Research Article
Open Access
CrossMark

# Sources of off-flavor in high nutrient-load Nile tilapia (*Oreochromis niloticus*) ponds in north-central Bangladesh

## Abstract

Recently, toxins and off-flavor compounds produced by phytoplankton in freshwater ponds have become a concern as it affects consumer acceptability and food safety. The purpose of this research was to investigate the relationship between phytoplankton abundance and water-sediment physicochemical parameters in high-nutrient-load Nile tilapia (*Oreochromis niloticus*) ponds from three sub-districts (upazila) in north-central Bangladesh. Water and sediment samples were collected from 9 randomly selected ponds of Sadar, Trishal, and Muktagachha upazila, and temperature, transparency, pH, phytoplankton concentration for water and pH, organic C and organic matter for sediment samples were determined. Water temperature and transparency were more or less similar across all the ponds, while pH varied significantly ($p<0.05$). Soil pH also varied significantly ($p<0.05$). The abundance of Bacillariophyceae, Chlorophyceae, and Euglenophyceae in pond water was almost equal but Cyanophyceae differed among the ponds with the highest in Muktagachha ($5.22\pm2.30\times10^4$ cells/L) and the lowest in Trishal ($4.84\pm0.740\times10^4$ cells/L). Correspondingly, Algal Genus Pollution Index (AGPI) was employed to study the water quality of Nile tilapia ponds, and it revealed that ponds in Muktagaccha had 'probable high organic pollution' compared to ponds in the other two locations. Five cyanobacteria genera were identified viz., *Anabaena*, *Aphanizominon*, *Gomphosphaeria*, *Mycrocystis* and *Osoillatoria* where *Anabaena* showed a strong positive correlation with water temperature and pH. The significantly higher abundance of cyanobacteria in Muktagachha is possibly linked to the favorable water temperature and pH and indicates a higher risk of off-flavor creation in the Nile tilapia ponds from this upazila. It is, therefore suggested that the right management measures must be put in place to control the cyanobacteria to ensure the profitability of fish farming.

**Keywords:** Off-odor, cyanobacteria, *Anabaena*, AGPI, temperature, tilapia farming

Volume 12 Issue 1 - 2023

AA Razu,[1] SA Haque,[2] MNA Khan,[3] M.Kamal,[1] MS Reza[1]*

[1]Department of Fisheries Technology, Bangladesh Agricultural University, Bangladesh
[2]Department of Fisheries, Bangamata Sheikh Fojilatunnesa Mujib Science and Technology University, Jamalpur
[3]Department of Fishing and Post-Harvest Technology, Chattogram Veterinary and Animal Sciences University, Bangladesh

**Correspondence:** M Shaheed Reza, Department of Fisheries Technology, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh, Fax +880 91 61510, Email msrez@bau.edu.bd

**Received:** January 23, 2023 | **Published:** February 03, 2023

## Introduction

Pond-grown tilapia constitutes the third largest sector of Bangladesh aquaculture. Tilapia farming is very popular among farmers due to its higher demand and better market price compared to other native fish species in the domestic market.[1] Annual production of tilapia stood at 392,095 metric tons in 2020-21, which represented 8.48% of total fish production of the country.[2] The majority of the products are sold and consumed domestically. Since its introduction in Bangladesh from Thailand back in 1954, they have been grown on freshwater as well as brackish water farms in earthen ponds using extensive, improved extensive, semi-intensive, intensive and highly intensive aquaculture systems. Thus, tilapia has made a significant contribution to food production, poverty alleviation and livelihood support in Bangladesh. However, as aquaculture systems become more intensive, undesirable scents or tastes, frequently referred to as 'off-flavor' are developed in fish before harvest.[3] It degrades the product's flavor and palatability.[4]

Off-flavor is primarily linked to the feed of the cultured animal, notably in catfish farms, as well as the environment and/or poor management practices.[5] Many types of off-flavors can be encountered in aquaculture products. Some of the more commonly encountered off-flavors are 'earthy', 'musty', 'woody', 'fishy', 'rancid', 'rotten' and 'petroleum'. The compound(s) responsible for the 'earthy-musty' odor in fish is geosmin, a highly odorous colorless neutral oil with a molecular formula of $C_{12}H_{22}O$,[6,7] or chemically related metabolites synthesized by aquatic microorganisms. Earthy and musty off-flavors have been observed in common carp,[8] catfish,[9] shrimp,[10] and tilapia[10] in aquaculture systems. Some pre-harvest off-flavors are induced by dietary items that are absorbed via the gastrointestinal system.[11] Even though off-flavors caused by diet are uncommon in fish-fed, pond-raised catfish eat a variety of items, some of which may create flavor issues. Other odorous substances produced by naturally occurring aquatic primary producers such as microphytes and microorganisms such as cyanobacteria cause pre-harvest flavor concerns.[12,13] Although, off-flavor does not directly endanger fish health, but it decreases the desirability of fish for processing, which leads to harvesting delays.[14] The off-flavors that arise reduce producer profit margins since processing must be delayed until the off-flavor is gone.

Water quality parameters and chemistry of bottom sediment are the most important factors for tilapia farming practices. As both water and sediment have a potential impact on production, it is necessary to find out the relationship between them. Sediment deposits on the bottom after a certain period of culture in which decomposed organic materials are converted into gases and minerals. Without that, the primary production of the pond might be hampered. But excess of those matters causes deterioration of pond water quality. Fish farmers in this region are not well aware of the effect of water quality deterioration and sediment chemistry which cause off-flavor problems, although Mymensingh and Jashore are the two major fish farming districts in Bangladesh.[15] Thus, measurements of water quality parameters and sediment chemistry are mandatory tasks for them. Recently, consumers claimed that fish produced in different parts of the country possesses an earthy-musty off-flavor.[16] To control and reduce the problem, it is important to identify the source and main factors responsible for the production of off-flavor in Nile tilapia ponds. The present study was, therefore, designed to identify the probable cause(s) of off-flavor in tilapia fish ponds by determining the physico-chemical parameters of water and sediments, the qualitative and quantitative estimation of phytoplankton population including pollutant algae that act as a bioindicator to water quality change.

