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# Understanding the Cause of Fish Kill in Nigeen Lake

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## ABSTRACT

Occurrences of fish kills are increasing in aquatic ecosystems worldwide, and have been attributed to natural phenomena, as well as human modification and pollution of terrestrial and aquatic environments. Thousands of fish were reported dead mysteriously in Nigeen Lake in August 2012, creating panic in the people of Kashmir Valley. The present investigation was carried to assess which fish species were killed and to determine the ecological conditions in the lake that lead to the fish kill. A combination of factors such as high temperature, low dissolved oxygen, summer kill phenomena and Cyanobacterial bloom lead to mass mortality of fish. Nigeen Lake was also compounded with upsurge of inorganic and organic matter. Ammonia, Total Phosphorus, Chloride and pH showed some rise at the time of fish kill. At some places, the dissolved oxygen level fell to meager 0.4-1.6 milligrams per litre which proved fatal for some fish species like *Crossocheilus Diplochilus* which died in large number. After comprehensive scientific tests, we found that many different mechanisms worked synergistically to cause fish kill.

**Keywords**: Fishkill, temperature, dissolved oxygen

## INTRODUCTION

Fish kills occur in virtually every aquatic environment worldwide from a wide variety of natural and human-induced causes. Natural causes include extreme temperature fluctuations, starvation, and disease and low dissolved oxygen (Venugopalan *et al.* 1998). Human-induced kills include known and accidental additions of sewage/organics, pesticides, acids, petroleum products, and fertilizers to waters containing fish (Olmsted and Cloutman 1974, Meade 2004). These fish kills can be small in localized areas or extremely large, killing millions of fish. Point source additions of chemicals and/or nutrients have often been shown to result in fish kill events. However, point source pollution problems have been dramatically reduced since the turn of the 20th century, and most fish kills reported in the recent literature are due to natural events and mostly related to dissolved oxygen problems in nutrient-rich systems (Barica, 1975, Trim and Marcus, 1990; Townsend *et al.* 1992, Mhlange *et al*. 2006). If, however, the nutrient-rich condition is a consequence of anthropogenic activities, the term natural would not be appropriate. When a fish kill occurs, whether the result of natural or other causes, the public becomes greatly concerned. By the time anyone arrives at the scene of a fish kill, the water chemistry and/or chemical that caused the kill has generally changed or moved downstream. For this reason several researchers have attempted to develop models to predict the occurrence of fish kills in lake systems so management agencies can prepare for these events (Barica, 1975; Mericas and Malone, 1984;Miranda *et al*. 2001, Quinlan *et al.* 2005).

In order to have an insight in to the basic limnology of the water body and identify the causes for this unfortunate phenomenon, a study was conducted by the present authors starting $6^{th}$ August, 2012 to check the physico-chemical features of the affected areas. As many authors have reported on the role of cyanobacteria blooming on the fish kills, an effort was also made to study the cyanobacterial population of the lake. Since our team was already entrusted with the collection of the limnological features of the whole Dal Lake, including the Nagin Basin from 2011 on monthly basis, the data procured during the post fish kill period are discussed in the present communication and compared with the pre kill data for deducing some conclusions regarding the causative factors for the episode.

**MATERIAL AND METHODS**

Nigeen (Fig. 1) is one of the five basins of the world famous Dal Lake. It is situated at a distance of about nine kilometers to the north of Srinagar city India, at an elevation of 1584m a.s.l., covering an area of 4.5 km². The water supply of the basin is maintained by Hazratbal basin of the Dal Lake in addition to the springs within the basin, and atmospheric precipitation. The agricultural runoff and domestic effluents are the other sources of water supply.

