Ammonia Concentrations in Different Aquaculture Holding Tanks

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Abstract

Ammonia was measured in collapsible pond, concrete tank, and earthen pond of the same size, volume and containing same fish biomass cultured under intensive system. Ammonia was also evaluated from a natural pond under extensive culture. Ammonia was measured in the afternoons for 12 weeks using Nessler method. Temperature and *p*H were measured in situ using Portable tester. Unionized ammonia was calculated from total ammonia using spreadsheet computation. Result showed total ammonia ranging from 1.4 to 10 mg/l with highest concentration recorded in collapsible pond and lowest found in natural pond. The unionized ammonia concentrations followed the same pattern with concentrations ranging from 0.002 to 1.13 mg/l. The trend in the total ammonia and unionized ammonia concentrations is: collapsible pond > concrete tank > earthen pond > natural pond. Temperature and *p*H ranged between 29.1 to 35.9 °C and 6.35 to 8.03 respectively, with the highest temperature and *p*H recorded in the collapsible pond and lowest temperature and *p*H found in natural pond. Temperature and *p*H followed seasonal pattern with lowest and highest temperatures and *p*H recorded at the end of rainy season and in the dry season respectively. High unionized ammonia recorded in the collapsible and concrete ponds was from excretion of high protein rich feed, decomposition of uneaten feed, high stocking density, low water exchange rates, water source and the alkaline medium of the systems. Low unionized ammonia in earthen pond and natural pond was attributed to the presence of phytoplankton, high water exchanges, feeding system, low acidity and relatively low temperature. Remediating measures such as the use of biofilters, aeration and reduction in feeding, temperature and *p*H should be employed to reduce the high concentration of unionized ammonia.

Introduction

Most studies have shown that the best feed for optimal fish production in aquaculture is one rich in high amount of protein. The amount of protein in the feed required by different fish species also varies ranging from 30% to 60% (Degani *et al.* 1989, Mustapha *et al.* 2014). The end product of digestion of the protein present in the feed is ammonia which is excreted through the gills and faeces. The amount of ammonia excreted by the fish is dependent on the percentage of protein present in the feed, the amount of feed put in the aquaculture holding tanks and the rate of feeding. Aside this, ammonia also enters the Aquaculture Holding Tanks (AHTs) through bacterial decomposition of organic matter such as uneaten feed or dead algae and aquatic plants diffusing from sediments (Durborow, *et al.* 1997, Hargreaves and Tucker 2004).

Ammonia exists in two forms ionized ammonia, NH_4^+, and unionized ammonia, NH_3, with the sum of the two commonly expressed as total ammonia. According to Arthur *et al.* (1987), the un-ionized ammonia, NH_3 is more toxic in aquatic ecosystem. Ammonia ranks second after oxygen in importance in water quality assessment of AHTs. This is so because ammonia is toxic to

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fish if it accumulates and its toxicity increases as temperature and *p*H of the water increase. According to Durburow *et al.* (1997), for every *p*H increase of one unit, the amount of toxic ammonia increases about 10 times. The problem of toxicity of ammonia to fish is more prevalent in AHTs where intensive aquaculture is practiced. This is because, planktonic algae which can uptake and assimilate ammonia thereby reducing the amount of ammonia in the AHTs are absent. It therefore, becomes imperative to measure ammonia concentrations as part of the routine water quality measurement in AHTs.

The toxic levels for unionized ammonia for short-term exposure usually lie between 0.6 and 2.0 mg/l for pond fish, and sub lethal effects may occur at 0.1 to 0.3 mg/l (Robinette, 1976). Meade (1985) however, reported that different fish species have different tolerance limit for unionized ammonia in culture.

The effects of high concentration of ammonia on fish in AHTs include damage to tissue, gill and kidney, reduction in growth, malfunctioning of the central nervous system, reduction in the oxygen-carrying capacity of the hemoglobin, poor feed conversion, poor growth, reduced disease resistance, susceptibility to infections, decrease fecundity, reduction of population sizes and fish kill. The manifestation of these effects depends on life stage of the fish, the period of exposure and the tolerance of the species.

