Impact of Global Carbon Foot Print on Marine Environment

R. Sanjeevi[1], Muhammad Bello Haruna[1], Sandeep Tripathi[1], Bipin Kumar Singh[2] and J. Anuradha[1]

[1]*Department of Biotechnology, Institute of Advance Science and Technology*
[2]*Department of Civil Engineering, NIMS Institute of Advance Engineering and Technology*
NIMS University (Rajasthan), Jaipur

Abstract: **Carbon footprint is one among the potential tool that could comprehend the impact of threats posed by global warming. The scenario of estimating *global carbon* (GC) emissions forms basis for the arena of recent research. Dynamics of seawater chemistry is governed by the release of increased carbon dioxide (CO_2) concentration into the atmosphere triggered by increasing industrial and agricultural activities of mankind. It is ultimately the *ocean* that absorbs a quarter of the CO_2 released every year into the atmosphere. The pioneer researchers emphasizing on GHG mitigation had believed that the carbon sink into ocean as a boon that could reduce its concentration from atmosphere, but in contrast by the decades passed resulted in ocean acidification (*Climate change's equally evil twin*). This is mainly because CO_2 gets dissolved in sea water forming carbonic acid. The gradual increase in acidity mainly on the surface inhibits the marine biodiversity especially on the livelihood of coral reefs. The Hector scale measures the average pH fall by 0.1 units that corresponds to 30% increase in proton concentration (H^+), since the industrial revolution began. It is predicted that in near future by end of this century CO_2 sink into ocean may raise the ocean acidity by 25-30 % more acidic than that it had since 1750s. These attributes bring the need for awareness among mankind to conserve marine organisms such as coral reefs, mussels, clams, urchins, starfish and some other species of fish.**

Keywords: Carbon footprints, GC, Ocean acidification, Hector scale, CO_2 sink.

I. INTRODUCTION

'*Carbon Footprint*' (*CF*) is an umbrella term that expresses the concentration of *Carbon-Di-Oxide* (CO_2) or Green house gases (*GHG*) emitted into the atmosphere and are expressed in CO_2equivalent unit. GC emissions from fossil fuels was found to be 32.3 billion metric ton (BMT) during the year 2012 and are estimated, likely to be around 35.6 – 43.2 BMT by the year 2020 – 2040 respectively [1].

China stands first, followed by USA and European Union in repertoire of CO_2 emitters all through the globe [2]. The global CO_2 emission has doubled over the past four decades *Viz a Viz* 6.46 and 11.71 BMT by the year 1995 and 2035 respectively. It has been evidenced from the continuous growth achieved in the developing and developed countries. The driving force that contributes to rise in CO_2 emission comprises country group namely developing and developed countries and the demand type based on the investment or consumption factor. In terms of countries, it is estimated that developing countries could emits double the carbon than that of developed countries during the year 2035. The visible pattern of identification of global carbon hotspots includes the phenomenon of carbon leakage within the microclimate but also spreading carbon footprint in to neighboring countries [3]. Among the country group, it is predicted that Eastern Europe contributes at high rate (19%) followed by China (17%) towards average global carbon concentration by 2035. The consumption factor includes its generation from electrical power production (25%), agriculture, forestry and other land use (24 %), transportation (14%), industrial processes (21%), residential service (6%) and miscellaneous usage (10%) [4]. Significant sources that are responsible for CO_2 emissions include the use of fossil-fuel and industrial processes. This comprises two-thirds of global green house gas composition.

II. GLOBAL CARBON FOOTPRINT

In recent years, the concept of *CF* is popularized among public, initiating awareness towards sustainability and to subsidize global climatic threat thereof. However, its definition and effects remains ambiguous. POST (2006) [5] defines *CF* as the total amount of greenhouse gases (*i.e.*CO_2 and other *GHG*), that are emitted throughout the *life-cycle* of a process or a product.

Wiedmann and Minx [6] proposed that *CF* '*is the measure of exclusively total CO_2 emitted directly and indirectly by an activity or is accumulated throughout the life stages of a product*'. Whereas, cumulative measure of *GHG* (*i.e.* inclusive of all *GHGs*) emitted, is termed as '*Climate Footprint*'. In the present study, we consider the measure of CO_2 emission count among the *GHGs* contributing to 'G*lobal Carbon Footprint*' (Fig. 1).

