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Microbial Assessment of Some Selected Fish Ponds in Awka, Anambra State: Comparative Study and Modelling

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Abstract

Selected Fish ponds in Awka Metropolis were analyzed for the presence of microorganisms. The presence of these organisms may be an indication of contamination of the fish pond which may be pathogenic to the fishes and humans as well through the consumption of these fishes. Their presence in fish intended for human consumption may constitute a potential danger thus causing diseases. All the samples were positive for bacterial and fungal growth. The total heterotrophic bacteria counts range from 3.3×103cfu/ml to 4.2×103 cfu/ml, the coliform counts range from 2.6×103cfu/ml to 3.7×103 cfu/ml. These microbial counts were statistically modelled using probability distribution. The bacterial isolates include *Staphylococcus aureus* (30%), *Escheichia coli* (40%), *Klebsiella* spp (10%) and *Salmonella* spp (10%). The molds are *Aspergillus* spp (75%) and *Mucor* spp (25%) while the yeasts are *Saccharomyces* spp (33.33%) and *Candida albicans* (66.67%). The result showed that there was no fish pond water sample that was free from bacteria and fungi contamination, an indication that the entire fish pond water samples were contaminated by microorganisms. Also, it was shown in this study that the gamma distribution provided best fit for the microbial count. It can be concluded from this study that there is need to monitor the quality of wastewater from fish ponds before being discharged into the environment since such wastewater harbours potential pathogens.

Keywords

Microbial Assessment, Fish Ponds, Microorganism, Microbial Count, Probability Distribution

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1. Introduction

Fish is an important part of the human diet, it serves as a source of cheap protein and is a rich source of minerals and nutrients for the sustenance of man [1], noted as the most reliable source of protein to various populations of individuals worldwide. Fish is preferred as a protein source as it can be consumed by all cadres of individuals regardless of their religious beliefs and nutritional preferences, a classic example being the Muslims who do not eat pork meat; this has resulted in the preference of fish over other sources of protein such as pork or red meat [2]. According to FAO (2002) [1], fish is a most reliable source of protein to various populations of individuals worldwide. The increased daily demand for fish and its products in Nigeria has led to increased fish production by both public and private sectors [3].

Fish ponds can be very different from one another depending on their location and climates. Temperatures can vary from moderately warm in the summer to completely freezing over in the winter. Usually ponds have a pH of approximately 7 but can be as low as 6 and as high as 10 depending on many

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factors. Large populations of algae and other aquatic plants can change a pond's pH depending on the time of day. These organisms take up more dissolved carbon dioxide through photosynthesis during the day and emit carbon dioxide during the night though respiration. Higher amounts of carbon dioxide help maintain pH at around 7 by dissociating into bicarbonate ions. With a large organic demand for carbon dioxide, the bicarbonate ion concentration and thus buffering capacity of the pond can be significantly reduced and the risk of a rapid pH change increased [4]. In aquaculture, there is a wide range of systems, from small ponds to large-scale commercial systems. Successful pond fish farming depends on the water physical, chemical and biological characteristics and on the species nutrition management. In pond fish farming all these factors are inter-related and require careful and constant monitoring to avoid contamination and/or degradation of the aquaculture environment [5, 6]. The aim of fish farmers is to produce high quality fish with high yields and economic value in order to attain profit maximization. This involves different methods of increasing the yield, for example, by fertilizing the ponds which have low natural food productivity with organic manure in order to naturally stimulate the food production [7]. This significant growth in fish consumption has enhanced people's diets around the world through diversified and nutritious food

Microorganisms have a very important function within the aquatic organisms because they participate in the nutrients conversion and these may affect the disease control of various water quality parameters such as pH, dissolved oxygen and ammonia. The bacteriological quality of water plays a vital role in the diseases spreading in farmed fish, fact that must be well known by the fish farmers who should understand the importance of maintaining a proper bacteriological water quality of the pond. In aquaculture bacterial pathogens represent an important cause of fish infections and mortalities [8]. Furthermore, the fish bacterial flora is the main source of occupational diseases affecting the fish handlers and some bacteria from the fish ponds, such as Enterobacteriaceae, are directly related to factors like: suspended matter, dissolved oxygen, organic detritus and nutrient salt. These may show positive or negative correlations in the management of the commercial systems. As a result, the bacterial number in the pond ecosystem is directly linked to the pond management [9].