The objectives of this work were to determine the concentrations of total and unionized ammonia in four different aquaculture holding tanks, their sources and possible management strategies to ameliorate the problem.

Materials and methods

Three different aquaculture holding tanks (AHTs) of the same size and dimension of 4.5 m × 4.5 m × 1m, (20 m^2 × 1m) volume capacity of 20 m^3 (20000 litres) and containing a fish population of 2000 fish and biomass of 500 ± 50 g cultured under intensive system were chosen for the measurement of ammonia concentrations. These AHTs were collapsible pond, concrete tank, and earthen pond where the African catfish *Clarias gariepinus* is cultured in them. Ammonia concentration was also evaluated from a natural pond containing African catfish *Clarias gariepinus* cultured under extensive system. The source of water to the collapsible pond, concrete tank, and earthen pond was the borehole water, while the natural pond had its water source from the rains.

Water was collected from the AHTs with 50 ml plastic water bottle in the afternoons at 1.00 pm weekly for 12 weeks between February and April 2015. Ammonia was measured using Nessler method with the aid of Hanna Multiparameter Bench Photometer for Laboratories Model HI 83200–02. Temperature and *p*H, of the AHTs were also measured in situ at the same time for the same period using Hanna Portable *p*H/EC/TDS/Temp combined waterproof tester Model HI 98129. Triplicate water samples of the AHTs were obtained and measured for ammonia, while *p*H, temperature, electrical conductivity and total dissolved solids measurements were also measured in triplicates in situ.

The unionized ammonia was calculated using spreadsheet developed by American

Fisheries Society to calculate unionized ammonia in freshwater.

Statistical analysis

Duncan Multiple Range Test (DMRT) of statistical analysis system 9.13 (SAS Institute, 2003) was used to analyze the result. Weekly mean of each parameter was compared using ANOVA at $P < 0.05$ to see the significant differences in each parameter among the four AHTs.

Results

The mean results of the total ammonia, unionized ammonia concentrations, *p*H and temperature fluctuations in the four AHTs are presented in Tables 1, 2 and 3 and Figs. 1, 2 and 3. Total ammonia ranged from 1.4 to 10 mg/l with highest concentration recorded in collapsible pond and lowest found in natural pond. The unionized ammonia concentrations followed the same pattern in the AHDs with concentrations ranging from 0.002 to 1.13 mg/l. Both the total ammonia and unionized ammonia were found to be lowest and highest in the first and last week of the research. The trend in the total ammonia and unionized ammonia concentrations in the AHTs is Collapsible pond > Concrete tank > Earthen pond > Natural pond. There was significant difference ($P < 0.05$) in the concentrations of total ammonia, and unionized ammonia among the four AHTs.

There were temperature and *p*H fluctuations in the four AHTs, with temperature and *p*H ranging from 29.1 to 35.9 °C and 6.35 to 8.03 respectively, with the highest temperature and *p*H recorded in the collapsible pond in week 12 and lowest temperature and pH found in natural pond in week 1. There was significant difference ($P < 0.05$) in temperature and *p*H among the four AHDs. The temperature and *p*H followed seasonal pattern with lowest temperatures and *p*H recorded in February corresponding to the end of rainy season and highest temperatures and *p*H recorded in April corresponding to the dry season. Significant differences ($P < 0.05$) were observed in the temperature and pH readings among the four AHTs.

Discussion

Intensive feeding with the high protein rich feed was been carried out in the collapsible pond, concrete tank, and earthen pond, while extensive aquacultural system was used in the natural pond. The highest concentration of ammonia and subsequently unionized ammonia recorded in the collapsible pond which is above the tolerable or safe limit for fish came primarily from digestion and excretion of high protein rich feed which constituted about 60% of the feed. Salin and Williot (1991) reported that ammonia usually represents 60–80 % of the end product of the protein digestion. Decomposition of uneaten feed and organic matter, high stocking density, low water exchange rates as well as the alkaline medium of the collapsible pond were also responsible for the high total ammonia and unionized ammonia concentrations recorded in the system. Temperature and *p*H has been shown to have profound effect on total ammonia and unionized ammonia in the ponds. Increase in temperature and *p*H >8 resulted in high concentrations of the compound in the AHDs. This is in agreement with the reports of other workers such as (Durbrow *et al*. 1997; USEPA 1999, Hargreaves & Tucker, 2004).