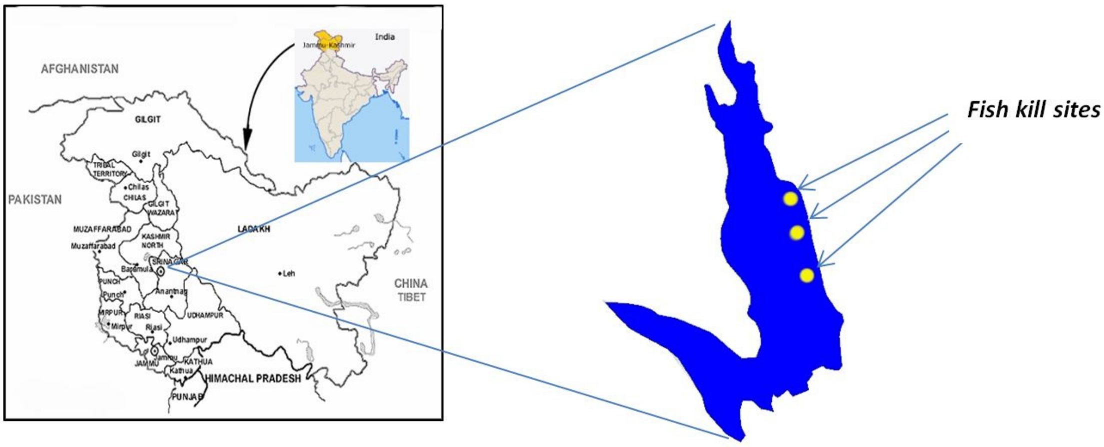


FIG.1: Location of Study Sites in Nigeen Basin

For determining the physio-chemical features, water samples from the fish kill zone were collected in one liter - plastic bottles. For determination of dissolved oxygen, DO bottles (glass) of 300 ml capacity were used. Water samples were analyzed in the laboratory adopting standard methods given in Mackereth (1963) and APHA (2005) as explained in Table 1.

For Cyanobacterial identification, sample was gently shaken to re-suspend all materials. It was allowed to settle for one minute and then 1-2 drops were removed from the middle of the sample and placed on a glass slide. Identification of cyanobacteria was done with the help an Olympus phase-contrast microscope at 100 to 400X using taxonomic keys by Bellinger and Sigee (2010), Biggs (2000), Cox (1996) and Edmondson (1959).The quantitative estimation was done in a Sedgwick-Rafter chamber (S-R cell) under the same microscope. Each colony of *Microcystis* and *Anabaena* was counted as a single cell.

**Table1. Water quality parameters, units and analytical methods used for water quality analysis.**

| S.No. | Parameters | Units | Analytical methods |
|---|---|---|---|
| 1 | Temperature | °C | *Instrumental method* |
| 2 | pH | pH units | *Potentiometric method* |
| 3 | Dissolved oxygen | mg $L^{-1}$ | *Winkler Azide -Modification method* |
| 4 | Electrical conductivity | µ$Scm^{-1}$ | *Conductivity cell potentiometric method* |
| 5 | Total alkalinity | mg $L^{-1}$ | *Titrimetric (methyl orange) method* |
| 6 | Chloride | mg $L^{-1}$ | *Argentometric method* |
| 7 | Total Hardness | mg $L^{-1}$ | *Complexometric method* |
| 8 | Total phosphorus | µg $L^{-1}$ | *Stannous chloride method* |
| 9 | Ammonia nitrogen | µg $L^{-1}$ | *Phenate spectrophotometric method* |
| 10 | Nitrate nitrogen | µg $L^{-1}$ | *Salicylate method* |

## RESULTS

The fish kill in Nigeen was characterized by three specific events that occurred during first week of August: Change in water quality/increase in water temperature, summer kill phenomenon and emergence of Cyanobacterial bloom. There were no recorded fish kill during the month of July which acted as our reference state. For the Comparative physicochemical analysis, water quality data prior (18th July) and after fish kill (6th August, i-e one day after fish kill) were studied (Table 2).Dissolved oxygen was found to be significantly ($p = 0.001$) lower in the range value of 0.4-1.6 mg/l and with mean value of 1.0 mg/l in the month of august (fish kill event) as compared to the July (no fish kill) with the mean value of 3.6 mg/l. Significant ($p < 0.05$) concentration of chloride was also observed after fish kill event with a mean value of 24.6 mg/l and on the other hand its mean value was 15 mg/l prior to the fish kill.

The lake tended to be alkaline at the time of fish kill with significantly high mean pH and mean alkalinities of 8 and 256 mg/l respectively. The lake was mostly productive after fish kill event with total phosphorus, Ammonia and Sechi depth averaging 66 µg/L, 280 µg/L and 1.5 m, respectively. Water was highly turbid reducing the visibility of the lake.

**Table 2. Mean value of eleven water chemistry variables measured in the Nigeen Lake before and after the fish kill event.**

| Parameter | *After fish kill* | *Before fish kill* |
|---|---|---|
| | Mean value | Mean value |
| Dissolved oxygen (mg/l) | **1.0** | 3.6 |
| Sechi depth (m) | 1.5 | 2.5 |
| Electrical conductivity ($\mu Scm^{-1}$) | 400 | 180 |
| Water Temperature ($C^0$) | **29.5** | 25 |
| pH | 8.0 | 7.32 |
| Chloride( mg/l) | 24.6 | 15 |
| Alkalinity( mg/l) | 256 | 94 |
| T. Hardness ( mg/l) | 130 | 88 |
| Nitrate (µg/l) | **303** | 121 |
| T. Phosphorus (µg/l) | 66 | 57 |
| Ammonia (µg/l) | **280** | 90 |

