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Effects of UV- radiation on fishes: A Review

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Abstract

Ultraviolet radiation (UV) is a part of the non ionizing region of the electromagnetic spectrum. Anthropogenic activities affect the ozone layer, resulting in a global increase in the level of ultraviolet radiation. Ozone depletion is resulting into elevation in solar ultraviolet-B radiation of 290-320 nm. Fish species are susceptible to UV-B radiation which induces the sunburn. UV-radiation affects the growth, mortality, behaviour, metabolism by affecting enzyme activities. Currently, stratospheric ozone dynamics and climate change interact strongly, enhancing the potential exposure of fish to UVR under water. Depletion of stratospheric ozone layer has created the threat of enhanced UV-B which causes the reduction of productivity of water bodies by reducing the rate of photosynthesis, plankton growth, and overall yield in most of the fish species. Due to these environmental changes, fish are exposed to new and complex interactions between UVR and environmental stressors, which potentially affects fish growth and survival. Understanding the ability of fish to cope and adapt to these environmental changes will be essential to evaluate the potential impact in fisheries and mitigate ecological problems.

Keywords: UV radiation, Ozone layer, Fish,

1. Introduction

The origin of life on earth is mainly supported by the solar spectrum which is the driving force for entire ecosystems and is comprised of electromagnetic spectrum including different wavelengths ranging from radio waves to gamma waves. These electromagnetic waves helped in the formation of early atmosphere on the earth and ultimately lead to the origin of early life.

Maxwell (1865) proposed the theory of electromagnetic waves. After that a revolution in the field of solar spectrum studies occurred and by 1920, the existence of UV radiation, its properties and relationship to sunlight were well established. Ultraviolet, visible and infra red rays are critically very important for life on the earth. Infra red light and visible light are the part of solar spectrum, which are responsible for increasing the temperature of the earth up to the survival range.

Ultraviolet radiation (UV) is a part of the non ionizing region of the electromagnetic spectrum which comprises approximately 8-9% of the total solar radiation. UV is traditionally divided into three wavelength ranges: UV-A (320-400 nm) represents approximately 6.3% of the incoming solar radiation and is comparatively less harmful part of UV-radiation. UV-B (280-320 nm) is of particular interest because this wavelength represents only 1.5% of the total spectrum, but can induce a damaging effect in plants, animals as well as at ecosystem level. UV-C (200-280 nm) is extremely harmful to organisms (Rai and Agrawal, 2017). Due to the depletion of the ozone layer, biologically active solar UV-B radiation (280-

320 nm) reaching the earth's surface has substantially increased over the past few decades.

2. Ozone layer and UV Radiation:

Ozone plays a vital role in the atmosphere. It is known that the protection of life on the earth from UV radiation is a result of the absorbance of these radiations by stratospheric ozone layer. While some ozone is also found in the tropospheric region, but its concentration is very low as compared to stratospheric ozone concentration. In stratosphere, it forms a thick covering around the earth which protects the living organisms from the harmful rays of solar spectra. The amount of UV-B reaching the surface of earth depends on the thickness of the ozone layer and atmosphere. This varies due to solar zenith. The angle of solar radiation changes with latitude, season, time of the day so that the highest effluence rate of UV-B radiation occurs in at the equatorial region in mid-summer at mid-day. However the relation ratio UVR to photosynthetically active radiation (PAR) is greatest during dawn and dusk (Kumar and Aara, 2016). Recently, due to anthropogenic activities this protective layer is depleting day by day and it is termed as Ozone Hole. The thinning of ozone layer less than 220 DU caused by ozone depleting substances such as halocarbons is called as Ozone hole.

The amount of UV-B radiation that penetrates through the ozone layer decreases exponentially with the slant path thickness/density of the layer. Correspondingly, a decrease in atmospheric ozone is expected to give rise to significantly increased levels of UV-B near the surface. According to IPCC 2007 report, it has been predicted that if the current rate of anthropogenic pollution and green house gases emission continues, it will result into tremendous stress on living system by increasing the concentration of heat trapping gases which will lead to rise in global temperature from 0.4^0C to 1.1 $^{\mathbf{0}}$C by 2025 and up to 5.8 $^{\mathbf{0}}$C by 2100. However, the proposed CO_2 concentration is 720 to 1020 ppm up to 2100 (Rai and Agrawal, 2017).

Solar UV undergoes significant absorption by the stratospheric ozone layer. With the depletion of the stratospheric ozone people and the environment will be exposed to higher intensities of UV. Recent anthropogenic activities have caused a considerable reduction in stratospheric ozone, with a corresponding increase in the amount of ultraviolet radiation hitting the earth surface (Newman *et al*., 2006).The increase in UV radiation is associated with several adverse effects on human health, agriculture, animals, plants, and materials. Extreme climatic condition in combination with anthropogenic contamination and increased solar UV-B may have a considerable impact on fresh water ecosystem (Vincent and Belzile, 2002). Intensity of solar UV radiation and the depth of UV penetration into the water column are key factors in assessing the potential for damage to aquatic organisms (Blaustein, 2001).