Harry and Boyd (1987) had also reported

TABLE 1

Mean total and unionized ammonia concentrations in the four AHTs

Week	*Total ammonia collapsible pond (mg/)*	*Unionized ammonia collapsible pond (mg/l)*	*Total ammonia concrete pond (mg/l)*	*Unionized ammonia concrete pond (mg/l)*	*Total ammonia earthen pond(mg/l)*	*Unionized ammonia earthen pond (mg/l)*	*Total ammonia natural pond (mg/l)*	*Unionized ammonia Natural pond (mg/l)*
1.	10.0 ± 0.0	0.85 ± 0.0	8.0 ± 0.0	0.48 ± 0.0	4.40 ± 0.0	0.01 ± 0.0	1.40 ± 0.0	0.002 ± 0.0
2.	10.0 ± 0.0	0.88 ± 0.0	8.0 ± 0.0	0.49 ± 0.0	4.50 ± 0.0	0.02 ± 0.0	1.50 ± 0.0	0.003 ± 0.0
3.	10.0 ± 0.0	0.89 ± 0.0	8 .0± 0.0	0.53 ± 0.0	4.50 ± 0.0	0.02 ± 0.0	1.53 ± 0.0	0.003 ± 0.0
4.	10.0 ± 0.0	0.92 ± 0.0	8.0 ± 0.0	0.54 ± 0.0	4.70 ± 0.0	0.03 ± 0.0	1.58 ± 0.0	0.004 ± 0.0
5.	10.0 ± 0.0	0.93 ± 0.0	8.0 ± 0.0	0.56 ± 0.0	4.70 ± 0.0	0.03 ± 0.0	1.60 ± 0.0	0.005 ± 0.0
6.	10.0 ± 0.0	0.95 ± 0.0	8.0 ± 0.0	0.72 ± 0.0	4.80 ± 0.0	0.05 ± 0.0	1.61 ± 0.0	0.008 ± 0.0
7.	10.0 ± 0.0	0.98 ± 0.0	8.0 ± 0.0	0.76 ± 0.0	4.80 ± 0.0	0.06 ± 0.0	2.18 ± 0.0	0.028 ± 0.0
8.	10.0 ± 0.0	1.01 ± 0.0	8.0 ± 0.0	0.77 ± 0.0	5.00 ± 0.0	0.19 ± 0.0	2.20 ± 0.0	0.030 ± 0.0
9.	10.0 ± 0.0	1.02 ± 0.0	8.0 ± 0.0	0.78 ± 0.0	5.10 ± 0.0	0.20 ± 0.0	2.44 ± 0.0	0.03 ± 0.0
10.	10.0 ± 0.0	1.07 ± 0.0	8.0 ± 0.0	0.80 ± 0.0	5.20 ± 0.0	0.36 ± 0.0	2.58 ± 0.0	0.065 ± 0.0
11.	10.0 ± 0.0	1.12 ± 0.0	8.0 ± 0.0	0.83 ± 0.0	5.50 ± 0.0	0.38 ± 0.0	2.96 ± 0.0	0.095 ± 0.0
12.	10.0 ± 0.0	1.13 ± 0.0	8.0± 0.0	0.84 ± 0.0	5.50 ± 0.0	0.42 ± 0.0	2.98 ± 0.0	0.099 ± 0.0

