OCEAN ACIDIFICATION AND HUMAN HEALTH

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Managing the Health Risks of Ocean Acidification

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Although the Earth's hydrosphere (combined mass of all the water on the planet) has been around for 4 billion years shaping continents and seas, about two centuries ago humans started having drastic effects on its dynamics. Beginning with redirecting water pathways, causing pollution, and in more indirect ways altering ecosystems' chemistry. Two major events throughout history influenced the present climate conditions: the agricultural and industrial revolutions. These anthropogenic phenomena changed forever how humans connect to the land and had a tremendous impact on the hydrosphere with consequences of eutrophication, acid rain, and ocean acidification.

The ocean contains 97% of Earth's water and covers about 70% of its surface. There is an intimate and fundamental connection between the ocean and human well-being. The ocean provides us with food, oxygen, livelihoods, blue spaces, and medicines (Falkenberg, 2020). Our physical health and mental health are extremely intertwined with the ocean's health, and its acidification will have consequences for the seafood, air quality, biodiversity, and its natural spaces. The impacts will show as malnutrition, poisoning, respiratory issues, mental health degradation, and loss of organisms often used in medical resources. To not let this happens is important that we promote strategies for managing the health risks of ocean acidification, which will need to be specific to every area of the world accordingly to their socio-economic characteristics. Furthermore, there is a need for exhaustive research to answer fundamental questions in the field of Oceans and Human Health (SOPHIE, 2020). Given the large scale on how ocean acidification is impacting and will later impact the communities around the world, researching in depth and becoming more aware of how we and the ocean interact with each other based on

policies, societal values, economics, and culture, will allow better adaptations to benefit both.

Climate Change and Ocean Acidification:

The ocean is responsible for generating 50% of the oxygen we need, regulating CO2 levels in the atmosphere, lowering the increasing temperatures due to global warming (90% of the excess heat is captured), and protecting coastal communities from climate variability. Human behaviors translated into policies are enabling the use of fossil fuels, which is the major cause of the elevated CO2 emissions and high concentrations in the atmosphere. The ocean takes at least 25% of those emissions due to the carbon cycle of Earth, in which carbon is exchanged to make the planet capable of sustaining life. By continuing life, the biogeophysical and chemical processes under the anthropogenic influence are altered to change life's cycle on destructive default. In the Global Carbon Cycle, carbon enters the ocean through the dissolution of atmospheric CO2. The deep ocean is the largest pool of cycled carbon, and it contains 50 times more carbon than the atmosphere, the exchange between the two happens through thermohaline circulation (Falkowski, 2000). Thermohaline circulation begins in the polar regions, where the water gets cold to form sea ice, so the liquid seawater density around the ice on the surface changes and sinks. The CO2 when it enters this process either travels through the food web or precipitates in the deep layers of the ocean. From 1751 (the beginning of the Industrial revolution) until today, the pH of the ocean went from 8.25 to 8.14 (Jacobson, 2005) This doesn't look like a major difference to the eye, but since pH Is measured on

the logarithmic scale would mean that by the end of the century, the ocean will double in acidity. The chemical causes can be explained by the interaction between carbon dioxide and water ($CO_2 + H_2O$) which becomes carbonic acid H_2CO_3. The dissociation of carbonic acid causes the presence of free hydrogen ions which lowers the pH of the seawater because acidic means the concentration of hydrogen ions is going to be higher. Carbonic acid directly impacts the secretion of calcium carbonate, which is used by marine organisms to create their shells and survive. If the water is more acidic, it becomes harder for these organisms to survive. Especially in high latitudes where the water is colder, the ocean sucks up more carbon dioxide than it does in tropical oceans. (Honisch, 2015) There are some snails, that are part of the zooplankton, called “pteropods”, which have a very fragile shell formed by calcium carbonate, and it happens to be very soluble in seawater. In these high latitudes, these snails experience a lot of acidifications, and by being the major food source of Pacific salmon not being able to feed on these snails anymore it might disappear. These changes have been already observed in oysters hatching but not being able to secrete their shells, in the pteropods and many plankton organisms growing in malformed shells, and sea urchins, crabs, and corals with impaired biological functions. Because of Anthropogenic Ocean Acidification, many organisms need to invest additional energy to maintain acid-base levels that play a role in their metabolism and survival.

Over the Earth’s history, in the Paleocene-Eocene (55 million years ago) the climate was very warm, and the carbonate calcium deposit dissolved. The acidification at that time is as large as the acidification predicted by the end of the century. The difference although is in that time it took 3 thousand years to get to that point, so what is happening in the

present is outpacing everything that has been observed in the entire earth's history. Many organisms got extinct. The ones more vulnerable are at the bottom of the food chain, which is alarming since it's base and fundamental to the entire food web. Without these organisms, life won't be possible to sustain (Monford, 2022).

