ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Extent of Tolerance of Crustacean and Rotifer Zooplanktons to Different pH Level: A Brief Resume.

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ABSTRACT

Water bodies are the most productive ecosystems and endeavours huge ecological importance. pH as an important parameter limits the population of zooplankton which in turn regulates the population interaction in aquatic ecosystems. This paper grossly encompasses the impact of variable level of aquatic pH level on the incidence, abundance, and survivability of zooplankton with a special reference to crustacean and rotifer zooplankton species. To sustain aquatic ecosystems, specific pH range which support zooplankton species is mostly needed. Thus, therefore, present review reflects on the impact of pH range on the zooplankton with special reference to crustacean and rotifers and their relative adaptation to alternative pH level.

Keywords: Zooplankton, pH, Rotifer, Crustacean.

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INTRODUCTION

The pH is a measure of the acidity or basicity of an aqueous solution. Mathematically, pH is the negative logarithm of the activity of the (solvated) hydronium ion, more often expressed as the measure of the hydronium ion concentration. The pH is defined as the decimal logarithm of the reciprocal of the hydrogen ion activity ($a_{H}+$) in a solution [1].

$$\mathrm{pH} = -\log_{10}(a_{\mathrm{H}^+}) = \log_{10}\left(\frac{1}{a_{\mathrm{H}^+}}\right)$$

Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline. Pure water has a pH very close to 7. The concept of pH was first introduced by Danish chemist Søren Peder Lauritz Sørensen at the Carlsberg Laboratory in 1909 and revised to the modern pH in 1924 to accommodate definitions and measurements in terms of electrochemical cells. According to the Carlsberg Foundation pH stands for "power of hydrogen". Marine waters have traditionally been considered a pH-stable environment with a pH value of 8 ± 0.5, due to the high buffer capacity found here [2, 3]. Contrary to that, the freshwater pH varies in pH value due to a number of reasons.

The word "zooplankton" is derived from the Greek *zoon*, meaning "animal", and *planktos*, meaning "wanderer" or "drifter". Individual zooplanktons are usually microscopic, but some are larger and visible with the naked eye. Examples of zooplankton include the copepods, salps and some jellyfish, larvae of sea urchins, starfishes, crustaceans, marine worms, and most fishes [4]. Some of the eggs and larvae of larger animals, such as fish, crustaceans and annelids, are also included in this group.

As the pH of aquatic environment has large impact on developing the nature of that ecosystem and limits the diversity of organisms also, thus, it can act as a limiting factor for zooplanktons also and can determines the zooplankton communities of that water body. Keeping this view, present review deals with the tolerance and existence of crustacean and rotifer zooplanktons to different pH levels of different types of water bodies.

IMPORTANCE OF ZOOPLANKTON

Zooplankton varies hugely in size, ranging from about 20 µm (micro-zooplankton) to 2 m in diameter (some jellyfish). Zooplankton communities are highly diverse, containing representatives of at least a dozen phyla. Zooplankton are heterotrophic (sometimes detritivorous) organisms. Zooplankton is an essential faunal group in an aquatic ecosystem, as it provides food for fish communities [5]. Their relationships with physico-chemical parameters are important for the management strategies of aquatic ecosystems [6].

Zooplankton provides an important food source for larval vertebrates and invertebrates in natural waters and in aquaculture ponds. Failure of fishing, in many countries is attributed to the reduced zooplankton [7, 8]. Aside from representing the bottom few levels of a food chain that supports commercially important fisheries, plankton ecosystems play a role in the biogeochemical cycles of many important chemical elements, including the ocean's carbon cycle [9]. Primarily by grazing on phytoplankton, zooplankton provide carbon to the planktic food web, either respiring it to provide metabolic energy, or upon death as biomass or detritus. Organic material tends to be denser than seawater, and as a result it sinks into open ocean ecosystems away from the coastlines, transporting carbon along with it. This process is known as the biological pump, and it is one reason that oceans constitute the largest carbon sink on Earth [10].