TABLE 2

Mean temperature measurements in the four AHTs

Week	*Collapsible Pond °C*	*Concrete Pond °C*	*Earthen Pond °C*	*Natural Pond °C*
1.	31.9 ± 0.1	30.9 ± 0.1	29.4 ± 0.1	29.1 ± 0.1
2.	32.5 ± 0.1	31.1 ± 0.1	30.1 ± 0.1	29.8 ± 0.1
3.	32.7 ± 0.1	31.6 ± 0.1	30.5 ± 0.1	30.1 ± 0.1
4.	32.8 ± 0.1	31.9 ± 0.1	31.1 ± 0.1	30.7 ± 0.1
5.	33.1 ± 0.1	32.5 ± 0.1	31.7 ± 0.1	31.3 ± 0.1
6.	33.4 ± 0.1	33.1 ± 0.1	32.3 ± 0.1	31.8 ± 0.1
7.	33.8 ± 0.1	33.7 ± 0.1	32.7 ± 0.1	32.2 ± 0.1
8.	34.3 ± 0.1	34.0 ± 0.1	33.6 ± 0.1	33.0 ± 0.1
9.	34.6 ± 0.1	34.1 ± 0.1	33.8 ± 0.1	33.3 ± 0.1
10.	35.0 ± 0.1	34.6 ± 0.1	34.0 ± 0.1	33.9 ± 0.1
11.	35.7 ± 0.1	34.8 ± 0.1	34.2 ± 0.1	34.1 ± 0.1
12.	35.9 ± 0.1	35.0 ± 0.1	34.8 ± 0.1	34.5 ± 0.1

TABLE 3
Mean pH measurements in the four AHTs

Week	*Collapsible Pond*	*Concrete Pond*	*Earthen Pond*	*Natural Pond*
1.	8.01 ± 0.2	7.88 ± 0.2	6.75 ± 0.2	6.35 ± 0.2
2.	8.01 ± 0.2	7.88 ± 0.2	6.82 ± 0.2	6.45 ± 0.2
3.	8.01 ± 0.2	7.90 ± 0.2	6.85 ± 0.2	6.50 ± 0.2
4.	8.02 ± 0.2	7.90 ± 0.2	6.90 ± 0.2	6.55 ± 0.2
5.	8.02 ± 0.2	7.90 ± 0.2	6.90 ± 0.2	6.60 ± 0.2
6.	8.02 ± 0.2	8.00 ± 0.2	7.10 ± 0.2	6.92 ± 0.2
7.	8.02 ± 0.2	8.01 ± 0.2	7.15 ± 0.2	7.15 ± 0.2
8.	8.02 ± 0.2	8.01 ± 0.2	7.60 ± 0.2	7.15 ± 0.2
9.	8.02 ± 0.2	8.01 ± 0.2	7.60 ± 0.2	7.20 ± 0.2
10.	8.03 ± 0.2	8.01 ± 0.2	7.85 ± 0.2	7.40 ± 0.2
11.	8.03 ± 0.2	8.02 ± 0.2	7.85 ± 0.2	7.50 ± 0.2
12.	8.03 ± 0.2	8.02 ± 0.2	7.88 ± 0.2	7.50 ± 0.2

