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Anthropization, Salinity and Oxidative Stress in Animals in the Coastal Zone †

Abhipsa Bal [1,2] and Biswaranjan Paital [1,*]

[1] Redox Regulation Laboratory, Department of Zoology, College of Basic Science and Humanities, Odisha University of Agriculture and Technology, Bhubaneswar 751003, India; abhipsa.hope@gmail.com
[2] Zoology Section, Department of Education in Science and Mathematics, Regional Institute of Education, Bhubaneswar 751022, India
* Correspondence: biswaranjanpaital@gmail.com; Tel.: +91-674-2397029
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Abstract: In coastal and abiding zones, ground water continuously faces a very slight but alarming increasing trend in salinity due to several reasons such as its excess loss or use, with constant dissolve of salts from earth surface and heat-trapping pollution from human activities, rising sea levels and finally high flooding. Many recent studies have indicated that even a slight elevation in ground water salinity may affect freshwater inhabitants highlighting the importance of research on the effects of low salinity stress on the coastal zone freshwater inhabitants.. Along with abiotic factors such as salinity, dissolved oxygen, pH, and alkalinity, the anthropogenic factors also cause many fold stress on the inhabitants in coastal zones. Climatic factors also play an important role in influencing the life of the coastal water inhabitants. For example, statistics such as correlation and discriminant function analysis indicate that sub-lethal salinity acts as a strong modulator in the inhabiting fish physiology in fresh as well as coastal water. Parameters such as gain in body weight, feed intake and irregularities in morphometry increase in higher salinities that is confirmed by the decline in the growth of fishes. Similarly, blood physiology such as significant loss in haemoglobin content, RBC count and eosinophils is coupled with amelioration in neutrophil count at higher salinities of 6 and 9 ppt in few freshwater organisms. Normal histo-architecture is also lost in most of the fish under high salinity conditions and higher anthropogenic loads. Generation of tissue damage in terms of oxidative stress is prominent under high fluctuations in abiotic factors including higher salinity or under high anthropogenic loads. So, loss of compromised normal physiology due to the toxic effects of low or high salinity in the saline water or fresh inhabitants including hardy fishes, respectively, under changing climatic conditions are evident. It alarms about maintaining water quality in coastal and allied zones globally in the coming decades.

Keywords: coastal water; environmental effect; global climate change; water salinity; hardy fish; multiple biological factors

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1. Introduction

Water is an essential component of the ecosystem which anchors life on the earth and integrates people from the varied cultural, societal and economic aspects. However, in the context of a sustainable environment, the frequent anthropogenic activities that have been remarkably burdening the ecosystem are emerging as a major concern worldwide [1]. These issues of global concern have currently received prior attention among researchers worldwide as they affect the sustainability of the planet and its inhabitants. Anthropogenic activities have put global water security at risk by negatively affecting the aquatic as well as the terrestrial ecosystem in various ways [1].

Climatic changes and human activities have induced shifts in salinity levels in marine and coastal freshwater ecosystems and have immeasurably affected the species diversity in the respective ecotones. The anthropogenic factors have subsequently inundated the geomorphology of the coastal wetlands, estuaries, etc. The amount of dissolved salts in water can have a significant impact on the survival of aquatic organisms in the context of varied salinity preferences which are species specific [2]. The major factor for the decline in the species richness in the areas is oxidative stress caused due to over production of reactive oxygen species (ROS) in response to the shifts in optimal salinity level [1,2].

The recurring anthropogenically induced climatic disturbances have caused a havoc in the biodiversity of the aquatic ecosystem in a specific manner by releasing toxic substances/xenobiotic compounds and further altering the hydrological parameters [1]. The source of anthropogenic activities largely includes the use of plastics ranging from nano- to macro-size in day to day life, rapid urbanization and industrialization, residual wastes generated from waste water treatment plants, constructions and works, wastes generated from discarded electronic devices, transportation, biocides and fertilizer based agriculture etc. Proliferation of injudicious human activities can lead to depletion of natural resources, habitat loss and rippling effect throughout the ecosystem [2]. The optimal values of different hydrological parameters like pH, alkalinity, dissolved oxygen, salinity, turbidity, conductivity, total dissolved solids, biological oxygen demand (BOD), chemical oxygen demand (COD) etc. help in sustaining life under water [3]. Anthropogenic activities induce a paradigm shift in the biotic and abiotic parameters and thus, leading to the disturbances in the dynamics of the aquatic biota. Among the abiotic factors, salinity is one of the significant factors which helps in maintaining the differential osmotic gradient concentration for survival of the organisms belonging to different aquatic habitats includes freshwater, groundwater and marine ecotones. A swift change in the salinity level can affect the availability of nutrients and physiological processes. Altered salinity induces transformations of biotope and biocenosis, cytotoxicity, abnormal growth, osmotic imbalance, infertility and/or reproductive disorders, neurodegenerative disorder along with various morphological and cellular anomalies [4,5]. The increase/decrease in salinity levels of the biota may induce immediate effects on the oxidative stress (OS) physiology of the organisms or might exhibit dysfunction of mitochondrial complex enzymes on prolonged exposure (Figure 1).