INCIDENCE OF ZOOPLANKTON IN RELATION TO AQUATIC PARAMETERS

Physico-chemical parameters may change due to several environmental incidences and it may in turn affect the biota including the zooplankton community. The freshwater zooplankton comprise mainly of Protozoa, Rotifers, Cladocerans, Copepods and Ostracods. Zooplankton are an important component of the aquatic biota and play a pivotal role in the food web by forming a link between the lower trophic level organisms (phytoplankton) and the higher trophic level organisms such as macro-invertebrates and fish. They are susceptible to variation in a wide number of environmental factors including water temperature, light, chemistry (particularly pH, oxygen, salinity, toxic contaminants) and food availability [11]. Zooplankton, like all organisms have a range of environmental conditions to which they are adapted. Changes of these parameters may indicate some alterations of the prevailing conditions of the ecosystem.

Rotifera, cladocerana, copepoda, and Ostracoda constitute the major groups of zooplankton. They occupy an intermediate position in the food web. Studies on zooplankton in Indian continent are made by a number of researchers like Arora [12], Mohan [13], Sharma [14], Michael *et al*. [15], Verma *et al*. [16], Rao *et al*. [17], Kodarkar [18], Babu Rao [19], Mishra *et al*. [20], Dhanpathi *et al*. [21], Trivedi [22], Baghela [23], Pandit *et al.* [24].

pH - AN IMPORTANT LIMITING FACTOR IN AQUATIC ENVIRONMENT

The pH of seawater plays an important role in the ocean's carbon cycle, and there is evidence of ongoing ocean acidification caused by carbon dioxide emissions [25, 26]). The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically [27]. Water pH not only determines the availability of certain chemical elements in the water, but it also enhances the toxicity of some metals [28]. Locke [29], Havens *et al*. [30] and Fischer *et al*. [31] emphasized that pH controls zooplankton community structure and food webs in acidified lakes. Out of different acidification variables tested by Walseng *et al*. [32], pH showed the strongest correlation with micro-crustacean composition. Thus, the present review paper goes through the tolerance range of pH on crustacean and rotifer zooplankton species.

EXTENT OF TOLERANCE OF CRUSTACEANS AND ROTIFERS TO DIFFERENT pH LEVEL

In water bodies with very low (<6) and very high (>9) pH values only a few zooplankton species are found which indicates that both acid and alkaline environments have a strong adverse effect on zooplankton [33]. In consideration of the survivability and sustenance of zooplankton can be classified in to two groups - (a) Acidophilic which prefer pH of below 7.0 and (b) Basophilic which prefer pH of above 7.0.

Acidophilic zooplanktons:

The acid adaptable species will be able to reverse evolutionary responses to environmental disturbance in the years following recovery [34]. Ceri *et al.* [35] reported that Arctic Ocean already experiences areas of low pH and high CO_2 and it is expected to be most rapidly affected by future ocean acidification. Copepods comprise the dominant Arctic zooplankton, which in the surface waters showed significant reduction and survival in high CO_2 experiments. The observations of Ceri *et al.* [35] imply that migratory zooplankton, by virtue of their daily exposure to a wide range of pCO_2 conditions, might not require evolutionary adaptation to future pCO_2 scenarios. In contrast, non-migratory zooplanktons are more likely to experience local extinction in the absence of evolutionary adaptation [35]. Brenda *et al*. [36] found that the initially mixed zooplankton assemblage of cladocerans, copepods, and rotifers in Shelf Lake-4 shifted toward rotifer dominance in acid treatments. Studies of Offem *et al.* [37] at Ikwori Lake, South-Eastern Nigeria reveals that the pH value limits between 5 to 6 with a total of sixteen (16) zooplankton species belonging to seven families of Decapoda, Cladocera, and Copepoda. It is apparent that direct physiological influences of acid stress are important, but that indirect (biotic) influences and variables which correlate with pH are often as important if not more so to the zooplankton [38]. Zhuang [39] in an experimentation collected samples of zooplanktons from some suburban water bodies of Chongqing City, a heavy acid rain areas in the southwest China. Lawrence *et al.* [40] found that the individual species of zooplankton generally decreased as pH of the lake was experimentally lowered over a number of years by additions of acids and the biomass of crustacean zooplankton was reduced when pH was reduced. Holopainen [41] examined the pH of a small, natural forest pond in eastern Finland decreased from 6.0 to 4.0 during a dry summer. The mean biomass of the zooplankton was also found lower in the acidic pond, which was mainly due to the small numbers of Crustacea in late summer, when the pH values were lowest. The low zooplankton biomass was probably caused directly by the low pH or indirectly by a shortage of food [41]. Observations of Yuichiro *et al.* [42] reveals that the sensitivity of zooplankton to lowered pH was species specific and the differences in swimming behaviour, food habit, size and presence of gills in the zooplankton were not significantly related to sensitivity to lowered pH. The marine zooplanktons are much more sensitive than freshwater zooplankton to acidic pH [42]. Certain zooplankton groups such as cladocerans begin to decline when pH levels drop below pH 6 [43]. While assessing the distribution of zooplankton species in lakes with pH levels of 3.5 to 7.6, Blouin [44] noted that zooplankton never occurred at low pH values (pH < 4.6). Moritsch *et al.* [45] reported that in the San Francisco Bay, zooplankton abundance also showed a positive correlation with pH and over the 0.55 units of pH decrease, the plankton abundance slowly decreased as well.