The means were compared with an analysis of variance and parameters were significantly different ($p \leq 0.05$)

Thousands of dead fish, mostly *Crossocheilus diplochilus* commonly known as *Tethur,* were observed on the shore. Some other fishes which were also affected by the fill kill included *Schizothorax* sp*., Cyprinus carpio* and *Puntius conchonius.* The dead fish were found to be accumulating in shallow water and along the shore. The densest quantity of dead fish was on the eastern side of the Nigeen. The amount of dead fish couldn't be quantified as the fish that remained on the bottom of the lake or that were consumed by scavengers was unknown. Upon examining the dead fish, we found some unique signs; *(i) Discoloration, (ii) reddening of the skin, (iii) black & white spots on the skin, (iv) Abnormal shape, (v) Swollen areas, (vi) Abnormal lumps, (vii) Bulged eyes (Popeyes) (viii) Lesions.*

Cyanobacteria were present in various patches in the Nigeen Lake mostly comprising *Microcystis* and *Anabaena* sp*.* (Fig. 2). They considerably reduced the light penetration in the Lake.

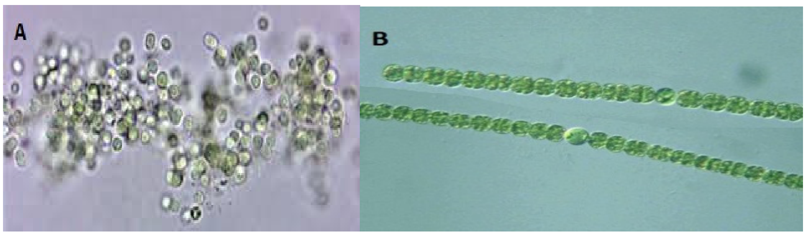


**Fig. 2: Microscopic view of *Microcystis* sp.(A) and *Anabaena* sp.(B)**

Nigeen Lake experienced what is called summer kill phenomena. Hot, cloudy and calm conditions prevailed for some days just before fish kill. Due to cloudy skies, photosynthetic rate was considerably reduced. As a result, primary producers (particularly algae) started diminishing, increasing the decomposing mass of the lake. The decomposing bacteria consumed the Lake's dissolved oxygen upon decomposition, which put the fish under stress. During night, the process of photosynthesis stopped but the decomposition continued which drastically reduced the already weakened oxygen profile. This means that a mass fish kill had occurred at night or during the early morning hours.

Interestingly, drought like situation prevailed in the valley just before fish kill. In June and July, the average rainfall in the Valley used to be 95 mm, while as in summer 2012; it was just 46 mm affecting the eco-system of water bodies. Hot (up to 34$^{o}$C) and cloudy weather was prevalent before the fish kill. The nearly two-month long dry spell was finally broken by sudden and intense rainfall. Soon after the rainfall, mass mortality of fish was observed.

## DISCUSSION

Nigeen basin is the narrow stretch of water making it ideal place for stationing house boats and conducting aquatic sports as a result the basin has been tremendously stressed. When fish kill occurred, the first assumption was that something terrible wrong was with the water body. Suspicions were raised as to whether human activity, such as a chemical spill, may have caused the fish to die. Sometimes these suspicions are warranted but most times they are not.

Three mechanisms were found to play their role synergistically in the massive fish kill, summer kill phenomena, Change in water quality/water temperature, and Emergence of Cyanobacterial bloom.

Although oxygen depletions can happen at any time, they are most likely to occur during warm summer months. A combination of hot weather and cloudy skies can be particularly deadly for fish, as the decrease in sunlight (i.e., from cloud cover) makes it difficult for algae and plants to photosynthesize. The reduction in photosynthesis results in a decrease in oxygen being released into the water column. When overcast skies persist for several days, oxygen levels can become severely depleted. (Florida LAKEWATCH, 2003).This is exactly what happened in the Nigeen Lake.