## Materials and methods

### Study area

The study was carried out during the period of January-June 2013 at the farmer's ponds, which were located at Trishal, Muktagachha and Mymensingh Sadar in Mymensingh district (Figure 1). Three Nile tilapia (*Oreochromis niloticus*) culture ponds from each upazila were randomly selected where the area of each pond was about 800 $m^2$ with a depth of about 1.5-2.0 m. The ponds were rain-fed, and the water depth varied according to rainfall. The pond lacked inlet facilities, but deep tube-wells were used to supply water.

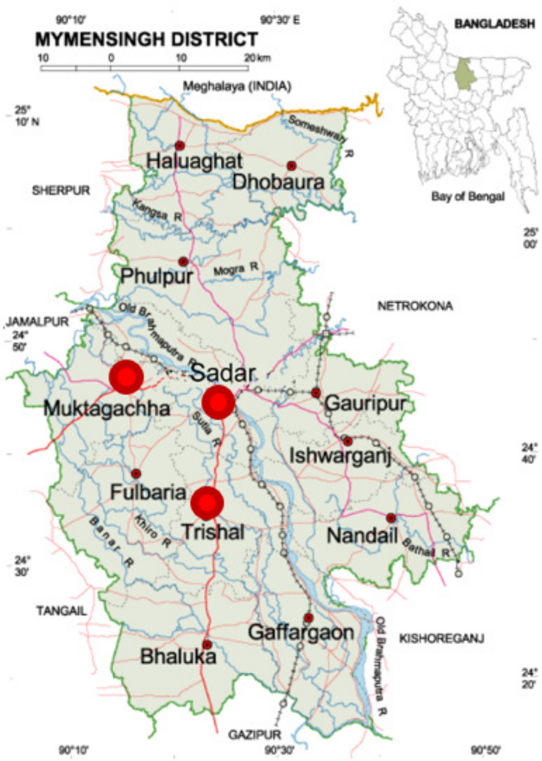


**Figure 1** Map showing the location of the study area at Sadar, Muktagachha and Trishal upazila of Mymensingh district (Source: Banglapedia).

### Water, phytoplankton and sediment sampling

Water samples were collected about 40 cm below the surface from each sampling site using a modified water sampler between 9.00 and 11.00 AM, on each sampling day. About 5 L of surface water was taken from different places in the pond and passed through a fine mesh (25 µm) plankton net. Filtered samples were taken into a measuring cylinder and carefully made up to a standard volume of 50 ml. The plankton samples were kept in 5% buffered formalin and transported to the Pond Dynamics Laboratory, Department of Fisheries Management, and Bangladesh Agricultural University (BAU) within 2h after placing them on ice in an insulated box. As for sediment, samples were collected from each pond with the help of an Ekman Dredge (covering an area of 225 $cm^2$), which was designed to trap normally a sediment column of 5-10 cm depth from the sediment-water interface area. Triplicate sediment samples from different locations were collected from each pond. Each sediment sample was put in a labelled plastic bag and carried to the laboratory.

### Determination of water quality parameters and analysis of phytoplankton

Water quality parameters were recorded (temperature, pH, dissolved oxygen, turbidity) on the spot from at least three places in pond by using a Celsius thermometer. Transparency was measured by Secchi disc and pH was measured by pH meter. Phytoplankton analysis was conducted as described previously.[17,18] From each 50 ml preserved sample, a 1 ml sub-sample was examined by using a Sedge Wick-Rafter cell (S-R cell) and a biological microscope (Model CH40, Olympus Optical Co. Ltd., Tokyo, Japan) with phase contrast facilities. For each pond, the mean number of plankton was recorded and expressed numerically per liter of water. One ml sub-sample from each sample was transferred to the cell and then all planktonic organisms present in 10 squares of the cell chosen randomly were identified and counted. Plankton identification was performed following APHA[19] and Bellinger.[20]

For each pond, the mean number of plankton was recorded and expressed numerically per liter of water. The quantitative estimation of plankton was done by using the following formula for quantitative estimation:[21]

$$N = \frac{A \times 1000 \times C}{V \times F \times L}$$

where, N = Number of plankton cells or units per liter of the original water, A = Total number of plankton counted, C = Volume of final concentrate of the sample in ml, V = Volume of a field in cubic mm, F = Number of fields counted and L = Volume of original water in liter.

For each pond, the mean number of plankton was recorded and expressed numerically per liter of water.

### Calculation of algal genus pollution index (AGPI)

The algal genus pollution index (AGPI) is a useful parameter that shows the organic pollution level of a water body.[22] The pollution index was assigned to each phytoplankton genera (considering >50 cells/ml) to calculate the AGPI for Nile tilapia ponds.

### Collection, treatment and analysis of pond sediment

In the laboratory, the sediment samples were thoroughly mixed up, stretched out on polythene papers and left for air drying at room temperature. The dried sediments were ground finely, sieved through a 0.03 mm meshed brass sieve and kept properly in a labelled polythene bag for chemical analysis in Humboldt Soil Testing Laboratory, Department of Soil Science, BAU, Mymensingh. Sediment pH was measured by a glass electrode pH meter (Model No. REX PHS-25).