Ozone and UV-B irradiance UV radiations are measured in two terms i.e. irradiance and fluence rate. Irradiance is the radiation falling on a flat surface per unit area per second and when it is multiplied by time then is called as dose. Fluence rate is the radiation falling on sphere per unit cross section per second and when fluence rate is multiplied with time, it is called as fluence. The amount of radiation passing through the ozone column is dependent not only on its concentration in the atmosphere, but also dependent on the elevation above the sea level and angle of the Earth's surface. The higher the elevation above the sea surface the shorter the path through the atmosphere that the radiation has to travel; which ultimately results in increase in irradiance (Rai and Agrawal, 2017).

Consequences of Ozone layer depletion In the last few decades, there has been an average of 7% increase in biologically active UV-B radiation in northern mid latitude due to depletion in stratospheric ozone layer (Yang *et al.,* 2007). UV–B radiation negatively impacts organisms in both terrestrial and aquatic system. Within living cells, nucleic acids, proteins and lipids are the primary target of UV-B damage. UV- B radiation acts synergistically with other stressors such as contaminants, disease and extremes thermal events (Bhandari and Sharma, 2010). Ultraviolet radiation is absorbed by biologically important molecules such as DNA, proteins, chromophores, which leads to wide ranging effects on organisms (Lin, and Fisher, 2007).

UV radiation has strong effects on aquatic ecosystems due to feedback between temperature, UV radiation, and greenhouse gas concentration. Higher air temperatures and incoming solar radiation are increasing the surface water temperatures thereby the great di erences between surface and deep waters temperature of water bodies. This increase in thermal stratification makes the surface layers shallower and leads to stronger barriers to upward mixing of nutrients necessary for photosynthesis. This also results in exposure to higher levels of UV radiation of surface-dwelling organisms.

In the upper photic zone, aquatic organisms are exposed to solar UV radiation. Although the UV-B irradiance amounts to only a few percent of the total solar radiation, this wavelength band can be hazardous since it affects biomolecules and cellular structures and may block enzymatic reactions and interfere with physiological responses such as motility and orientation. UV-B radiation can either directly alter biomolecules or induce the formation of reactive oxygen species (ROS) inside the cell, such as singlet oxygen (Donat, *et al.*, 2015).

3. Effect of U V -Radiation on Fishes:

UV radiation is able to scatters rapidly in water with biologically useful amounts to at least 50-m depth in clear aquatic environments (Kumar and Aara, 2016). Penetration of solar UV-B radiation in earth's surface water column has recently increased due to ozone depletion (Kerr and McElroy 1993). An increase in UVR penetration has the potential to cause considerable stress to aquatic organisms. Phytoplankton compositions are affected by different environmental factors such as pH, temperature, light and environmental pollutants (Buzzi, 2002).

Climate change, phototoxic chemicals and UV-B can act as potential force for evolutionary changes, genetic diversity and function of ecosystem. Individual genetic sensitivity is also an important determinant of the susceptibility to UV radiation. Such radiation may have negative effects on the aquatic ecosystem, resulting in decrease biomass productivity, including fish yield (Kumar and Aara, 2016). Aquatic species in general, and fishes in particular, are vulnerable to stress induced changes in their environment primarily through their skin and gills, which are constantly being exposed to the surrounding water.

Fish are susceptible to UV- B radiation with sensitivity varying within groups. Skin damage is the most commonly reported effect of solar UV-B on fish. UV- B induced changes have also been noted in fish inhabiting natural water. Eggs and larvae also have limited behavioral capabilities to avoid UV-B exposure due to their reduced mobility and some species cannot detect UV-B radiation in the early developmental stages (Olson *et al*., 2006).

Sunburn or the effects of sunlight and UV radiation on fish has been described by a number of researchers and was first recognized as a problem in aquaculture situations where fish are held in relatively shallow water. Although, the damage itself may not be lethal for the fish, secondary bacterial, parasitic, and particularly fungal infections can lead to high mortality (Roberts 1989).

Fishes are susceptible to UV-B radiation which induces the sunburn. Dermal lesions, characterized by white to gray necrotic areas and erosion, particularly behind the head and on or near the dorsal fin, have been correlated with exposure to sunlight or to ultraviolet radiation (Bullock and Roberts 1981; Bullock 1982). UV-radiation affects the growth, mortality, behaviour, metabolism by affecting enzyme activities (Kumar and Aara, 2016).