In Awka Metropolis, the rearing of African catfish (*Clariasgariepinus*) is helping in the provision of food and its usefulness cannot be over-emphasized as the demand for fish is expanding rapidly throughout the world [10]. There is an intricate relationship between the fish, their biotic and abiotic environments and changes in one component may reflect and affect the other [11]. Pond water or water used in intensive fish rearing contain many microorganisms which could be pathogenic or opportunistic pathogen to fish, human, and planktons [12]. These contaminating microorganisms have been attributed to questionable water quality which can be traced to the water sources and high stocking densities [13]. Water sources for earthen ponds are usually untreated surface water runoffs from streams, rivers, lakes, stored waters while underground water source is being utilized for most concrete ponds. The aim of this study is to assess the microbiological quality of fish ponds in Awka metropolis and the specific objectives are to; assess the microbial load of local fish pond in Awka metropolis, isolate the microorganisms (Bacteria and fungi) associated with fish ponds, identify the isolated bacteria and fungi, and to determine a suitable statistical probability distribution for modelling total bacterial and total coliform count based on specific criterion values.

2. Materials and Methods

2.1. Sample Collection

Using a sterile container, ten (10) fish pond water samples were randomly collected from various fish ponds within Awka metropolis and the samples were named based on the area collected from. The collected samples were transported immediately to Microbiology Laboratory of Nnamdi Azikiwe University, Awka for analysis.

2.2. Sample Preparation

The work bench was disinfected using 90% alcohol. The media used in this work are Nutrient Agar, MacConkey Agar and Sabouraud dextrose agar. The media were all prepared in accordance to manufacturer's instructions. 9ml of sterile distilled water was pipetted into each test tube (5 test tubes). 1 ml of fish pond water sample was added to the first tube containing 9ml of sterile distilled water and homogenised. 1ml was drawn out from the first test tube to the second test tube and gradually repeated until the fifth test tube. 1ml from the fifth test tube was discarded and this was done to all the fish pond water samples. The dilutions of 10^{-3} and 10^{-5} folds of the fish pond water samples were inoculated on sterile Petri dishes and molten Nutrient Agar, MacConkey Agar and Sabouroud dextrose agar were poured on the samples, homogenized and allowed to gel. The plates were incubated at room temperature for 24 hours for bacteria and 72 hours for fungi. The samples were labelled appropriately as samples A-J.

2.3. Microbial Counts

The fish pond water samples were assessed for Total Bacterial Counts (TBC) and Total Coliform Counts (TCC). Dilutions were selected so that total number of colonies on a

plate was between 30 and 300 for TBC, while for TCC, dilutions were selected for plate counts between 15 and 150. Calculation of colony forming unit (CFU) per ml for the bacteria was based on the formula:

$$\frac{CFU}{ML} = \frac{Number\ of\ colonies\ X\ dilution\ factor}{Volume\ of\ sample\ inoculated} \quad (1)$$

2.3.1. Total Bacterial Count

One millilitre of the diluted water sample from the chosen dilution was placed on the petri dish and molten nutrient agar was poured on it and homogenized. It was allowed to solidify for 15 min and incubated for 24 hours at 37°C. Finally, the counts were made using digital colony counter.

2.3.2. Total Coliform Count

The pour-plate technique was used. One milliliter aliquot of each of the diluted samples (10^3) was plated out on sterile MacConkey agar (MA). Incubation was at room temperature for forty-eight hours in an inverted position. Discrete colonies of coliform bacteria that developed were counted, sub-cultured on sterile MA plates and later stored on sterile MA slants for characterization and identification.

2.4. Isolation and Characterization of Bacterial Isolates

After colony counting, 10 colonies were randomly picked from the plates for further characterization. The bacterial colonies that developed on the nutrient agar plates were sub-cultured by streaking on a freshly prepared nutrient agar plates until pure colonies were obtained accordingly to the conventional procedure [14].

2.5. Identification of Bacterial Isolates

The pure bacterial isolates were identified on the basis of their morphological and biochemical characteristics. The observed tests include color, shape, elevation, consistency, margin, catalase test, MRVP (Methyl Red-Voges Proskauer test), fermentation of sugars, citrate utilization, indole, hydrolysis of starch and sensitivity tests. In order to determine the identity of bacteria isolates, results were compared with standard references of Bergey's Manual of Determinative Bacteriology.