Ocean Acidification and Human Health:

Ocean Acidification is often perceived as an issue of the marine realm when is also an emerging human health issue. Therefore, there are emerging areas of study that contrast the two by studying different pathways (Fleming 2020).

i. Seafood quantity and quality: Fishing and aquaculture are at least used by more than 4.5 billion in the world to obtain nutrients, especially in Gambia, Sierra Leone, Ghana, Cambodia, Bangladesh, Indonesia, Sri Lanka, and the Maldives. The dependency between marine species within the food web would make it inevitable for these countries to not be affected by ocean acidification. The consumption of fatty acids and omega-3 has been essential in human nutrition for improving muscles, digestion, fertility, and brain development. The reduction of the quantity and quality of seafood because of ocean acidification would become more visible in lower and middle-income countries. Malnutrition and undernourishment would worsen. This is a very important factor to take into consideration when it comes to strategies and policymaking in global health and international agreements.

When it comes to fish quality chemical pollutants and natural toxins need to be considered. As in the case of PCB, polychlorinated biphenyls, a pollutant found and bioaccumulated in fish that has neurological degrading effects if consumed by humans.

ii. Respiratory Issues: Natural toxins in algal bloom can be harmful, which is already been reported in the case of red tides in Florida. Ocean acidification and high levels of CO2 impact the phytoplankton bloom cycles. Red tides have been correlated with causing coughing, sneezing, and tears in the short term. Meanwhile, causing respiratory irritation and asthma in the long term. The American Lung Association in Florida recommends avoiding red tide areas, don't exercise outside for people living close to the beach, and keeping an eye out for the symptoms.

iii. Mental Health: Blue spaces are associated with mental health benefits because of the levels of physical activity and general health that they promote. Swimming, snorkeling, freediving, scuba diving, surfing, wakeboarding, coastal walking, there are so many activities being done around the world connected to the ocean that are opportunities for quality time in people's livelihoods. The ocean is a place, that has both physical and emotional importance for humans. With ocean acidification, access to the ocean will become regulated by the conditions of beaches and seawater.

iv. Loss of Biodiversity: the great biodiversity found in the seas is yet to be explored. Some coral reefs are usually found in deeper waters 40-150 meters and are not well studied, and with the advancing of ocean acidification,

many organisms could never be discovered. The National Ocean and Atmospheric Administration suggests that the ocean with its amazing biodiversity and many yet-discovered species may be a rich source of new medicines (NOAA, 2022).

Strategies for Managing the Health Risks of Ocean Acidification:

As human-driven changes continue to happen to the ocean, politically there are new collaborations worldwide trying to have a handle on the current situation. The UN Paris Climate Agreement and the UN Decade of Ocean Science for Sustainable Development that goes from 2021 to 2030 have the aim to implement policies suggested by reported international research. With a population of 8 billion people that mainly use non-renewable energy and marine resources, and continue to dump waste materials into the ocean and chemically pollute the seas, how can it be ready to counteract ocean acidification health outcomes?

The strategies for managing the health risks of ocean acidification need to aim at restoring the ocean's well-being and preventing harmful health outcomes.

Mitigation strategies for anthropogenic ocean acidification require efforts at different levels. In the case of the US, the Federal Clean Water act has been a way to limit acidification-inducing pollutants and promote monitoring (Sverker, 2019). Other countries like Brazil have the OA Research Network, while Germany and the United Kingdom have the OA Research Programme.

Economically, CO2 taxes could be the most cost-effective strategy to limit emissions and change behaviors. In the case of Sweden, this has been implemented since 1991 together with subsidies that target the production of renewable energy sources.

Ecologically, there are different ways to enhance benefits and limit negative effects:

i. Conservation of marine ecosystems by creating protected areas and sanctuaries
ii. Restoration of areas that have been damaged by ocean acidification
iii. Monitoring levels of Ocean Acidification in seawaters
iv. Adapting Human Activities
v. Framing Socio-economic Characteristics of Impacted Communities

Ultimately, what is good for the health of humans is good for the ocean and vice versa, in the last century it has been established that the way we are leading has not been benefiting either of the two. Future research and collaboration by individuals and institutions who are working in the sectors of public, environmental, and global health should come to the same table with oceanographers, marine biologists, and environmentalists. Transdisciplinary research and awareness of new perspectives need to become the norm upon which we decide to act upon.

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