## Data Analysis

One-way analysis of variance (ANOVA) was carried out to test the significant variations between the cases. For analysis of relationships, correlation analysis was done to determine the positive / negative relationships between the quality factor of water and sediment of Nile tilapia ponds. Significant differences were determined among treatments at the 5% level ($p<0.05$). Statistical tests were performed by computer-based statistical software SPSS (Statistical Package for Social Science) version 11.5.

## Results

### Water quality parameters of Nile tilapia ponds

Physico-chemical parameters, temperature, pH, and transparency were determined and results are shown in Table 1. The temperature of each case was more or less similar in the different study areas which ranged from 27 to 29°C for pond water. The values were found to be 27.33±0.33, 28.00±0.00 and 27.67±0.67°C in the case of Trishal, Muktagachha and Mymensingh Sadar, respectively. The highest value was recorded in Trishal while the lowest was found in the ponds of Muktagachha upazila. Water pH varied from 6.91 to 7.30 with mean pH of 7.08 ±0.08 in the different study areas of pond water. The mean value of pH were 7.30±0.08, 6.91±0.11 and 7.02±0.06 in Trishal, Muktagachha and Mymensingh Sadar respectively. ANOVA showed that there was a significant difference in the case of water pH among the three upazila. Water transparency varied from 26 to 30 cm with mean transparency of 27.45±0.41 in the different study areas of pond water. The mean value of transparency were 27.67±0.33, 28.00±0.58 and 26.67±0.33 in Trishal, Muktagachha and Mymensingh Sadar respectively. ANOVA showed that there were no significant differences among the areas. The highest value was noted in Muktagachha and the lowest for those for Mymensingh Sadar.

### Sediment parameters of Nile tilapia ponds

The sediment chemistry data, collected from three study areas on pH, organic carbon and organic matter was examined statistically and the observed value were shown in Table 1. The level of soil pH varied from 6.55 to 6.79 with mean pH of 6.71 ±0.04 in the different study areas of pond soil. The mean value of soil pH were 6.76±0.02, 6.68±0.08 and 6.68±0.02 in Trishal, Muktagachha and Mymensingh Sadar respectively. The mean value of soil organic carbon were 1.22±0.04, 1.24±0.14 and 1.40±0.03% in Trishal, Muktagachha and Mymensingh Sadar respectively while the mean organic matter were 2.44±0.05, 2.45±0.04 and 2.51±0.02 in Trishal, Muktagachha and Mymensingh Sadar respectively (Table 1). The highest value was noted in Mymensingh Sadar and the lowest was found in the pond of Trishal.

### Microphyte abundance of Nile tilapia ponds

The abundance of microphytes observed in Nile tilapia ponds of 3 upazila is shown in Figure 2. Considering all pond samples and microphyte groups, Euglonophyceae was nearly double in ponds of Muktagacha (2.81±0.17×$10^4$ cells/L) and Sadar (2.46±0.833×$10^4$ cells/L) compared to those of Trishal (1.720.83×$10^4$ cells/L). Across all ponds, Cyanophyceae were the dominant group at the time of sampling, although their abundance varied significantly across the ponds ($p<0.05$) with the lowest in Trishal (4.84±0.740×$10^4$ cells/L) and highest in Sadar (5.372.24×$10^4$ cells/L). The abundance of Bacillariophyceae, on the other hand, was found to be 2.57±0.396×$10^4$ cells/L, 3.24±0.248×$10^4$ cells/L and 2.90±0.458×$10^4$ cells/L, and those of Chlorophyceae were 2.69±0.750×$10^4$ cells/L, 3.70±0.476×$10^4$ cells/L and 3.53±0.718×$10^4$ cells/L in case of Trishal, Muktagachha and Sadar, respectively. There were no significant differences ($p>0.05$) among the areas when ANOVA was performed. At the genus level, Bacillariophyceae consisted of *Cyclotella*, *Concinodiscus*, *Diatom*, *Navicula*, *Synedra, Nitzschia*; Cyanophyceae- *Anabaena, Mycrocystis, Osoillatoria;* Chlorophyceae- *Spirogyra, Ankistrodesmos, Chlorella, Spirogyra* and Euglenophyceae- *Euglena*, *Phacus* were the dominant genera (Table 2).

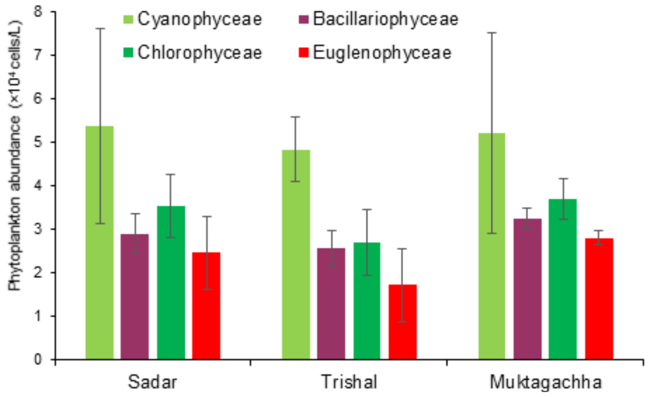


**Figure 2** Phytoplankton assemblages at the Nile tilapia ponds in selected upazila.

### Relationship between water-sediment parameters and AGPI

According to Palmer,[22] several phytoplankton species are unable to tolerate the slightest of pollution while few species may able to persist or even attain greater abundance under the same situation. Based on these criteria, AGPI values of Nile tilapia ponds in Trishal, Muktagaccha and Sadar were calculated and values are shown in Table 3. It was observed that ponds in Muktagaccha upazila fall into the 'high organic pollution' category (AGPI=25.67±1.15) while those in Sadar (18.67±2.52) and Trishal (15.67±1.15) were judged to be in 'probable high organic pollution' category. Our previous study of AGPI values in pangasius catfish ponds in this region revealed that ponds in Trishal were 'high organic pollution' ponds.[18] Khan et al.[23] reported that several contiguous ancient ponds in the Noakhali district of Bangladesh had AGPI values as high as 27, while Das et al.[24] reported high values for wastewater-fed urban fish ponds in Bankura, India. These results together with water-sediment parameters suggest that Nile tilapia ponds has a high supply of nutrients, probably arising from un-used feed and fish faeces deposited at the bottom, resulting in a heightened level of pollution.[18,25]