2.6. Biochemical Tests

The biochemical reactions test such as Gram's straining, catalase test, coagulase test, sugar fermentation test, urease test, citrate utilization test, oxidase test, methyl-red test, voges-proskauer test, indole test and motility test was performed to identify the isolated bacteria. While several commercial systems for identifying bacteria are available, these are often difficult to obtain or too expensive to use in developing countries.

2.7. Isolation of Fungi

The diluted water samples were also pour-plated into sterile sabourand dextrose agar plates under strict aseptic condition. The agar plates were allowed to set and incubated at 280C for 7 days. Fungi growth observed were subcultured into freshly prepared sabourand dextrose agar plates using a sterile inoculating needle and incubated as above in order to obtain pure cultures of the various fungi isolates. These subcultures were carried out about five times in order to obtain pure fungi culture.

The fungi were identified using the lactophenol cotton-blue staining technique and viewed under x40 objective. A wet mount of the organisms on the clean glass slide was done; part of the fungal mass was teased off, placed on the slide and wetted with the stain. The preparation was then covered with a cover slip and viewed under a microscope with the x40 objective lens. The results obtained were recorded, and compared with the colonial morphologies of already characterized fungi in the fungal atlas for confirmation of the identities of the isolates.

2.8. Statistical Analysis

Total bacterial count (TBC) and Total coliform count (TCC) were modelled using some standard theoretical probability distribution. Selection criterion used in this study includes, Alkaike Information Criterion, Bayesian Information Criterion, Negative Log-likelihood, etc. These criterion employed to determine the distribution of provides best fit for the data set as shown in [15-17]. Relevant descriptive statistics and statistical plots were shown.

2.8.1. Weibull Distribution

The probability density function of a Weibull random variable is;

$$f(x) = \frac{\lambda}{\alpha}\left(\frac{x}{\alpha}\right)^{\lambda-1} e^{-(x/\alpha)^{\lambda}} \quad (2)$$

And the corresponding cumulative distribution function for the Weibull distribution is;

$$F(x) = 1 - e^{-(x/\alpha)^{\lambda}} \quad (3)$$

$Where x \geq 0, \alpha, \lambda > 0$

2.8.2. Exponential Distribution

The probability density function of an Exponential random variable is;

$$f(x) = \beta e^{-\beta x} \quad (4)$$

And the corresponding cumulative distribution function for the Weibull distribution is;

$$F(x) = 1 - e^{-\beta x} \quad (5)$$

$Where x \geq 0, \beta > 0$

2.8.3. Gamma Distribution

A random variable X that is gamma-distributed with shape α and rate β is denoted as;

$$X \sim \Gamma(\alpha, \beta) \equiv Gamma(\alpha, \beta)$$

The corresponding probability density function, and cumulative distribution function in the shape-rate parametrization is given as;

$$f(x; \alpha, \beta) = \frac{\beta^{\alpha}}{\Gamma(\alpha)} x^{\alpha-1} e^{-\beta x} \quad (6)$$

$$F(x; \alpha, \beta) = \frac{1}{\Gamma(\alpha)} \gamma(\alpha, \beta x) \quad (7)$$

$Where x \geq 0, \alpha, \beta > 0$

2.9. Selection Criterion

The Akaike's information criterion, developed by [18] under the name of "an information criterion" (AIC) and proposed in [19], is a measure of the goodness of fit of an estimated statistical model. The AIC is not a test of the model in the sense of hypothesis testing; rather it is a test between models - a tool for model selection. Given a data set, several competing models may be ranked according to their AIC, with the one having the lowest AIC being the best. From the AIC value one may infer that e.g. the top three models are in a tie and the rest are far worse, but it would be arbitrary to assign a value above which a given model is "rejected". In the general case, the AIC is computed as;

$$AIC = -2 \log L + 2K \quad (8)$$

Where k is the number of parameters in the statistical model and L is the maximized value of the likelihood function for the estimated model.

The Bayesian information criterion (BIC) or Schwarz Criterion is a criterion for model selection among a class of parametric models with different numbers of parameters. Choosing a model to optimize BIC is a form of regularization. It is very closely related to AIC. In BIC, the penalty for additional parameters is stronger than that of the AIC. The formula for the BIC is given as;

$$BIC = k \log n - 2 \log L(\hat{\theta}) \quad (9)$$

3. Results and Discussion

Table 1. Total Plate Counts of fish pond samples.