Basophilic zooplanktons:

Farshad *et al.* [46] studies on Zooplankton Diversity in Nanjangud Industrial Area of India and reveals the existence of zooplanktons species made up of Rotifera, Copepoda, Cladocera, Diptera and Nematoda at pH level 7.01 to 7.19. Manikarachchi *et al.* [47] at the Polhena reef area of southern Sri Lanka found that the zooplankton community was identified to occupy 17 groups, dominated by copepods, crustacean nauplii and foraminiferans at the pH range of 8.0 to 8.64. Akindele *et al.* [48] at Opa Reservoir catchment area, Ile-Ife, Nigeria, found the pH ranged from 6.70 to 8.11 and the zooplankton fauna of the rivers comprised two phyla with forty-six species. Onyema *et al.* [49] in the Agboyi creek of South-western Nigeria found pH values ranged between 6.9 and 7.10 where a total of 17 zooplankton species of two major phyla of zooplankton (arthropoda and rotifera) were represented. Of these, the phylum Arthropoda was the more abundant, accounting for 54.05% of the total species composition while the phylum Rotifera made up 45.95% of the total species composition. Pedersen *et al.* [50] experimented with the pH of natural seawater samples and adjusted it to pH 8, 8.5, 9 and 9.5 respectively and in result; no copepods were found in the pH 9 and 9.5 incubations. Studies of Varadharajan *et al.* [51] shows the maximum pH of 8.2 and a minimum pH 7.8 with the 26 species of zooplankton comprising Foraminifera (9 species), Calanoida (6 species), Cyclopoida (4 species), Appendicularia (4 species) Hydroida(1 speceis), Rotatoria(1 species) and Sagittoida(1 species). In Ogunpa and Ona rivers, Nigeria, Akin-Oriola [52] found forty-nine species of zooplanktons from both the rivers and they were composed of Protozoa (6 species), Rotifera (32 species), Cladocera (6 species) and Copepoda (4 species). The zooplankton fauna of Ogunpa and Ona rivers were dominated by the Rotifera while the family Brachionidae recorded the highest species richness. The pH ranges was 6.8-8.9 on their total study time. At the Paoay Lake in Luzon Island in the northern Philippine the pH values obtained ranged from 6.75 to 7.88 and there twenty seven species including 11 rotifers, 8 cladocerans and 8 copepods were recorded [53]. The study of Silva *et al.* [54] in a tropical inverse estuary (Northeast Brazil) reveals that the pH ranges from 7.7 to 7.9 and a total of 157,464 zooplankton individuals belonging to 16 rotifer species and 3 cladoceran species were present there. Shil *et al.* [55] in their study reported that at the pH range between 7.1 to 8.1 a total of 11 zooplankton species including 4 copepod, 2 rotifer, 2 cladocera, 2 ostracoda and 1 shrimp larvae was found. From the studies of Manjare *et al.* [56] that can be understood that in the pH values ranges from 7.32 to 8.63 and the zooplankton were represented by four groups of zooplanktons viz. Rotifera, Cladocera, Copepoda and Ostracoda. Studies of Bozkurt *et al.* [57] at Lake Gölbaşı (Hatay, Turkey) indicates that pH values ranges from 7.19 to 7.89 covers an zooplankton assemblage included 91 species including 61 species of Rotifera, 20 species of Cladocera and 10 species of Copepoda. Lakes having a higher (alkaline) pH are found to be richer in zooplankton species [58].

