen, aquaculture and tourism.

Small island developing states (SIDS) were thought to be heavily impacted as their socioeconomic status is dependent on the ocean [8]. Tourism is an important source for economic growth for many SIDS, as they have attractions that make them exotic and unique. These attractions include diving, snorkeling, and sightseeing. A change in the marine environment and ocean processes, due to OA, may result in a reduction of people visiting such attractions. This may in turn result in a negative effect on the economic growth of SIDS [8]. Fish and shellfish are other components that are vital for SIDS's livelihood, and OA was seen as a big threat until recently [8]. OA is predicted to have a higher effect in colder waters than warmer ones, and therefor SIDS in the tropical region might not be impacted as heavily as first thought, but rather the regions closer to the poles [9] [8].

The complexity of indicating OA and the importance of future research

OA is a significantly complex indicator [10], which is notably impacted by the dynamic natural processes that occur in oceans. Therefore, it is challenging to gain accurate results that allow spatial and temporal comparison [10]. From past research, there has been a clear trend in the extent of OA within the open oceans [10]. Contrarily, biological processes occur at a much higher extent in coastal regions, complicating the pattern of the research [b]. In order to separate these natural processes from OA and improve monitoring methods, the International Oceanographic Commission has recommended to interpret at least two of four parameters within scientific research [10]. These parameters include total amount of dissolved inorganic carbon (DIC), overall of alkalinity (TA), partial pressure of carbon dioxide (pCO_2) and concentration of hydrogen ions (pH) [10].

It is vital that we research OA because accurate measurements on OA will provide the necessary information that will allow the best possible management responses.

Over the past 50 years, there has been a rapid increase in research on OA. Today most research focuses on the implications of OA towards the marine environment and economy. For example, the OA coordination Center Portal for OA biological response data has created a data compilation to provide easy access to the data on the biological implications of OA for all users. Currently, the data center has a total of 1121 scientific papers, oldest one published in 1967 [12]. However, we found little research which focused on finding the optimal solution to either minimize the effects of OA, prevent them or to reverse its effects, if possible. This information is important and urgent as it will provide a framework that local communities can use to combat OA.

One issue with the current research is that the methods tend to use different units, making it difficult to compare results [12]. Thus, it is important to develop criteria that may be followed worldwide and will ensure accurate measurement techniques. With this information, research can be comparable spatially and temporally.

Moreover, it is clear that biological processes impact the patterns of OA, complicating future predictions [13]. Therefore, it is also necessary to gain greater knowledge of marine biological processes. Knowing this will clarify the impacts of human activities contributing to OA and separate this from biological processes[13].

Conclusion

Thus, the fact that OA has such an impact on marine life in the ocean and on SDG target goals, should be the reason to not neglect its global importance. To reduce the impact of OA directly caused by anthropogenic CO_2 levels, we should implement the parameters within scientific research, and have full transparency with measuring indicators. Communicating this issue more clearly to the general public is necessary, as awareness of the problem at hand pushes us forwards towards taking a stand against climate change and the rise in CO_2.

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