Sample	Total Bacterial Count (CFU/ml) (10^3)	Total Coliform Count (CFU/ml) (10^3)
A	3.6	3.2
B	3.3	3.0
C	3.5	3.3
D	3.4	2.6
E	3.7	3.0
F	4.0	3.0
G	4.2	3.7
H	3.6	3.4
I	3.5	3.0
J	4.2	3.5

Table 2. Morphological/Cultural Characteristics of Bacterial Isolates.

Isolate	Colour	Shape	Margin	Elevation
A	Cream	Irregular	Entire	Flat
B	Cream	Circular	Entire	Flat
C	Pale Cream	Circular	Entire	Flat
D	Cream	Irregular	Entire	Flat
E	Cream	Circular	Entire	Flat
F	Cream	Circular	Entire	Flat
G	Cream	Circular	Entire	Flat
H	Pale Cream	Circular	Entire	Flat
I	Cream	Circular	Entire	Flat
J	Cream	Irregular	Entire	Flat

Table 3. Morphological/Cultural Characteristics of Yeast Isolates.

Isolate	Colour	Shape	Margin	Elevation
K	Cream	irregular	Lobate	Flat
L	Cream	Irregular	Lobate	Flat
M	Cream	Circular	Entire	Flat

Table 4. Morphological/Cultural Characteristics of Mold Isolates.

Isolate	Colour (top view)	Colour (Under view)	Texture
N	Pale Brown	White	Powdery
O	Pale Brown	White	Powdery
P	Greyish	White	Fluffy
Q	Pale Brown	White	Fluffy

Table 5. Biochemical Characteristics of the Bacterial isolates.

Isolate	Gram Reaction	Motility	Catalase	Coagulase	Indole	M.R	Citrate	Oxidase	V.P	Urease	Sugar Fermentation					Probable Organism
											Glc	Mal	Lac	Suc	Gal	
A	Gram positive cocci	-	+	+	-	+	+	-	+	+	A+	A+	A+	A+	A+	*Staphylococcus aureus*
B	Gram negative rods	-	+	-	-	-	+	-	-	+	AG	AG	AG	AG	AG	*Klebsiella*spp
C	Gram negative rods	+	+	-	+	+	-	-	-	-	AG	AG	AG	AG	AG	*E. coli*
D	Gram positive cocci	-	+	+	-	+	+	-	+	+	A+	A+	A+	A+	A+	*Staphylococcus aureus*

Isolate	Gram Reaction	Motility	Catalase	Coagulase	Indole	M.R	Citrate	Oxidase	V.P	Urease	Sugar Fermentation					Probable Organism
											Glc	Mal	Lac	Suc	Gal	
E	Gram negative rods	+	+	-	+	+	-	-	-	-	AG	AG	AG	AG	AG	*E. coli*
F	Gram negative rods	+	+	-	+	+	-	-	-	-	AG	AG	AG	AG	AG	*E. coli*
G	Gram negative rods	+	+	-	-	+	-	-	-	-	AG	AG	-	-	-	*Salmonella* spp
H	Gram negative rods	-	+	-	-	-	+	-	-	+	AG	AG	AG	AG	AG	*Klebsiella* spp
I	Gram negative rods	+	+	-	+	+	-	-	-	-	AG	AG	AG	AG	AG	*E. coli*
J	Gram positive cocci	-	+	+	-	+	+	-	+	+	A+	A+	A+	A+	A+	*Staphylococcus aureus*

Key: + = Positive, - = Negative, GLC = Glucose, LAC = Lactose, MAL = Maltose, FRC = Fructose, SUC = Sucrose

Table 6. Microscopic and biochemical Characteristics of Yeast Isolates.

Isolate	Gram Staining	Germ Tube Test	Sugar Fermentation					Probable Organism
			Gluc	Malt	Lact	Sucr	Fruc	
K	+	+	+	+	-	-	-	*Candida* albicans
L	+	+	+	+	-	-	-	*Candida albicans*
M	+	-	+	+	-	+	+	*Saccharomyces* spp

Key: + = Positive, - = Negative, GLC = Glucose, LAC = Lactose, MAL = Maltose, FRC = Fructose, SUC =

Table 7. Microscopic Characteristics of Mold isolates.