PRIME CAUSES FOR THE CHANGE OF AQUATIC pH

Due to Anthropogenic effect:

Jha *et al*. [59] carried out a qualitative analysis of zooplankton in Lake Mirik in Darjeeling, Himalayas. This lake was polluted due to the pollutants let into the lake from external sources and the pH of the lake became acidic and it was also confirmed by the analysis of other physiochemical parameters and planktons. In this condition, only cladocerans and copepods were found. Maria *et al*. [60] in one experiment of pH 9.5 incubation; the proto-zooplankton biomass decreased close to detection limit and most proto-zooplankton species incubated at pH 9.5 died. Their study indicates that elevated pH (>9) in nature will affect the entire zooplankton community mainly by reducing the species richness and by favouring algal blooms due to loss of grazing [60]. Fabry *et al*. [61] concludes that ocean acidification and the synergistic impacts of other anthropogenic stressors provide great potential for widespread changes to marine ecosystems.

Due to the variation of temperature:

Temperature is an important factor that affects the chemical and biological reactions in water. Temperature regulates self-purification capacity of water [62]. A rise in water temperature accelerates chemical reactions which in turn reduces solubility of gases and also elevates metabolism of aquatic organisms, leading to decrease in dissolved oxygen and increase in free carbon dioxide. As pH is a measure of the hydrogen ion concentration, a change in the temperature of a solution will be reflected by a subsequent change in pH [63]. Khaire *et al*. [64] also stated that temperature brings out changes in pH. Anderson [65] at trophic lake, Washington has recorded higher pH during summer season and lower pH at winters showing direct relation between pH and temperature. Higher pH during summer season may be due to decrease in water level which elevates the water temperature, but higher pH values during winter season may be due to increase in number of phytoplankton due to high values of dissolved oxygen in winter. Lower pH values were observed in monsoon season may be due to high turbidity caused by flooding of water body which elevates water temperature and decreases the photosynthetic activity resulting in accumulation of free carbon-dioxide [66].

Seasonal variation of plankton population in relation to alternative pH level:

Pandey *et al.* [67] in river Ramjan of Bihar, India, revealed that abiotic parameters (e.g., pH, transparency, temperature, dissolved oxygen and some micronutrients) in relation to seasonal fluctuation influence zooplankton abundance. In this study, size of the Rotifer community was the largest one which showed a negative correlation with pH, dissolved oxygen and transparency. Abundance of cladocera got second position among the total collection and showed negative correlation with pH, transparency and phosphate. Mustapha [68] at a small, shallow tropical African reservoir (Oyun reservoir, Offa, Nigeria) found that the surface water pH fluctuated between slight acidity and moderate alkalinity. The lowest monthly mean pH was 6.8 ±0.05 obtained during the dry season in January 2002, while the highest was 8.2 ±0.2 obtained in the wet season of August and September of 2003. pH was significantly ($p<0.05$) higher during the wet season. He also demonstrates that, fourteen genera of zooplankton were identified from the reservoir. They belong to Rotifera (8 genera), Cladocera (3 genera) and Copepoda (3 genera). A total of 1709 organisms/m^3 of zooplankton number was recorded in the reservoir.

Salient characteristics of zooplankton due to adaptive response to variable pH level:

It was observed that 2–3 times the number of genera is found in waters with a pH greater than 5 as compared to those with a more acidic pH [69]. Optimum hatching conditions observed by Rojas *et al*. [70] for *Moina sp*. were pH 5 to 9. It was also observed by Beklioglu *et al.* [71] that increasing pH values led to an increase in the numbers of *Daphnia hyalina*, particularly at pH 10, but population density declined at pH 11. However, a pH exceeding 10.5 negatively impacts growth, reproduction and survival of most *Daphnia* species [72, 73, 74]. *Leptodiaptomus minutus* copepod populations had higher acid tolerances [75].

CONCLUSION

Thus, it can be concluded that the pH value is dependent on a number of factors and zooplankton abundance showed a significant relation with pH value. The qualitative and quantitative analysis results indicated that the species of zooplankton were found to decline gradually with a reduction of pH value ranging from 8.80 to 4.01. All the evidences suggest that effects of low and high pH on zooplankton are the greatest below pH 5.0 and above pH 9.0 respectively. As the pH value of the water bodies' decrease below 4.5, the plankton abundance slowly decreased as well and as the pH value increases over 9.5 the zooplankton abundance decreases also. Thus, it is now apparent that most of the crustacean and rotifer zooplanktons can tolerate and thrive well at the pH level of 4.5 to 9.5 approximately.

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