III. OCEAN ACIDIFICATION AND DECALCIFICATION

Rapidity of industrialization and urbanization results in higher consumption of energy and resources leaving behind uncontrolled waste generation. This contributes to increase in greenhouse gas emissions, and therefore, affecting the atmosphere and earth's global temperature. Among these, the most critical issue impacted on our planet is due to the climatic change caused by increased release of CO_2 into the atmosphere [7, 8]. Most of the resultant CO_2 originates from burning of fossil fuels that eventually sinks into ocean causing potential risk to marine biota [9]. It is estimated that about 25–30% of anthropogenic CO_2 emission were engulfed by world's ocean since mid 18th century [10, 11]. Subsequently, Ocean thus experiences several changes like, warming of surface and deep water, reduced oxygen concentration from surface water, reduced calcium carbonate saturation levels and *pH* [12]. The resulting perturbation in ocean chemistry is said to be the phenomenon called *Ocean Acidification* (*OA*) [9, 13].

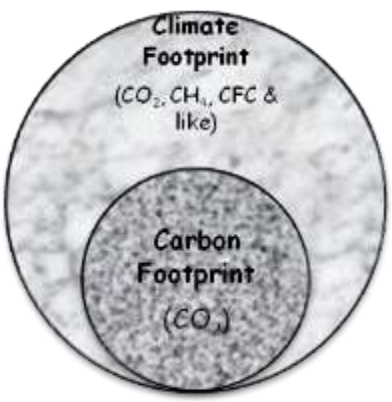

Fig. 1: Components contributing to *Carbon footprint* and *Climate footprint*.

Advancement in industrial and urban development, agricultural practices, uncontrolled burning of fossil fuels and like, liberates CO_2 into atmosphere. It causes increased OA at rate attributes to warming of surface water (4–5°*C*) and decrease in oceanic pH (~0.06–0.32 units) that had not been observed since few million years [14–17]. Increasing CO_2concentration into the ocean results in dissolution of CO_2 (*aq*.), forging carbonic acid (H_2CO_3), dissociating to bicarbonates (HCO_3^-), carbonates (CO_3^{2-}) and releases hydrogen ion (H^+) there by effects decrease in oceanic pH. Dynamics of seawater chemistry (*i.e. warming and stratification*) is governed by the rate of CO_2 concentration released into the atmosphere that is triggered due to increased industrial and agricultural activities of mankind. It is ultimately the *ocean* that absorbs a quarter of the CO_2 released every year into the atmosphere. The following chemical reactions (*Step 1–3*) elicit the clear *cause–effect–relationship* of *OA* process with global carbon flux.

$$\textbf{Step:1}\ CO_2 + H_2O \rightarrow H_2CO_3(\text{Carbonic acid})$$

$$\textbf{Step:2}\ H_2CO_3 \leftrightarrow HCO_3^-(\text{Bicarbonate ion}) + H^+(\text{Proton})$$

$$\textbf{Step:3}\ HCO_3^- \leftrightarrow CO_3^{2-}(\text{Carbonate ion}) + H^+(\text{Proton})$$

$$\textbf{Step:4}\ H_2CO_3 + CaCO_3 \rightarrow Ca^{2+}(\text{Calcium ion}) + 2HCO_3^-(\text{Bicarbonate ion})$$