Sunburn is a normal response of the skin to adequate amounts of UV light and all types of UV light, i.e. UV-A, UV-B or UV-C can cause it. The difference, however, lies in the energy required, the type of erythema caused and the case with which it appears. The UV-A need thousand times more energy to cause sunburn in compared to UV-B. UV-C has much shorter latent period and a shorter duration than UV-B, so UV-C does not reaches on the earth surface because these rays were filtered out by the ozone layer in stratosphere. Due to effect of UB-B, level of glutiathione reductase decreases resulting the dispersal of melanophores in fish. (Ali *et al.*, 2004). However, they also discussed that UV rays were responsible for aggregation of melanophoreson the fish. Thus dispersal or aggregation of melanophores on fish may be a result of species variation in the sensitivity of the effector cells.

Fish skin lacks the keratinized outer layer, which acts as a protective layer against stressors for many vertebrates (Bullock, 1982). Consequently, this multilayered assemblage of cells should serve as an integral part of its defense system and respond rapidly to external stimuli (Zaccone *et al.*, 2001). However, Little and Fabacher, (1994) reported that sensitivity against UV-radiation depends upon the species differences.

The skin of fish composed of two layers: epidermis and dermis. Epidermis is the outer layer and includes mucous cells, epidermal club cells (ECCs), and filament cells; and where as inner layer, dermis contain scales and various pigment cells.

The epidermis is the region that acts as the living interface between the fish and the external environment (Roberts and Bullock, 1981). ECCs could provide a first line of defence against agents such as pathogens or parasites that penetrate through the skin, or promote the healing of damaged tissue as a result of agents such as UV radiation (Blazer *et al.,* 1997; Chivers *et al*., 2007).

Both hypertrophy and hyperplasia in club cells of skin were observed in fishes exposed to UV-B radiation (Blazer *et al*., 1997). These cells may be important in the protection against UV damage, perhaps simply through the proliferative response or through the increased production of a substance that functions as a natural sunscreen.

The eggs and larvae of many fish are sensitive to UV-B exposure. Exposure to UV radiation whether of solar or artificial origin that is pointless in aquatic environments carried potentials risks to animals and plants, especially those inhabiting shallow water (Rozema, 2002).

Because fish are poikilotherms, ambient temperature has pervasive effects on their physiological function including immune function and growth. Temperature along with photoperiod cause seasonal change in the behavior and immune function of fish affecting both innate and acquired immune responses.

UV-B damages the macromolecules, provokes free radical production and induces a significant decrease in antioxidants (David *et al*., 2006). Depletion of ozone layer and increase in UV radiation interact DNA, protein, chromophores and skin pigments in aquatic animals (Laura *et al*, 2011). Significant decrease in antioxidative enzyme, catalase was found in fishes after exposure to artificial UV-B radiation. However, its intensity of decreasing was species specific (Kumar and Aara, 2016).

Alves and Agasti (2020) reviewed that ultraviolet B and A radiations adversely affect the fish at different lifecycle stages, including embryo, larvae, juveniles and adults. The most evident negative effects during the early development stages are an increase in mortality and incidence in developmental malformations, growth reduction, a loss in body condition, and behavioral, physiological and metabolic changes in juveniles and adults occur under short- or long-term UVB exposure. The skin of fry/ fingerlings undergoes profound morphological and functional changes, even after acute exposure to UVR. Impairment of molecular and cellular processes was evidenced in all development stages by increasing the levels of DNA damage, apoptosis and changing tissues' antioxidant status.

Chromophoric dissolved organic matter (CDOM) functions to protect aquatic organisms from the harmful effects of UV radiation by attenuating solar radiation selectively (Williamson and Zagarese, 1994). However, CDOM concentrations in lakes are declining as a result of anthropogenic activity (Williamson *et al*., 2001). In cultured fishes, dietary niacinamide (10 mg/kg of feed) protect the fish skin from sunburn caused by UV light (Poston and Wolfe, 1985).

4. Conclusion

With the recognition of the importance of UV radiation effects on aquatic ecosystems, there has been a plethora of publications which show that solar UV-B can adversely affect the community structure of various aquatic ecosystems. These studies document substantial impact on individual aquatic species yet considerable uncertainty remains with respect to assessing effects on ecosystems. Several studies indicate that enhanced ultraviolet radiation affect the aquatic ecosystem and also the productivity and biodiversity of fish by alteration in macromolecules. Ecosystem response to climate variability involves both synergistic and antagonistic influences with respect to UV radiation-related effects on aquatic ecosystems and these influences significantly complicate comprehension and prediction at the ecosystem level. Thus it can be concluded that UV radiation may be a more important factor than previously recognized in determining community structure in aquatic ecosystems.

Depletion of stratospheric ozone layer has created the threat of enhanced UV-B which causes the reduction of productivity of water bodies by reducing the rate of photosynthesis, plankton growth, and overall yield in most of the fish species. So, the scope of further research should be focused on the selection of tolerant fish species for improving knowledge, scope of genetic improvement and other responses against combination of stresses for better understanding and management of fish culture with changing climate.

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