### Relationship between water-sediment parameters and off-flavor plankton

The correlation matrix of water parameters shows a positive trend of significant relationships between temperature and transparency with phytoplankton genera (Table 4). *Cyclotella, Navicula*, and *Nitzschia* of the Bacillariophyceae group, demonstrated a strong association with transparency, while *Anabaena* of Cyanophyceae and *Ankistrodesmus* of the Chlorophyceae group with water temperature. *Surirella* of Bacillariophyceae groups also showed favorable temperature-phytoplankton interactions. When the correlation of pH, organic C and organic matter content of pond sediment with an abundance of plankton genera were determined, *Aphanizomenon* and *Gomphosphaeria* demonstrated an association with pH, while *Oscillatoria* showed an association with both organic C and organic matter (Table 5). Generally, blue-green algae have been reported to cause off-flavors and cannot be seen with the unaided eye. The cyanobacterial species that have been associated with geosmin-related off-flavor in catfish aquaculture are *Anabaena, Aphanizomenon,* and *Lyngbya.*[26] Also in trout farming systems in the UK, a geosmin-producing species of *Oscillatoria* has been associated with an earthy taint in cultured catfish.

**Table 1** Physico-chemical parameters of water and sediment in Nile tilapia ponds at three upazila in Mymensingh

| Parameter | Location | | | Level of significance |
|---|---|---|---|---|
| | Trishal | Muktagachha | Sadar | |
| Water parameter | | | | |
| Temperature (°C) | 27.33±0.33 | 28.00±0.00 | 27.67±0.67 | NS |
| pH | 7.30±0.08a | 6.91±0.11b | 7.02±0.06ab | * |
| Transparency (cm) | 27.67±0.33 | 28.00±0.58 | 26.67±0.33 | NS |
| Sediment parameter | | | | |
| pH | 6.76 ±0.02a | 6.68±0.08b | 6.68±0.02ab | * |
| Org. Carbon (%) | 1.22±0.04 | 1.24±0.14 | 1.40±0.03 | NS |
| Org. matter (%) | 2.44±0.05 | 2.45±0.04 | 2.51±0.02 | NS |

Mean ± SE, *Values with different superscript indicate a significant difference at 5% significance level based on Tukey's test, NS = Not significant

**Table 2** List of phytoplankton genera observed in the water of Nile tilapia ponds at three upazila in Mymensingh

| Upazila | Pond no. | Phytoplankton genera |
|---|---|---|
| Sadar | 1 | *Actinastrum, Anabaena, Ankistroedesmus, Aphanzomenon, Chorella, Closterium, Cosmarium, Cyclotella, Gomphosphaeria, Hildenbrandia, Nitszchia, Oscillatoria, Scenedesmus, Stichococcus, Surirella, Volvox* |
| | 2 | *Anabaena, Ankistroedesmus, Chlorella, Closterium, Cosmarium, Cyclotella, Hildenbnandia, Nitzchia, Oscelitaria, Pediastrun, Phacus, Pleurococcus, Scenedesmus, Tetraedon, Tetraedon* |
| | 3 | *Anabaena, Chlorella, Closterium, Cosmarium, Hildenbrandia, Nitszchia, Oscillatoria, Pleurococcus, Scenedesmus, Soirulina, Stichococcus, Tetraedon, Trachelomonas* |
| Trishal | 1 | *Anabaena, Ankistroedesmus, Aphanizomenon, Chlorella, Cyclotella, Oscelitaria, Scenedesmus, Surirella, Tetraedon, Volvox* |
| | 2 | *Anabaena, Ankistroedesmus, Chlorella, Cosmarium, Cyclotella, Euglena, Pediastrun, Phacus, Scenedesmus, Soirulina, Surirella, Tetraedon* |
| | 3 | *Anabaena, Ankistroedesmus, Cosmarium, Cyclotella, Cyclotella, Euglena, Hildenbnandia, Oscillatoria, Phacus, Stichococcus, Surirella, Tabellaria* |
| Muktagachha | 1 | *Anabaena, Ankistroedesmus, Aphanizomenon, Chlorella, Closterium, Cosmarium, Cyclotella, Euglena, Flagellaria, Microcystis, Navicula, Nitszchia, Oscillatoria, Pediastrun, Phacus, Spirulina, Stichococcus, Surirella, Volvox* |
| | 2 | *Chlorella, Closterium, Cosmarium, Cyclotella, Euglena, Microcystis, Navicula, Nitszchia, Oscillatoria, Phacus, Scenedesmus, Tetraedon* |
| | 3 | *Anabaena, Ankistroedesmus, Chlorella, Closterium, Cosmarium, Cyclotella, Euglena, Microcystis, Navicula, Nitszchia, Oscillatoria, Phacus, Spirulina, Stichococcus, Tabellaria, Tetraedon* |