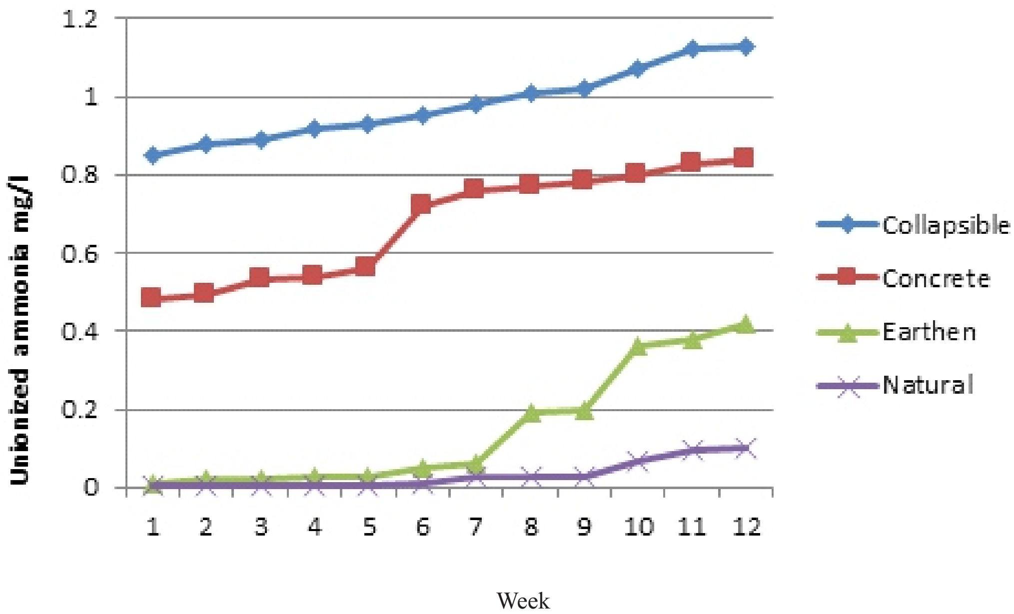

Fig. 1. Mean unionized ammonia in the tanks

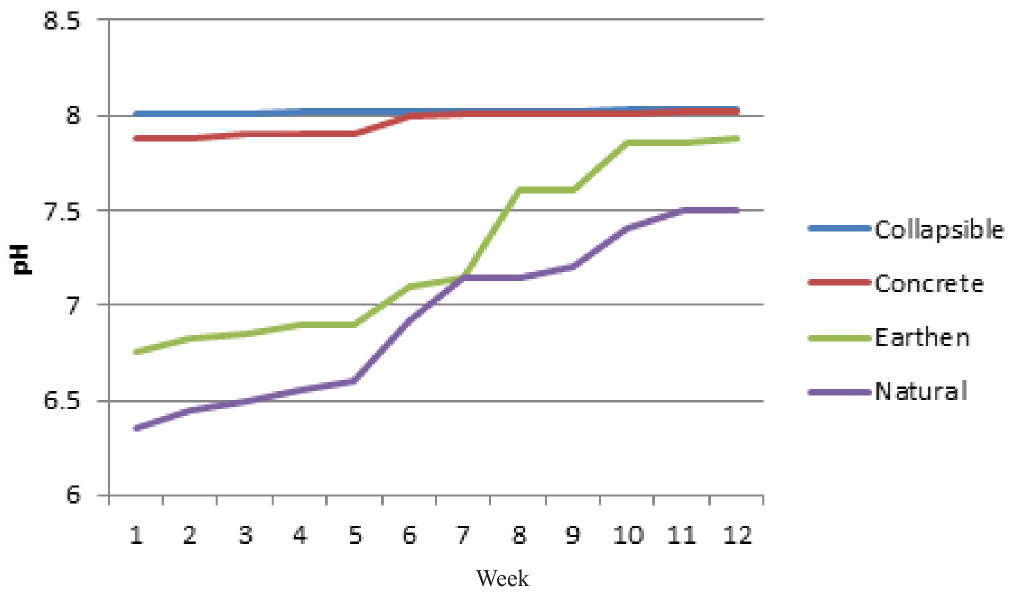

Fig. 2. Mean *p*H in the tanks

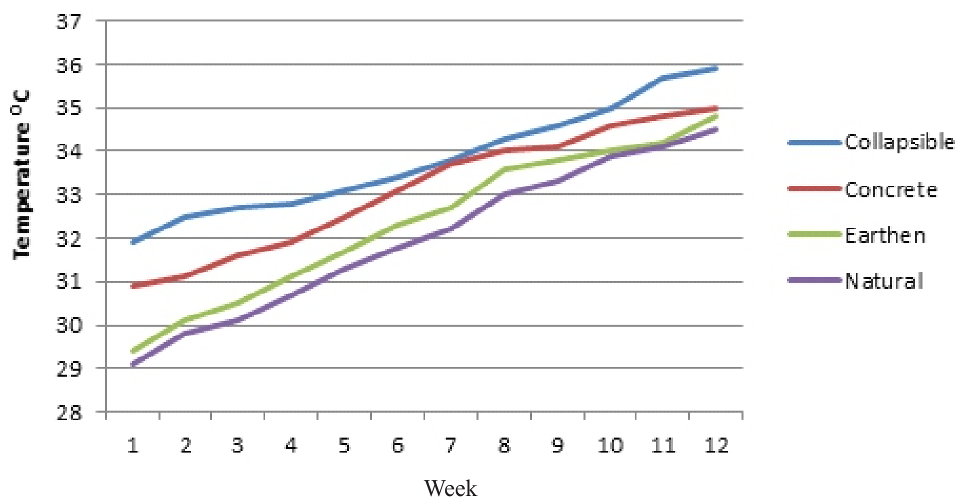

Fig. 3. Mean temperature in the tanks

that ammonia concentration increases rapidly when water exchanges are low, while Francis-Floyd *et al.* (1996) linked decay of uneaten food and organic matter to high ammonia concentrations in ponds. Another source of ammonia in the pond could be the borehole water used for the fish production which could contain some amount of ammonia. The season, especially dry season of tropical climate tend to have effect on total ammonia and unionized ammonia concentrations in the ponds with the highest concentration recorded when temperature is high. The highest temperature recorded in collapsible pond was due to the material used for making the pond which readily absorbs heat.

The increase concentration of ammonia and unionized ammonia observed in concrete pond which was above the safe or tolerable limit for fish production was also due to reasons adduced for the high concentration found in collapsible pond. The difference in concentrations of ammonia and unionized ammonia between the two was due to slight disparity in temperature, relatively high water exchange and very low alkalinity of the medium.

The low level of total ammonia and unionized ammonia in earthen pond was attributed to the presence of phytoplanktons in the pond which uptake, assimilate and produce carbon dioxide from photosynthesis and respiration. This scenario has been reported by Wurts (2003) and Durbrow *et al.* (1997). Relative low temperature as compared to the collapsible and concrete ponds and low *p*H which was < 8, as well as high water exchanges were responsible for the low level of total and unionized ammonia in the earthen pond. The concentration of ammonia and unionized ammonia recorded in the earthen pond is safe for fish habitation and production.