Isolate	Hyphae	Type of Asexual Spores	Presence of Rhizoid/ Stolon	Probable Organism
N	Septate	Conidiospores	Stolon	*Aspergillus* spp
O	Septate	Conidiospores	Stolon	*Aspergillus* spp
P	Aseptate	Sporangiospores	Rhizoid	*Mucor* spp
Q	Septate	Conidiospores	Stolon	*Aspergillus* spp

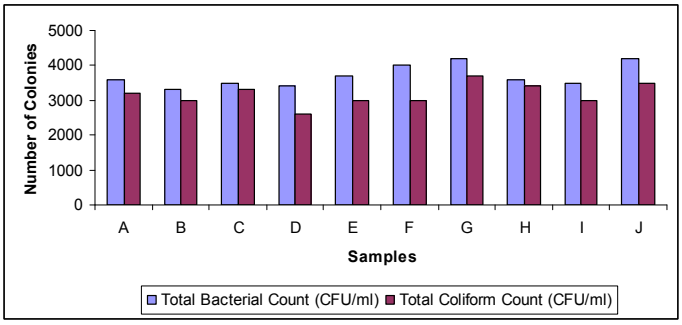

Figure 1. Total Bacterial and Coliform Count.

Table 8. Descriptive Statistics on the Total Bacterial Count.

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Skewness	Kurtosis	Variance
3.300	3.500	3.600	3.700	3.925	4.200	0.5829315	1.926211	0.1044444

We observe that the data on bacteria count is positively skewed with variance of 0.1044444

Table 9. MLE's of parameters on the Total Bacteria Count.

Model	Estimates		
	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\lambda}$
Exponential	-	0.2702703	
Gamma	149.68979	40.45652	-
Weibull	12.319797	-	3.8747329

For all competing distributions using the bacteria count dataset, Table 10 shows parameter estimate.

Table 10. Log-likelihood, AIC, and BIC values of models fitted for the Total Bacteria Count.

Model	Negative LL	AIC	BIC
Exponential	23.08333	48.16666	48.46924
Gamma	2.207707	8.415414	9.020584
Weibull	3.160523	10.32105	10.92622

From Table 10, the gamma has the highest negative log-likelihood values and the lowest AIC, and BIC values; hence it is chosen as the most appropriate model amongst the considered distributions, implying that it provides a better fit

than the exponential distribution and the Weibull distribution in modeling bacteria count for this study.

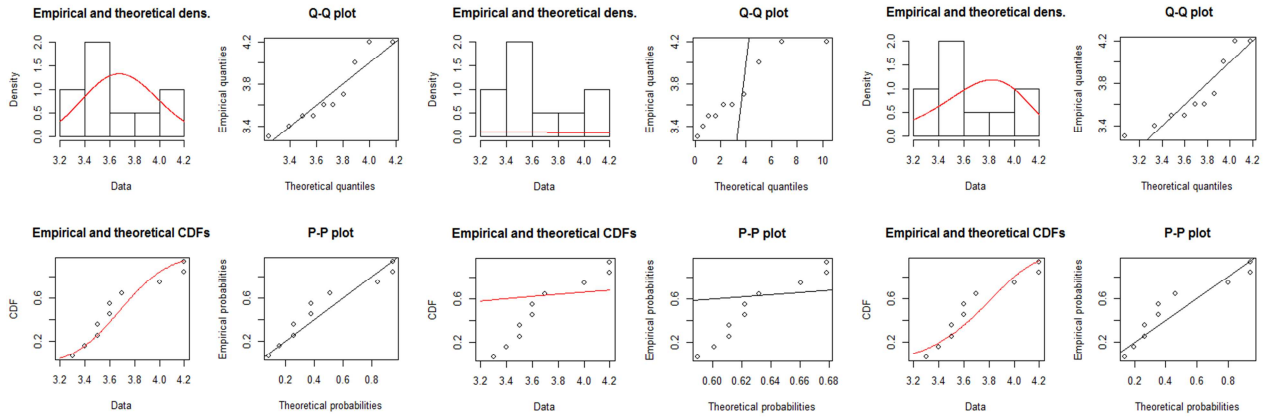

Figure 2. The fitted Gamma, Exponential, and Weibull distribution respectively for the Total Bacterial Count.

Table 11. Descriptive Statistics on the Total Coliform Count.