**Table 3** Pollution index of algal genera observed in water of Nile tilapia ponds at three upazila in Mymensingh according to Palmer (1969)

| Algal genus | Pollution index | Sadar | | | Trishal | | | Muktagachha | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Pond 1 | Pond 2 | Pond 3 | Pond 1 | Pond 2 | Pond 3 | Pond 1 | Pond 2 | Pond 3 |
| **Cyanophyceae** | | | | | | | | | | |
| -Oscillatoria | 5 | 5 | 5 | 5 | 5 | | 5 | 5 | 5 | 5 |
| **Chlorophyceae** | | | | | | | | | | |
| -Ankistrodesmus | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | | 2 |
| -Chorella | 3 | 3 | 3 | 3 | 3 | 3 | | 3 | 3 | 3 |
| -Closterium | 1 | 1 | 1 | 1 | | | | 1 | 1 | 1 |
| -Scenedesmus | 4 | 4 | 4 | 4 | 4 | 4 | | | 4 | |
| **Bacillariophyceae** | | | | | | | | | | |
| -Nitszchia | 3 | 3 | 3 | 3 | | | | 3 | 3 | 3 |
| -Cyclotella | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 |
| -Navicula | 3 | | | | | | | 3 | 3 | 3 |
| **Euglenophyceae** | | | | | | | | | | |
| -Euglena | 5 | | | | | 5 | 5 | 5 | 5 | 5 |
| -Phacus | 2 | | 2 | | | 2 | 2 | 2 | 2 | 2 |
| Score (Average± SD) | | 18.67±2.52 a | | | 15.67±1.15 a | | | 25.67±1.15 b | | |

*Pollution classification: 0–10=lack of organic pollution; 10–15=moderate pollution; 15–20=probable high organic pollution; 20 or more=high organic pollution; Means within each row sharing different upper case were significantly different ($p<0.05$)

**Table 4** Correlation between water parameters and the phytoplankton abundance

| Phytoplankton Groups | Genus | Water parameters | | |
|---|---|---|---|---|
| | | Temperature (°C) | pH | Transparency (cm) |
| Bacillariophyceae | *Cyclotella* | 0.667 | 0.667 | 0.000* |
| | *Navicula* | 0.667 | 0.667 | 0.000* |
| | *Surirella* | 0.000* | 1 | 0.667 |
| | *Nitzschia* | 0.667 | 0.667 | 0.000* |
| Cyanophyceae | *Anabaena* | 0.000* | 1 | 0.667 |
| Chlorophyceae | *Ankistrodesmus* | 0.000* | 1 | 0.667 |

*Significant correlation at the level of $p<0.05$

**Table 5** Correlation between soil parameters and the phytoplankton abundance

| Phytoplankton Groups | Genus | Soil parameter | | |
|---|---|---|---|---|
| | | pH | Org. Carbon | Org. Matter |
| | *Aphanizomenon* | 0.000* | 1 | 1 |
| Cyanophyceae | *Gomphosphaeria* | 0.000* | 1 | 1 |
| | *Oscillatoria* | 1 | 0.000* | 0.000* |

*Significant correlation at the level of p<0.05

## Discussion

The surrounding environment of the pond is one of the major contributors to off-flavor in fish. During the grow-out stage, these pre-harvest flavors develop. A variety of biological factors in pond water are responsible for the formation of this unpleasant flavor, which makes the fish less appealing to consumers. Physico-chemical factors, in general, have a significant impact on fish health and overall production in aquaculture systems. It also has a close relationship with sediment characteristics. To identify the origins of off-flavor in a tilapia fish pond, it is very important to measure temperature, pH, transparency, odor-producing phytoplankton, and pH, organic C and organic matter in the sediment.

Nile tilapia (*O. niloticus*) is an exotic fish and can tolerate a wide range of environmental factors. The water temperature of experimental ponds ranged from 27 to 29°C during the experiment in the different study areas was found suitable for the growth of plankton and fish. The findings of the present study were more or less similar to the findings of Azim et al.[27] Temperatures of water 28-32°C are ideal for the species, with 34°C being the best temperature for culture.[28] The higher the temperature, the greater the need for oxygen and food, and thus the faster the rate of fish growth.[29] Water pH is considered an important factor in fish culture and is treated as the productivity index of a water body. For pond fish culture the suitable range of pH is 6.5.[30] Swingle[31] stated that pH ranges from 6.5 to 9.0 are suitable for pond fish culture and a pH of more than 9.5 is unsuitable because free $CO_2$ is not available in this situation. Villadolid et al.[32] stated that low pH adversely affected the plankton productivity and subsequent growth of fish. In the present study, the level of pH of water varied from 6.75 to 7.25 with mean pH of 7.08 ± 0.08 in different study areas of pond water. The mean value of pH were 7.30±0.08, 6.91±0.11 and 7.02±0.06 in Trishal, Muktagachha and Sadar respectively, which was more or less similar to the findings of Dewan et al.[33], Azim et al.[34] and Kohinoor et al.[35], those values were also within the suitable range for fish culture. The present results are supported by the pH ranges of 6.5-10.0 for tilapia culture[36] and 7.3-8.3.[37,38] Water transparency grossly indicates the presence or absence of natural food particles of fish as well as the productivity of a water body. Transparency generally measured by the Secchi disk, has an inverse relationship with the abundance of plankton. The abundance of phytoplankton increases in a water body then the Secchi disk reading becomes lower and vice-versa. In the present study, the water transparencies were found to vary from 26 to 30 cm, which was more or less similar to the study of Azim et al.[34], and Kohinoor.[39] The correlation matrix of pond water shows that there was a positive trend of correlation with temperature, which meant if the temperature was reduced, transparency decreased.