The time of year a fish kill occurs can help in the determination of potential causes for the kill, and early on researchers reported observations that many fish kills occur in the summer after storm events (Swingle, 1968 and Barica, 1975). The examination of fish kill in Nigeen Lake strongly supports both observations. The fish kill in Nigeen Lake occured in the warm month of august, and the frequency was highly correlated to the amount of rainfall and the elevated temperature of the water. Heavy thunderstorms can also have an adverse effect on oxygen levels, especially after extended periods of dry weather or during hot weather. If conditions have been dry for a long time, heavy rains tend to wash large amounts of organic matter such as dried leaves, grasses, etc. into nearby canals, lakes, and ponds. As bacterial organisms begin to decompose the new material, oxygen is used at a faster rate than normal. This can be a problem during hot weather as there is less oxygen in the water. (Florida LAKEWATCH, 2003). Similar type of fish kill was also found in our study as the Lake body experienced continuous rainfall for two to three days after a long dry period. Strong thunderstorms with abundant rainfall can dramatically change water chemistry of a lake in many ways; so several mechanisms probably work independently and/or in concert to produce a fish kill. Townsend *et al*. (1992) documented a fish kill in Donkey Camp Pool, Australia, caused by a large storm that increased an organic load with a high oxygen demand. Thus, while fish kill frequency is strongly correlated to rainfall events, the exact mechanisms that cause individual fish kills are probably different and lake dependent. Systematically investigating fish kills will most often yield information needed to determine the exact mechanism of individual fish kills (USFWS, 1990; AFS,1992).

Lakes in summer are subject to much higher surface temperatures, decreasing the physical ability of water to hold oxygen. Many lakes are also stratified during the summer making it difficult for oxygen to diffuse to greater depths. Data from Nigeen Lake showed that it had the highest algal abundance in summer between June and October. Given these factors, the more biological activity in a lake, the greater the chances some climatic event will switch an oxygen balance to more respiration than photosynthesis. From the water chemistry of the Nigeen Lake it is evident that more productive eutrophic lakes have a higher probability of experiencing a fish kill; therefore, any summer period natural or human-induced limnological change in these productive lakes that causes algal or aquatic plant populations to collapse or respire more than photosynthesize has the potential to cause a fish kill.

Our results suggest that the excessive fish kill in Nigeen Lake in August was mainly caused by the low dissolved oxygen content in the water during night accompanied with high temperature as well as high pH and ammonia. Warm water is less capable of holding oxygen gas in solution than cool water. This physical phenomenon puts the fish in double jeopardy because at high water temperatures their metabolic rates increase, hence their physiologic demand for oxygen increases (Francis-Floyd, 2003). Most species of fish are distressed when the oxygen content falls to 2-4 $mgL^{-1}$ (Muller and Stadelmann, 2004); mortality usually occurs at concentrations less than 2 $mgL^{-1}$(Francis-Floyd, 2003). The ability to tolerate low dissolved oxygen levels depends on the species of fish (Francis-Floyd, 2003). *Crossocheilus diplochilus* had suffered the most in Nigeen Lake.

The increase in water temperature was accompanied by sudden changes in water pH and ammonia (Table 2). At elevated levels of pH, most of the ammonium is converted to toxic ammonia (NH3), which can kill fish (Randall and Wicks, 2000). According to Randall & Wicks (2000), many fishes have difficulty excreting ammonia when exposed to alkaline conditions. As a result toxic levels of ammonia may rise in the fish due to impaired excretion, which may prove fatal to the fish.

Oxygen depletion in eutrophic lakes at night is a well-known consequence of "excess" algal biomass. Mass mortality of fish may be associated with the bloom of *Microcystis* and *Anabaena*. Supporting our hypothesis can also be drawn from other studies (Schwimmer and Schwimmer, 1964; Collins,1978) which suggest that a critical masses of cyanobacteria decomposed naturally and this decomposed products plus toxic cellular materials released into the water during cell lysis might have caused death of fishes. Cyanobacteria can produce a wide range of toxins, including microcystins (Tanner *et al*., 2005). The concentration of these toxins may not be lethal to the fish, but they may affect the condition of the fish, making them more vulnerable to the unfavorable environmental conditions (Wolfstein, 2003). The likelihood of appearance of ecologically critical situations in lake depends on weather conditions. In Nigeen Lake, extensive fish kills are likely to occur again in summers (as happened in August, 2013), when high temperature is accompanied with low dissolved oxygen. Eutrophication and increase in temperature are acting in the same direction: both are increasing the probability of fish kill.

Our findings are consistent with decades of conventional wisdom in the primary literature and centuries of aquaculture practices. Fish kill generally occur in nutrient-rich systems, in the summer during the hottest months. These kills can be triggered by storms and increased rainfall that also coincide with the summer period. We recommend that state agencies (Fisheries department and LAWDA) in charge of fish populations use resources to systematically investigate all fish kills and maintain reports that can later be merged with ambient limnological data. Analyses like these will help agencies better understand and potentially predict the occurrences of fish kills.

## CONCLUSION

Many different mechanisms working independently or in concert can be responsible for a fish kill, depending on the limnology of an individual water body. In summer, high temperature spells the high oxidation of nutrients and brisk depletion of oxygen levels in the lake can lead to such a phenomenon.

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