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Skewness	Kurtosis	Variance
2.600	3.000	3.100	3.170	3.375	3.700	-0.02085412	2.49753	0.1001111

We observe that the data on bacteria count is positively skewed with variance of 0.1044444

Table 12. MLE's of parameters on the Total Coliform Count.

Model	Estimates		
	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\lambda}$
Exponential	-	0.3154574	
Gamma	100.27061	34.78578	-
Weibull	11.583034	-	3.306835

For all competing distributions using the coliform count dataset, Table 13 shows parameter estimate.

Table 13. Negative Log-likelihood, AIC, and BIC values of models fitted for the Total Coliform Count.

Model	Negative LL	AIC	BIC
Exponential	21.53732	45.07463	45.37722
Gamma	2.181635	8.36327	8.96844
Weibull	2.417529	8.835057	9.0440228

From Table 13, the gamma has the highest negative log-likelihood values and the lowest AIC, and BIC values; hence it is chosen as the most appropriate model amongst the considered distributions, implying that it provides a better fit than the exponential distribution and the Weibull distribution in modeling coliform count for this study.

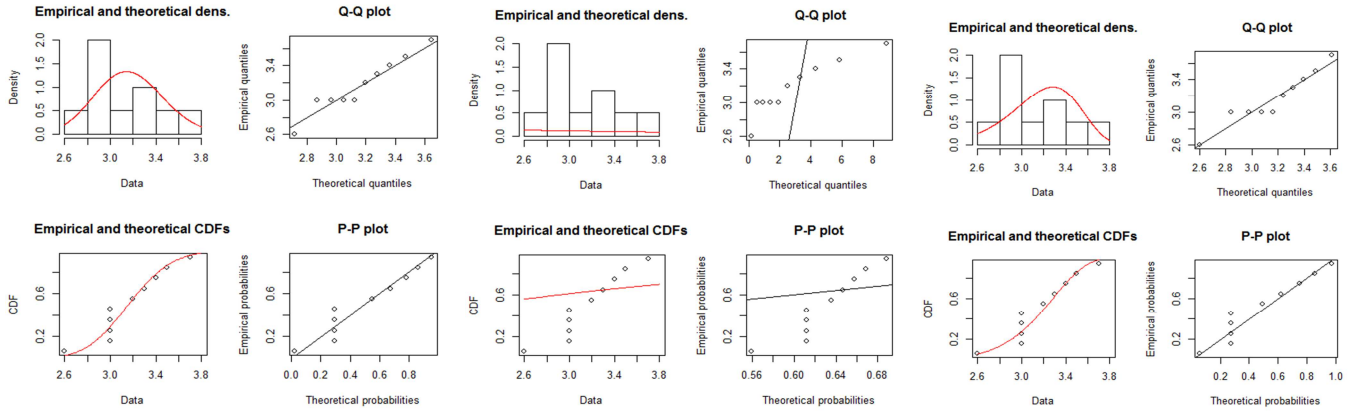

Figure 3. The fitted Gamma, Exponential, and Weibull distribution respectively for the Total Coliform Count.

Generally, the microbial count did not vary significantly between the ponds (Table 1). Total heterotrophic bacteria count was highest in pond G and J (4.2 x10^{3}cfu/ml) and lowest in pond B (3.3x10^3 cfu/ml)). The result of the microbiological characteristics showed that Gram negative bacteria were dominant in the bacteria isolated from the ponds. Bacteriological analysis of the pond water samples showed four different genera (Table 5) which are *Escherichia coli, Staphylococcus* sp., *Salmonella* sp., and *Klebsiella* sp. The fungal genera isolated are presented in tables 6 and 7 and