The plankton population indicates the productive status of a pond, representing both direct and indirect sources of food for fish. According to Palmer,[22] several microphyte species are unable to withstand even the tiniest amount of pollution, yet a few species may be able to endure or even increase in abundance in the same scenario. Microscopic observations were used to try to identify these assemblages up to the genus level. During the study period, a total of 20 genera of phytoplankton (Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae) were identified. Bacillariophyceae was the most dominant group in terms of the number of genera among phytoplankton in of every three different areas. Among phytoplankton Bacillariophyceae-*Cyclotella*, *Concinodiscus*, Diatom, *Navicula*, *Synedra, Nitzschia*; Cyanophyceae- *Anabaena, Mycrocystis, Osoillatoria;* Chlorophyceae- *Spirogyra, Ankistrodesmos, Chlorella, Spirogyra* and Euglenophyceae- *Euglena* were the dominant species. Mollah and Haque[40] identified 6 genera of Bacillariophyceae, 11 genera of Chlorophyceae, 5 genera of Cyanophyceae and 3 genera of Euglenophyceae in two ponds. Dewan et al.[33] recorded 27 genera of phytoplankton and 9 genera of zooplankton. Kohinoor[39] recorded 34 genera of phytoplankton and 12 genera of zooplankton from the BAU campus, Mymensingh. Cyanophyceae was the most abundant phytoplankton community and Euglonophyceae was the least abundant group in Trishal, Muktagachha and Mymensingh Sadar. In the present study, Cyanophyceae was the dominant group whereas Euglonophyceae was less in number. The mean abundance of Cyanophyceae in different groups was significantly different among the four groups. *Microcystis* spp. are known off-odor producers, *Anabaena* spp. and *Oscillatoria* spp., colonized the ponds, indicating that the latter two Cyanophyceae might have caused off-odor in tilapia raised in an integrated pond-cage culture system. Jüttner and Watson[13] reported that off-odor causing *Oscillatoria spendida*, *O. brevis*, *O. tenuis*, *Lyngbia subtilis* and *L. allogei* can grow in benthic form, thriving on the surface of the side-net and bottom parts of the cage. It is possible in this study that actinomycetes also inhabited the cage bottom, thriving on decomposing feeds and settled particulate materials, which were then eaten by tilapia, hence the presence of Cyanophyceae in tilapia's stomach. Cyanophyceae and other benthic Cyanophyceae thus consumed by tilapia could have contaminated the fish with off-odors since the lining of the gastrointestinal tract is another possible route of uptake of off-odor compounds.[41] Interestingly, when AGPI values of Nile tilapia ponds in Trishal, Muktagaccha and Sadar were calculated, it was observed that ponds in Muktagaccha upazila fall into the 'high organic pollution' category (AGPI=25.67±1.15) while those in Sadar (18.67±2.52) and Trishal (15.67±1.15) were judged to be in 'probable high organic pollution' category.

The value of sediment pH varied from 6.55 to 6.79 with mean of 6.71 ±0.04 in the different study areas of pond soil in Mymensingh district which is more or less similar to Kohinoor.[39] This author measured several soil parameters in the field laboratory of Bangladesh Agricultural University, Mymensingh and recorded that soil pH ranged from 6.5 to 7.5. Hossain et al.[42] reported that the pH value ranged from 6.02 to 7.10 in the old Brahmaputra floodplain soil. In the present study, the mean value of soil pH were 6.76 ±0.02, 6.68±0.08 and 6.68±0.02 in Trishal, Muktagachha and Mymensingh Sadar respectively. ANOVA shows that there were significant differences in soil pH among the areas. The mean value of soil organic carbon (%) were 1.22±0.04, 1.24±0.14 and 1.40±0.03 in Trishal, Muktagachha and Mymensingh Sadar respectively. The highest value was noted in Muktagachha and the lowest result was also found in the pond of Muktagachha. This result was consistent with the result of Begum[43] reporting that organic carbon ranged from 0.80 to 2.86% in different areas. The mean value of soil organic matter (%) were 2.44±0.05, 2.45±0.04 and 2.51±0.02 in Trishal, Muktagachha and Mymensingh Sadar respectively. The highest value was noted in Mymensingh Sadar and the lowest result was found in the pond of Trishal. This is more or less similar to the findings of Karim[44] reporting that the organic content of Ghatail soil ranged from 0.33 to 2.96%. However, it is regarded that organic matter has a close relationship with organic carbon. The correlation matrix of pond soil shows that there was a positive correlation with sediment removal, which meant if sediment removal was reduced, the organic matter content increased. There was also a positive significant correlation with organic carbon and its value is 0.997. Almost all the water quality parameters were within the optimum range with few exceptions. The phytoplankton group Cyanophyceae and the pH of water and soil are these exceptions.