Further, salinity not only interrupts the osmotic balance but also leads to disruption of the organelle membranes of the aquatic invertebrates as well as the vertebrates [6,7]. This review aims to assemble and analyse the ecotoxicological impact of human activities driven rise in salinity and its effect on oxidative regulation pathway. The assessment of the information in the present review will be helpful to understand and mitigate the harmful effects of anthropogenic factors and climatic changes on aquatic life in a very precise manner.

Figure 1. The anthropogenic inputs have intensified the physicochemical parameters as well as the disturbances in climatic changes. Climatic changes and anthropogenic factor mediated salinity fluctuations have threatened the oxidative health status of the aquatic organisms in the coastal areas.

2. Anthropogenic Activities, Levels of Salinity and Ecological Threat

Rapid development of industries to meet the daily demands of a rising population results in production of more human generated wastes which include CO_2 emissions, undigested pharmaceutical compounds [8], nanoparticles from wastewater treatment plants, return flow from irrigated fields [9], organic and inorganic biodegradable nutrients, heavy metals accumulation, human pathogens [10], etc. The anthropogenic inputs led to transformation in the dynamics of the rivers, lakes, estuaries, coastal wetlands etc. through deposition of sediments, change in velocity of water flow [4], rise in sea level due to climatic changes, increase in risks of flood, change in tidal patterns [11,12], shifts in physicochemical parameters of the aquatic ecosystem (for e.g., pH, turbidity, salinity, etc.) [13], increase in toxicity and salinity levels of groundwater sources [14] etc.

Accelerated increase in sea level due to climatic factors is linked to anthropogenic factors [12]. The rise in the sea level has threatened the coastal estuaries, lagoons, wetlands and groundwater resources in the respective areas. From the above cited literature, it is evident that with the increase in abundance of microplastics, heavy metals, xenobiotic compounds and other toxic substances in the sediment, the risk of entering those compounds into the food chain is apparent [15]. The species richness, species diversity and habitat spatial structure of aquatic inhabitants have become vulnerable in due course of salinization. In addition, ocean acidification, heavy rainfall and fluctuations in temperature modulate the salinity levels of the aquatic community [16]. Thus, irrespective of the cause behind the salinization of aquatic community which may be due to natural or anthropogenic factors, the physiology of coastal water inhabitants is disturbed in general and oxidative stress physiology in particular (Figure 2).

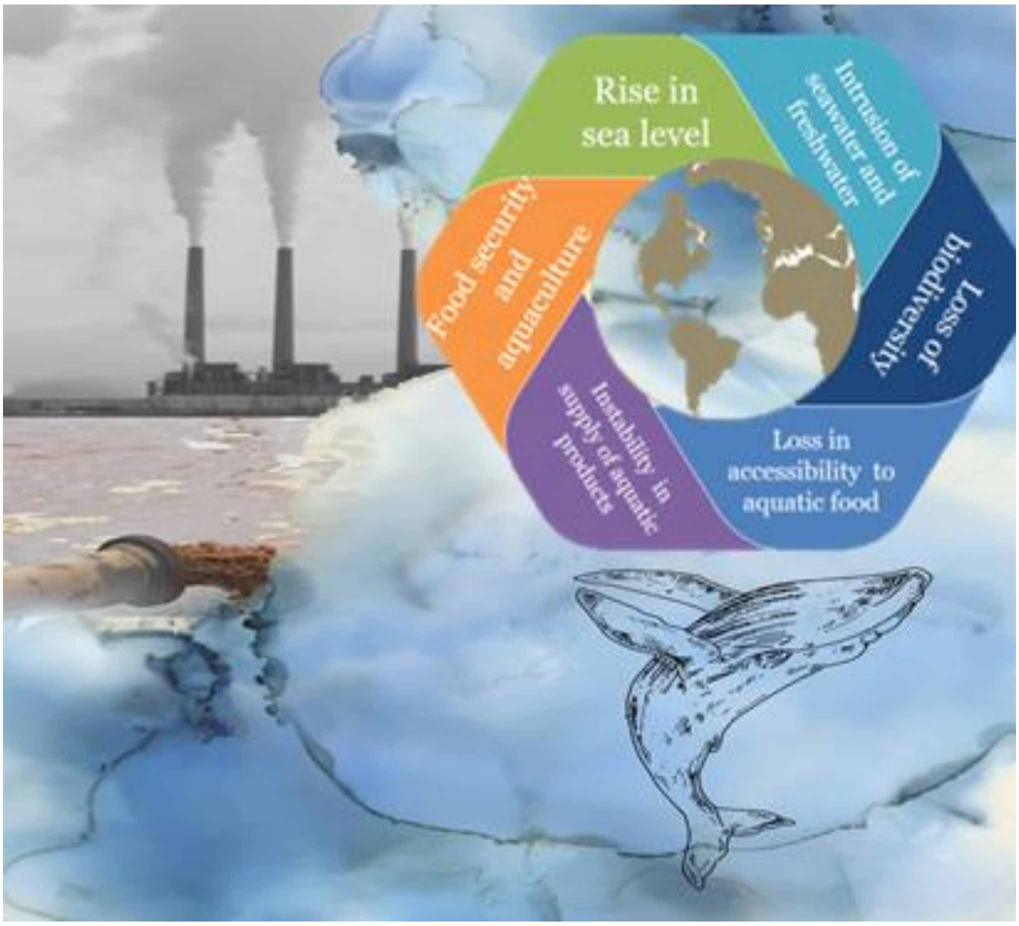

Figure 2. Human activities have led to a rise in the sea level and intrusion of the seawater into freshwater biota. The salinization of these ecotones has resulted in loss of biodiversity, accessibility to aquatic food, instability in supply of aquatic products. Thus, this has indirectly threatened the sectors of food security and aquaculture.