they include *Aspergillus* sp., *Mucor* sp., *Candida albicans* and *Saccharomyces* sp. The coliforms isolated were an indication of the contamination of the pond water with fecal materials which may result to the presence of pathogenic organisms. The fecal material may be as a result of fertilization of the ponds with animal manure which is discharged directly into the fish ponds, or excreted by the fish into the ponds or through runoff [20]. The diverse groups of bacteria isolated from these ponds are in line with the report of [21] who worked on pond water suggesting that allochthonous bacteria from feed added to the ponds are the principal source of bacteria of health importance and [22] who reported similar organisms in the microbiological study of El-quanter fish pond. The presenceof pathogenic microorganisms especially *E. coli, Salmonella, Shigella* and *Vibrio* can lead to the transmission of water borne diseases such as, Typhoid fever, Cholera, food poisoning and gastroenteritis [23] on consumption of improperly cooked fish cultivated in these ponds. *E. coli* was the most dominant organism occurring in both concrete and earthen ponds. The presence of *E. coli* in water or food indicates the possible presence of causative agents of many gastro intestinal diseases [7]. *Pseudomonas*, *Proteus*, *Staphylococcus* species have been implicated in food poisoning [24]. *Aeromonas* species were also predominantly present in both ponds. This organism is one of the most opportunistic pathogen for fresh water fish and the main etiological agents in disease outbreak were several mortalities were recorded [25]. Fungal infection is an important economic and limiting factor in intensive fish production. The observation is consistent with the work of [26] who noted that *Aspergillus* and *Mucor* species are believed to penetrate into the environment through dead plants materials and remains for long period of time. Similarly, [27] cited *Aspergillus* sp. as the most abundant fungi during his study on the microbiological and physiochemical analysis of fish pond water in Ugheli Delta state Nigeria. In contrast to the present result, [28] reported *Cladosporium* sp. as the dominant fungi specie. The occurrence of *Fusarium* sp. and *Mucor* sp. in earthen ponds could be attributed to the fact that the earthen ponds was a more conducive environment for their growth and proliferation due to the presence of soil and plants in the earthen ponds. The isolation of *Aspergillus* spp, *Rhizopus* spp in this study is in agreement with the work of [29] that identified them as mycoflora in decreasing sequential order in market bush mango. The presence of *A. flavus* in these samples might probably makes the consumption of a fish hazardous to man according to the findings of [30] which was also identified in the study. The works of [31]) also identified *A. niger* and *A. flavus* which pose potential health hazard to its numerous consumers which was also isolated in this study. The isolation of *A. niger A. terreus, A. flavus* as contaminants of fish and fish water is in agreement with similar findings earlier by [32] and [33]. Isolation of molds belonging to the following genera *Aspergillus spp,* and *mucor* spp in this study agreed with the findings reported by [34] and [35] which was also identified the same organism from fish. The yeast *Saccharomyces cerevisiae* is one cell organism which produces alcohol from the fermentation and break of sugar to alcohol. Yeast is an available feed ingredient for fish feed process besides it is easy to find [36]. In nature yeast are found in all habitats [37]. The isolation of the *Saccharomyces cerevisiae* (yeast) in the study is in agreement with the findings of [36] that most yeast has been used as aqua feeds. The isolation of yeast from the study is in agreement with the findings of [38] and [39], that yeast are used for supplementation based diets with deficient amino acids was shown to have beneficial effect on fish growth. [38] noted that the growth of bacterial population is the outcome at the influx of washed organic matter in the water intake source from the surrounding areas. It is natural that the incoming nutrient load finds its way firstto the surface, thereby encouraging bacterial proliferation. [6] also observed the presence of coliforms in the water of all six studied fish farms in Brazil. As shown in the present and other works, aquaculture environment is characterised by fluctuations of physicochemical parameters and bacteriological indicators caused nutrient loads, trophic changes, climatic characteristics, and therefore special attention should be paid to the frequency of limnological and sanitary aspects of the water.

4. Conclusion/Recommendation

The result showed that there was no fish pond water sample that was free from bacteria and fungi, an indication that the entire fish pond water samples were contaminated by microorganisms. The contamination could have arisen from different sources which include air, source of water and fish feeds could have been responsible for the introduction of these organisms into the fish pond. Also, it was shown in this study that the gamma distribution provided best fit for the microbial count. It is hereby recommended that microbiological analysis of wastewater from fish ponds be regularly conducted to check for signs of possible infections

The ministry of agriculture should ensure that the fish farmers are supplied with healthy fry for their stock. Good quality water such as borehole should be used in the fish pond rather than water from questionable sources such as river, stream, and surface-runoff. The fish feeds should be sourced from reputable manufacturers. Water in the fish pond should be changed completely at regular intervals. Concrete ponds should be used for rearing of fish rather than earthen

ponds. Waste water should be treated either by physical methods which involve filtration through slow sand filters, rapid sand filters, sand-beds or chemical methods such as addition of disinfectants eg chlorine before final disposal into surrounding drains.

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