The variations of physico-chemical properties in pond waters were directly linked to phytoplanktonic abundance, which produces off-odor substances in the ponds. We observed a substantial link between temperature and transparency in several planktonic groups such as Bacillariophyceae, Cyanophyceae, and Chlorophyceae. At all ponds at Trishal, Muktagachha, and Sadar, Cyanophyceae was the most dominant planktonic group. The water temperature, which creates off-odor compounds in tilapia fish ponds, was found to have a significant link with the *Anabaena* species of the Cyanophyceae group. Geosmin concentrations were shown to be closely linked with cyanobacterial taxa *Anabaena* which is the source of off-odor in tilapia pond.[45] A significant correlation was also found between the sediments parameters and phytoplanktonic occurrence. The highest number of associations with sediment parameters was found from the group of Cyanophyceae namely *Aphanizomenon, Gomphosphaeria* and *Oscillatoria*. Among the species, *Oscillatoria* showed a significant relationship with organic C and organic matter which is the prime source of off-odors by producing geosmin and MIB. Pimolrat et al.[45] also reported that *Oscillatoria* formed geosmin and MIB in the tilapia ponds. Moreover, due to the short life span of these pollutant algae, the AGPI values also identified those ponds as ‘high organic pollution’ ponds in this region.[24] The development of some of these harmful algae can even be toxic for farmed fishes.[46]

## Conclusion

The physico-chemical and biological parameters observed in Nile tilapia ponds in the Mymensingh district revealed that the large number of phytoplankton genera thrived in high nutrient-load ponds. Also as per Algal Genus Pollution Index (AGPI), it was revealed that ponds in Muktagaccha were ‘probable high organic pollution’ compared to ponds in other locations. It may, therefore, be concluded that water quality parameters and sediment chemistry vary with locations having wider impacts on primary productivity and fish production as well as producing factors for off-odor in tilapia culture. It is recommended that necessary measures such as increased water exchange and artificial oxidation in the pond can be done before fish are harvested to reduce off-flavor in the fish which would assure the profitability of fish farmers, as well as benefit the consumers.

## Acknowledgments

We would like to acknowledge the kind help we received from fish farm owners during the study.

## Conflicts of interest

We declare that the research was conducted in absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

1. Shamsuzzaman MM, Islam MM, Tania NJ, et al. Fisheries resources of Bangladesh: present status and future direction. *Aquac Fish*. 2017;2:145–156.
2. DoF. *Yearbook of Fisheries Statistics of Bangladesh*, 2020-21. Fisheries Resources Survey System (FRSS), Department of Fisheries. Bangladesh: Ministry of Fisheries and Livestock. 2022;38:138p.
3. Tucker CS, Van der Ploeg M. Managing off-flavor problems in pond-raised catfish. *Stoneville, Mississippi: Southern Regional Aquaculture Center*. 1999.
4. Smith JL, Boyer GL, Zimba PV. A review of cyanobacterial odorous and bioactive metabolites: Impacts and management alternatives in aquaculture. *Aquaculture*. 2008;280(1–4):5–20.
5. Schrader KK, Rimando AM. *Off-flavors in aquaculture: An overview*. In: Off-flavors in aquaculture. Rimando, A.M. & Schrader, K.K. (eds), ACS Symposium Series 848. American Chemical Society. 2003;1–12.
6. Gerber NN, Lechevalier HA. Geosmin, an earthy-smelling substance isolated from actinomycetes. *Appl Microbiol*. 1965;13(6):935–938.
7. Yamprayoon J, Noomhorm A. Geosmin and off-flavor in Nile tilapia (*Oreochromis niloticus*). *J Aquat Prod Technol*. 2000;9(2):29–41.
8. Aschner M, Laventer C, Chorin-Kirsch I. Off-flavor in carp from fish ponds in the coastal plain and the Gelid. *Bamidgeh*. 1969;19:23–25.
9. Brown SW, Boyd CD. Off-flavor in channel catfish from commercial ponds. *Trans Am Fish Soc*. 1982;111(3):379–383.
10. Lovell RT, Broce D. Cause of musty flavor in pond-cultured penaeid shrimp. *Aquaculture*. 1985;50:169–174.
11. From J, Horlyck V. Sites of uptake of geosmin, a cause of earthy-flavor in rainbow trout (*Salmo gairdneri*). *Canadian Fish Aquaculture Science*. 1984;41:1224.
12. Izaguirre G, Hwang CJ, Krasner SW, et al. Geosmin and 2-methylisoborneol from cyanobacteria in three water supply systems. *Appl Environ Microbiol*. 1982;43(3):708–714.
13. Jüttner F, Watson SB. Biochemical and ecological control of geosmin and 2-methylisoborneol in source waters. *Appl Environ Microbiol.* 2007;73(14):4395–4406.
14. Tucker CS, Hanson TR, Kingsbury SK. Management of off-flavors in pond-cultured channel catfish with weekly applications of copper sulfate. *North Am J Aquaculture*. 2001;63(2):118–130.
15. Mehar M, Mekkawy W, McDougall C, et al. Tilapia (*Oreochromis niloticus*) trait preferences by women and men farmers in Jessore and Mymensingh districts of Bangladesh. *Aquaculture*. 2023;562:738799.
16. Petersen MA, Alam MA, Rahman MM, et al. Geosmin off-flavour in pond-raised fish in southern Bangladesh and occurrence of potential off-flavour producing organisms. *Aquacult Environ Interact*. 2014;5:107–116.
17. Ferdous J, Reza MS, Khan MNA, et al. Effects of water treatment chemicals on plankton biomass in aquaculture. *J Agrofor Environ*. 2008;2(2):9–13.
18. Rahman A, Khan MNA, Kamal M, et al. Sources of off-flavor in pangasius catfish (*Pangasianodon hypophthalmus*) ponds. *J Aquac Mar Biol*. 2021;10(3):138–144.
19. APHA (American Public Health Association). *Standard Methods for the Examination of Water and Wastewater*. 14th ed. American public health Association, Washington DC, 1992;874p.
20. Bellinger EG. *A key to common algae: Freshwater, estuarine and some coastal species*. Institute of Water and Environmental Management. 1992;138p.

21. Rahman AKA. Tilapia in Bangladesh. In Paper Contributed to the Workshop on Tilapia in Capture and Culture-Enhanced Fisheries in the Indo-Pacific Fishery Commission Countries (ed. by E. A. Balayut), 27–29 June 1991, Bogor, Indonesia. FAO Fisheries Report No. 458, Supplement. FAO, Rome, 1992;pp139–142.