The pioneer researchers emphasizing on *GHG* mitigation had believed that the carbon sink into ocean, as a boon that could reduce its concentration from atmosphere. In contrast by the decades passed the resulted *OA* is considered as '*climate change's equally evil twin*'. This is mainly because CO_2that gets dissolved into sea water forming carbonic acid increases solubility of calcium carbonate ($CaCO_3$) (*Step: 4*). Thus, reduced $CaCO_3$ concentration creates demand and is unavailable to the marine organisms such as coral reefs, sea urchins, and oysters etc. for the generation of shells. Additionally, in combination with carbonic acid, it drives the dissolution of shell. The weakened shell formation impacts on survivorship of marine organisms by facilitating less protection from predators, desiccation and physical damage. Hypercapnia interrupts on growth, reproduction and nutrient uptake of marine biota thereby affecting the efficacy of marine food webs and ecosystem. The continual *OA*, poses risk to marine ecosystem (*i.e.* structure and function), particularly to calcareous organisms such as corals and other species that depends on calciferous protective structure. The effect of *OA* on marine ecosystem and its consequences is relatively an unexplored research avenue since a decade. It has been evident from the recent eco-toxicological studies that marine biota is imposed by anthropogenic pressures due to ocean warming and acidification [18]. These identified stressors pose deleterious impacts on marine organisms (Figure 2).

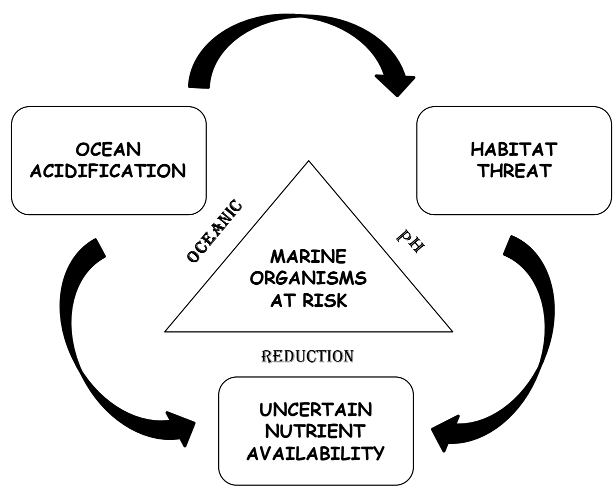

Fig. 2: Effect of '*Ocean Acidification*' on marine ecosystem.

Increasing surface water temperature causes biochemical changes that are lethal on one hand and hypercapnia results in narcotic effect on the other hand. These documented signs indicate that if not control measures and eventual inventory of retro-fitting techniques occur, to mitigate the *GHG* emissions; marine lives would surely face threat for their habitat or uncertainty for nutrient availability or may even get extinct before being discovered.

IV. IMPACTS OF OCEAN ACIDIFICATION ON MARINE ORGANISMS

Overall impact on ecosystem results from the synergistic effect of increase in surface water temperature and hypercapnia. Their co-action might cause deleterious effects on calcareous organisms.

In particular, calcified algae, coral reefs, larval stages of most of the marine fauna and like is negatively impacted. The other organisms like fleshy algae, diatoms and fishes are less impacted. Some of physiological and biochemical processes that are likely to limit the lives of marine organism's attributes to, (a) pH reduction imbalances the extracellular fluids there by affecting metabolic efficacy, and (b) hypercapnia results in the neurological effects. The mechanism of decalcification impacts in sequential effects that include, (i) reduction of calcareous skeletal structure; (ii) loss of habitat; (iii) loss of nutrient availability; and (iv) loss of biodiversity with extinction [13, 19].

V. PERSPECTIVE OF OCEAN ACIDIFICATION

Summing up the acidification of sea water and limitation of carbonate for building and maintenance of shells imposes vulnerability to marine species. In other words, it is not only the threat to marine life but also has potential impact on humans, who are dependent on them. Human beings experience socioeconomic problems including provision for protein, revenue and livelihoods due to changing marine ecosystems. The due cause responsible is rapidity in industrial and urban development that is leaving behind higher waste generation. So, it is of prime importance to work on integrated waste management, by incorporating retro-fitting ideas that are clean and green needs to be adopted to stop fast paced degrading environment and to ensure sustainability. The criterion comprises the three pillars (3P's) of sustainable development that includes economic progress (Profit), environmental stewardship (Planet) and social development (People) [20]. Thus, at present the concept of '*Waste*' is changed, to that "*the best waste is which is not produced*". In order to ameliorate the direct impacts posed by ocean acidification, the *4R concept* of *refuse*, *reduce*, *reuse* and *recycle* of raw materials has to be practiced towards achieving the vision for zero emissions and zero waste.

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