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Thermal Stress in the Aquatic Ecosystem: Causes, Consequences, and Control Measures

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In our day-to-day lives, we often hear about many different types of traditional pollutants like chemicals, particulates, and plastics, which are getting a whole lot of attention; thermal stress is being overlooked. Thermal well-being plays a pivotal role in all organisms, specifically aquatic organisms. Aquatic creatures are strictly poikilothermic, i.e., their body temperature is the same as the surrounding temperature; abrupt temperature changes can lead to a catastrophe for them. This is why thermal stress is often considered a recipe for disaster. Thermal pollution is considered a significant environmental threat due to its far-reaching consequences. It is defined as the sudden increase in the temperature of a water body arising due to multiple factors. Thermal homeostasis is recognized as a critical determinant of numerous physiological processes like respiration, enzyme activity, metabolism, growth, reproduction and overall health. There exists a minimum and maximum temperature tolerance limit for every organism, below and above which lies the zone of intolerance, where it becomes difficult for the organism to survive.

Causes of thermal stress

Thermal pollution in aquatic environments arises from natural and human-induced factors such as power plants, industrial factories, climate change, urban and surface runoff, deforestation, soil erosion and reduction in stream water flow. Amongst all these, the lion's share is held by power plants and industrial factories, which withdraw water from rivers and streams to cool their generators and machinery and release the warm water back into the water bodies, elevating the temperature of freshwater habitats, thereby disturbing the delicate balance that once existed. Thermal pollution in aquatic environments is an inevitable outcome of operations at nuclear and thermal power plants Issakhov et al., (2021). One of the growing causes of thermal stress is urban and surface runoff. In order to meet the demand of the growing population, urbanization is surging at a faster pace, due to which forests are cleared off, buildings of asphalt, concrete and cement are being constructed, are highly impervious and absorb excessive heat, extensive use of refrigerators, air-conditioner to beat the self-generated heat is creating a zone which is experiencing temperatures several folds higher compared to suburban and rural areas. This effect is known as the urban heat island (UHI)effect. UHI affects the adjacent water bodies as the warmer water flows down to these water bodies in urban and surface runoff when heavy rain lashes down, thereby impairing the water quality.

Consequences

In aquatic environments, thermal pollution can have conspicuous impacts on various levels of biological organisation, from individual organisms to entire ecosystems. Disruption in fish and amphibians' habitats, detrimental impact on biodiversity, changes in body configuration, behavioural patterns, decrease in feeding intensity, difficulty in breathing, changes in skin colouration and an increase in metal toxicity are some of the many impacts caused by

alteration in thermal regimes. The added heat can lead to a cascade of adverse effects. Elevated temperature causes a drastic decline in dissolved oxygen levels as the increase in temperature decreases oxygen solubility. Sensitive species are the most affected by changing temperatures, threatening their survival. Rapid temperature changes can lead to thermal shock, which can cause extreme fish-kill events. Increasing temperatures alter the water properties, significantly enhancing the toxicity of chemicals. The viscosity and density of water also decrease, affecting the pollutants' dispersion. Thermal stress causes a decline in dissolved oxygen levels. As a compensatory response, there is an increment in metabolism and respiration rates to meet the exigencies, which leads to an increased influx of chemicals (heavy metals), thereby increasing the bioavailability of chemicals.

Studies have shown that with an increase in temperature, there is a disturbance in the metabolism of the microalgae. In a study concerning the effects of high temperatures and exposure to copper on the microalgae *Scenedesmus quadricauda*, by Yong et al., (2018) determined that the combination of these factors caused significant disturbances in the metabolism of the microalgae.. It has been reported that elevated temperatures can destabilize homeostasis in zooplankton, leading to protein denaturation and reductions in reproduction and survival rates. Studies also show that with increasing temperature, the rate of bioaccumulation of mercury increases. The activity of antioxidant enzymes decreases as temperature increases. Additionally, thermal pollution can exacerbate the effects of other pollutants and stressors, compounding its environmental impact. Teixeira et al., (2012) reported,thermal pollution modifies benthic cover and affects fish communities by changing their composition and reducing species richness.

Control Measures

Mitigating thermal pollution is the need of the hour in order to ensure the health of both aquatic ecosystems and organisms. There exist multiple ways to attenuate thermal pollution; cooling ponds are one of them; these are large shallow ponds or reservoirs designed to dissipate heat from thermal power plants. This low-cost method often needs more effectiveness due to low cooling efficiency. Next are cooling towers, tall structures used to cool heated water and work on the principle of evaporative cooling. The initial cost of construction of a cooling tower is high, but its cooling efficiency is higher than that of cooling ponds. Another mitigation measure can be the construction of spray ponds. These are large reservoirs where overheated water is cooled using a spray system. Spray ponds are cost-effective and easy to operate; the one disadvantage is the requirement of a massive land area for construction. Co-generation also offers a reliable solution to address the problem of thermal pollution. Cogeneratico-generationocess is where the waste heat can be reused or recycled for domestic and industrial heating instead of being released into the water body.