The anthropogenic factors are also found to influence many other physiological events in both fresh water and saline water species. An increase in salinity is found to have an influence on the DNA and RNA content of cells [1]. Decrease in haemoglobin content, alleviated RBC and eosinophils count is found to be associated with the elevated count of neutrophils at higher salinities of 6 and 9 ppt in few freshwater organisms such as *Heteropneustes fossilis* [1,5,7]. Changing salinity in water is also related to the altered histoarchitecture in many aquatic organisms because the usual histo-architecture in most freshwater or marine fishes is lost under saline or fresh water intrusion to their habitat, respectively. This fact is also correlated to be higher under the exposure of such organisms to the altered salinity and anthropogenic loads. Higher anthropogenic loads are always inductive for the generation of tissue damage which is due to the generation of higher reactive oxygen species accumulated OS in aquatic animals. Generation of tissue damage in terms of OS is prominent under high fluctuations in abiotic factors including higher salinity or under high anthropogenic loads [1,5,7,] Figures 1 and 2.

3. Salinization Induced Oxidative Stress Physiology in Aquatic Inhabitants

Higher/lower levels of salinity mediated physiological disturbances in the inhabitants of coastal water ecosystems are significant. The freshwater species face hypersalinity mediated OS (for e.g.,) whereas, the marine species more frequently, are exposed to hyposalinity mediated OS (for e.g., *Paralichthys olivaceus*). Osmoregulatory physiology plays a major role in adaptation of the organism to salinity changes of the aquatic community. The energy incurred by the osmoconformers to adapt to salinity changes is lower than that of osmoregulators [17]. However, only a handful of investigations have reported the regulation of OS in the aquatic biota of coastal water in response to salinity. The OS incurred by those species and their respective study of antioxidant profile in invertebrates and vertebrates is precisely described.

3.1. Oxidative Stress Physiology in Aquatic Invertebrates

Salinity induction critically affects the sperm quality in free spawning mussels which perform external fertilization. The sperm is exposed to various stressors like UV-radiations and salinity alterations once they are released into the aquatic environment. Studies in *Mytilus galloprovincialis* have reported OS, impaired DNA, limited mitochondrial activity along with restricted sperm motility causing a decline in rate of fertilization [18]. As increase in salinity activates the oxidative stress physiology pathway by accelerating the antioxidant activities of superoxide dismutase (SOD) and catalase (CAT) in monogonot rotifer *Brachionus plicatilis* [19].

3.2. Oxidative Stress Physiology in Aquatic Vertebrates

Hyposalinity can cause oxidative damage and distress the antioxidant profile of organisms. A decline in physiological performance of Paralichthys olivaceu to cope up with the hyposalinity conditions have been revealed in the context of decreasing values of hematocrit and hematological parameters [20]. Furthermore, levels of antioxidant enzymes such as catalase increased in response to the oxidative damage caused in the liver cells. With the further intensification of stressor, apoptotic factors were also reported in the species [21]. Maintenance of osmoregulatory physiology is also associated with the antioxidant capacity as well as oxidative health of species (Xenopus laevis) during salinity shifts. Accelerated amount of electron leakage during the oxidative phosphorylation for the physiological adaptation and osmoregulatory responses towards the survival of the species often contributes to oxidative stress. Therefore, the total antioxidant capacity is inversely proportional to the plasma osmolality in hypersaline conditions [22].

Various investigations have recognized the source of anthropogenic factors in establishing a transformed hydrological community in terms of physico-chemical parameters, species diversity index, etc. Conversely, very few investigations have reported the status of oxidative health of the aquatic inhabitants in response to anthropogenically mediated salinization of water bodies in coastal areas.

4. Conclusions

The aim of this review was to accentuate the understanding of oxidative stress physiology of the aquatic populations induced by anthropogenic mediated salinization of the aquatic biota in the coastal regions. Anthropogenic factors have either led to an increase or decrease in salinity in different aquatic communities. These slight fluctuations in the optimal level of salinity affect the oxidative health of the inhabitants in these communities by accelerating the production of ROS, insufficient amount of antioxidant enzymes, limited mitochondrial respiration, etc. Moreover, the OS also affects the growth, development, physiological adaptations and performance, reproduction, etc. The OS incurred by the species is also associated with the apoptotic factors responsible for cell death. Thus, climate change, anthropogenic load, abiotic factor stress alone or in combination induces (oxidative) stress in aquatic organisms, therefore, their economic value is influenced.

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