Extensive system of feeding where no high protein rich feed were introduced, presence of algae and other phytoplankton, high water exchanges, low acidity of the pond (*p*H < 8), low temperature as compared to the other AHDs and low decomposition in the natural pond were some of the reasons why the system had the least amount of total and unionized ammonia concentrations among the four AHDs. The concentration of ammonia and unionized ammonia observed in the natural pond is very good and even well below the recommended safe limit for fish habitation and production in aquaculture.

In the collapsible and concrete ponds where intensive system of fish culture brought increase in the total ammonia and unionized ammonia concentrations, it is desirable to put in remediating measures to control and ameliorate the effects of the high total and unionized ammonia concentrations in order to have successful fish productions in these systems. Some of these measures include using biofilters in the ponds, aerating the ponds for high water exchange; reduce feeding of the fish, reducing temperature and pH in the ponds especially during the dry season.

The probable effects of high concentration of ammonia on the fish species reared in collapsible and concrete tanks include damage to tissue, gill and kidney, reduction in growth (Rodrigues *et al*. 2013), malfunctioning of the central nervous system (Randal and Tsui, 2002), reduction in the oxygen-carrying capacity of the hemoglobin, poor feed conversion, poor growth, reduced disease resistance, susceptibility to infections, decrease fecundity, reduction of population sizes and fish kill (EPA 1999). The manifestation of these effects will depend on the life stage of the fish, the period of exposure and the tolerance of the species to ammonia concentrations.

Conclusion

Total and unionized ammonia concentrations in the collapsible and concrete ponds exceeded the tolerable limit for fish production. Thus, for enhanced fish production in the two systems, measures which will reduce total and unionized ammonia concentrations should be employed. Regular measurement of total ammonia should be carried out and the best time for the measurement should be in the afternoon when the temperature and pH of the water is highest.

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