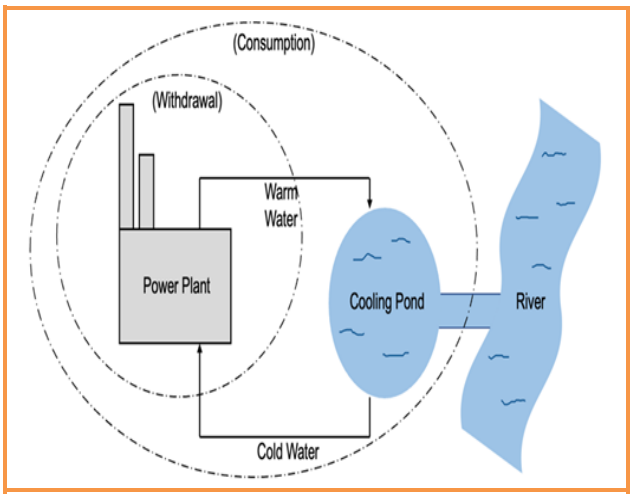

Fig.1. Cooling Pond

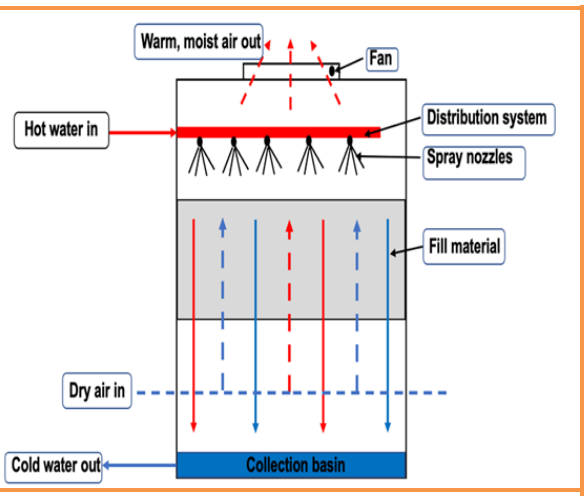

Fig. 2. Cooling Tower

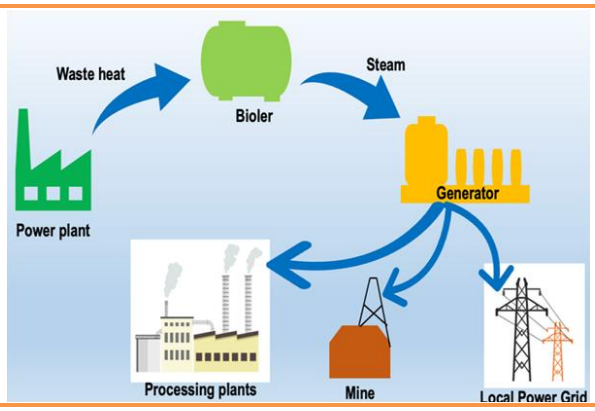

Fig.3. Co-generation

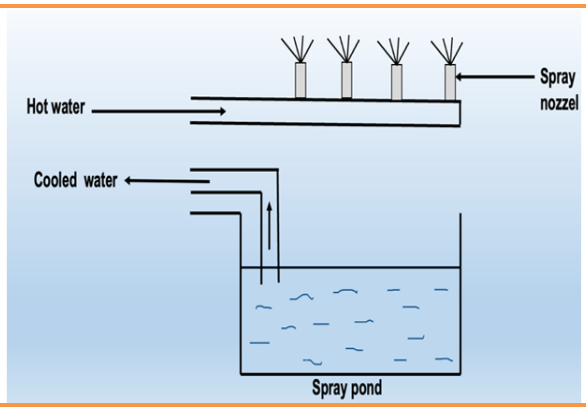

Fig.4.Spray Pond

Conclusion

Mitigating thermal pollution is crucial for protecting aquatic ecosystems and ensuring the health of aquatic organisms. Cooling ponds, cooling towers, spray ponds, artificial lakes and cogeneration are some of the many abetment measures that can be adopted. Collaborative efforts between industries, policymakers, and environmental organizations are crucial to creating effective solutions and promoting a healthier environment.

Way Forward

Both acute and chronic temperature changes can have profound effects on aquatic life, underscoring the importance of understanding and managing thermal conditions in aquatic environments to ensure the health and stability of ecosystems. Thermal pollution significantly threatens aquatic ecosystems, damaging biodiversity, habitat integrity, and health. The rising temperatures caused by climate change, urbanisation, and industrial practices disrupt species distributions, alter food webs, and exacerbate the prevalence of diseases. A multifaceted approach is essential to combat this challenge, encompassing ecological restoration, sustainable management practices, and robust community engagement. By implementing proactive measures, such as restoring riparian habitats, improving water quality, and fostering public awareness, we can mitigate the impacts of thermal pollution. Collaborative efforts between governments, organisations, and local communities will safeguard aquatic ecosystems, ensure their resilience, and preserve their vital services for nature and human well-being. Through concerted action and commitment, we can protect our water bodies from the adverse effects of thermal pollution and promote a healthier, more sustainable environment for future generations.

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