22. Palmer CM. Composite rating of algae tolerating organic pollution. *J Phycol*. 1969;5(1):78–82.

23. Khan NS, Uddin A, Bari JBA, et al. Evaluation the potentiality of ancient ponds by Palmer's algal pollution index, Noakhali, Bangladesh. *Int J Fisheries Aquatic Res*. 2019;4(4):28–31.

24. Das D, Pathak A, Pal S. Diversity of phytoplankton in some domestic wastewater-fed urban fish pond ecosystems of the Chota Nagpur Plateau in Bankura, India. *Appl Water Sci*. 2018;8:84.

25. Da CT. Evaluation of locally available feed resources for striped catfish (Pangasianodon hypophthalmus). *Acta Universitatis Agriculturae Sueciae*. 2012;89.

26. Schrader KK, Blevins WT. Geosmin–producing species of Streptomyces and Lyngbya from aquaculture ponds. *Canadian J Microbiology*. 1993;39(9):834–840.

27. Azim ME, Wahab MA, Van Dam AA, et al. Optimization of stocking ratios of two Indian major carps, rohu (*Labeo rohita* Ham.) and catla (*Catla catla* Ham.) in a periphyton-based aquaculture system. *Aquaculture*. 2001;203:33–49.

28. De Silva SS, Phuong NT. Striped catfish farming in the Mekong Delta, Vietnam: A tumultuous path to a global success. *Rev Aquacult*. 2011;3:45–73.

29. Poxton M. Water quality. In: Lucas SJ, Southgate PC (eds) Aquaculture farming aquatic animals and plants. Black well Publishing Company Ltd, Oxford, 2003;pp47–73

30. Boyd CE, Teichert-Coddington D. Relationship between wind speed and reaeration in small aquaculture ponds. *Aquacultural Engineering*. 1992;11(2):121–131.

31. Swingle HS. Standardization of chemical analysis for water and pond muds. *FAO Fish Rep*. 1967;4(44):397–421.

32. Villadolia DV, Panganiban M, Media TG. The role of pH in pond fertilization. *Indo Pacific Fish Coun Proc*. 1954;5(11):109–111.

33. Dewan D, Wahab MA, Beveridge MCM, et al. Food selection, electivity and dietary overlap among planktivorous Chinese and Indian major carp fry and fingerlings grown in extensively managed, rain-fed ponds in Bangladesh. *Aquaculture Research*. 1991;22(3):277–294.

34. Azim ME, Talukder GS, Wahab MA, et al. Effect of liming and maintenance of total hardness levels on fish production in fertilized ponds. *Progress Agric*. 1995;6(2):7–14.

35. Kohinoor AHM, Islam ML, Wahab MA, et al. Effect of mola (*Amblypharyngodon mola*) (Hamilton) on the growth and production of carbs in polyculture. *Bangladesh J Fish*. 1998;2(2):119–126.

36. Shoko AP, Limbu SM, Mrosso HDJ, et al. A comparison of diurnal dynamics of water quality parameters in Nile tilapia (Oreochromis niloticus, Linnaeus, 1758) monoculture and polyculture with African sharp tooth catfish (*Clarias gariepinus*, Burchell, 1822) in earthen ponds. *Int Aquat Res*. 2014,6:56.

37. Stone NM, Thomforde HK. Understanding your fish pond water analysis report. Cooperative Extension Program, University of Arkansas at Pine Bluff, US Department of Agriculture and county governments cooperating. 2004;1–4.

38. Kamal D, Khan AN, Rahman MA, et al. Study on the physico chemical properties of water of Mouri River, Khulna, Bangladesh. *Pakistan J Biol Sciences*. 2007;10(5):710–717.

39. Kohinoor AHM. Development of culture of technology of three small indigenous fish mola (*Amblypharyngodon mola*), punti (*Puntius sophore*) and chela (*Chela cachihs*) with notes of some aspects of their biology. MS Thesis. Department of Fisheries Management, BAU, Mymensingh. 2000;63pp.

40. Mollah MFA, Haque AKMA. Studies on monthly variations of plankton in relation to the physico-chemical condition of water and bottom soil of two ponds. II: Zooplankton. *Bangladesh J Fish*. 1978;1(2):99–103.

41. Lukassen MB, de Jonge N, Bjerregaard SM, et al. Microbial production of the off-flavor geosmin in tilapia production in Brazilian water reservoirs: Importance of bacteria in the intestine and other fish-associated environments. *Front Microbiol*. 2019;10:2447.

42. Hossain MF, Akter MS, Majumder UK, et al. Effect of tillage practices and nitrogen levels on the physical properties of soil. *Pak J Biol Sci*. 2003;7:1876–1879.

43. Begum M. Effects of fertilizers in different forms and combinations on the pond water quality and productivity under polyculture systems. *PhD Thesis, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh, Bangladesh*. 2003.

44. Karim MR. Properties of some selected soil series of floodplain and hill soils of Bangladesh. MS Thesis, Department of Soil Science, Bangladesh Agricultural University, Mymensingh. 2009;43p.

45. Pimolrat P, Whangchai N, Chitmanat C, et al. Off-flavor Characterization in high nutrient load Tilapia ponds in northern Thailand. 2015;15:273–281.

46. Keawtawee T, Fukami K, Songsangjinda P, et al. Nutrient, phytoplankton and harmful algal blooms in the shrimp culture ponds in Thailand. *Kuroshio Sci*. 2012;5:129–136.