ISSN: 2347-5129
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.352
IJFAS 2015; 3(1): 43-47

www.fisheriesjournal.com
Received: 20-06-2015
Accepted: 24-07-2015

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Effect of chemical accumulation and temperature on fish production in Lebanese water ponds

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Abstract
This work focuses on the evaluation of water quality in four different constructed Tilapia fish breeding wetlands in Lebanon under several conditions. The complete analysis of water included the organoleptic evaluation, physical parameters, chemical and bacteriological characteristics. It has been found that water in created water ponds for fish production does not correspond to international water quality standards. The results reveal that the study area faces bacteriological pollution level in this area is above the criterion specified for aquaculture. It was found out that the water quality was not good and the phosphate and nitrite contents in the water were above standard level and thus needs to be treated continuously. While the impact of this study on the environment is of crucial importance to the local farmers, the whole region will benefit from the provided model in order to obtain good water with all the biological nutrients, at the same without any excess of non-desirable compounds.

Keywords: Water ponds, Wetlands, Water quality, Fish species, Agriculture.

1. Introduction
Aquaculture is the interesting aim of promoting production to meet the increasing demand for aquatic products. Large-scale commercial tilapia farming is limited to the culture of three species: *Oreochromis aureus, Oreochromis mossambica, and Oreochromis niloticus*. The latter species has aquaculture potential and is known as the Nile Tilapia; this species is by far the most commonly grown tilapia species in fish farming [1, 2]. Farming strategies for tilapia range from the simple to the very complex. Simple strategies are characterized by little control over water quality and food supply and by low fish yields [3]. Water is one of the most essential factors for civilization. Water quality degradation by various sources becomes an important issue around the world. Usage of more land for agricultural purposes, soil salinization, increase in the use of agricultural Fertilizers have become problems threatening natural water source. As greater controls over water quality and fish nutrition are imposed, production costs and fish yields are increased. Across this spectrum, there is a progression from low to high management intensity [4]. In traditional pond culture of Tilapia, proper environmental conditions are maintained by balancing the input of feed with the natural primary production capacity of the pond [5]. Commercial intensive aquaculture systems are built and they are managed similarly in today's farms. Critical environmental parameters include the concentrations of dissolved oxygen, un-ionized ammonia nitrogen, nitrite nitrogen, suspended solids and carbon dioxide in the water [6, 7]. It should be noted that many of the physical properties and chemical and biological characteristics are interrelated. For example, temperature, which is a physical property, affects both the amount of gases dissolved in water and the biological activity in this water [8]. The measurement of turbidity is based on comparison of the intensity of light scattered by a sample to the light scattered by a reference suspension under the same conditions [9]. The results of turbidity measurements are reported in nephelometric turbidity units (NTU). The concentration of nitrites is a result of the nitrification process as well as some fish wastes. The nitrogen gas formation is due to the reduction of nitrites [10]. Phosphorus exists in ponds as phosphates or hydrogen phosphates. These compounds constitute an important parameter that should be identified in order to enhance fish production [11]. Water quality in the intensive ponds depends on the water entering, the biological processes within, and the water leaving the ponds [12]. Within all intensive ponds provided good growth conditions, with tilapia biomass having influence on water quality [13]. The tilapia biomass increased in organic nitrogen compounds exclusively in paddle-wheel aerated ponds and reduction of the organic nitrogen load is done through a more efficient

removal of food particles [14, 15, 16]. Draining sediments accumulated on the bottom will prevent the occurrence of anaerobic conditions that allows denitrification and phosphorus liberation [17]. The only case to consider in this paper is that the water exchange system in which the amount of pollutants increases is a function of time, season and location of the farm. All measurements were done during the four seasons since in Lebanon the seasons are very different during the year [18]. All basins are used for tilapia fish production that are commercialized and used in situ for food service in restaurants [19, 20]. None of the owners is satisfied by the current yields and the analysis of water was of crucial need. The aim of this present investigation is to analyze water samples from four Lebanon's locations in order to determine the concentration of chemical and biological pollutants.

2. Material and methods

2.1 Chemicals

Chemicals and reagents used for the study of analysis work were purchased from Sigma-Aldrich Co. (St. Louis, MO, USA), while other chemicals, kits and glassware were purchased from Merck (Beirut, Lebanon).

2.2 Samples and analysis

Water samples were taken from four Lebanon's locations which are “Halim's farm” in the suburb of Beirut, “Al Khodar's farm” in Tripoli, “Baacir's farm” in Mount Lebanon and “Al Chawi's farm” in the Bekaa valley and they were investigated in order to determine the concentration of the chemical and biological pollutants. These water samples were collected in sterile bottles and transported to the laboratory, where bacterial analysis was done within 4 hours of collection. Temperature, color, transparency and solid suspension were measured before bacteria analysis began. Assays and measurements were performed according to French standards [21]. The characteristic parameters of the tropic level are: total phosphates expressed in mgP /1 (NF T 90-023); - Nitrates (NF T 90-012), nitrite (NF T90-013) and ammonia nitrogen (NF T 90-015), expressed in mgN / 1. Total coliforms, fecal streptococci, and Pseudomonas aeruginosa were measured using spread plate and membrane filtration methods as described in Standard Methods for the Examination of Water and Waste water [22]. Protein, lipids and ash were determined according to the standard AOAC method [23].

2.3 Statistical analysis

All experiments were carried out in triplicate. Data were expressed as means ± S.D. Differences were evaluated by one-way analysis of variance (ANOVA) test completed by Dunnett’s test. Differences were considered significant at $^{**}p < 0.01$. The concentration was calculated by nonlinear regression curve with the use of Prism Graphpad Prism version 4.0 for Windows [GraphPad Software, San Diego, CA, USA (www.graphpad.com)].

3. Results and discussion

Although the temperature for all locations was within the acceptable range, the values of solid suspension change between locations and thus the transparency and color are changed (Table I). Halim’s location had the maximum activity since it has the lowest transparency and consequently the highest solid suspension and color. The second main step was to investigate the bacteriological aspect of these farms (Table II). The amounts of total coliforms show an increase from winter to summer which is primarily due to the effect of increasing temperature on the bacteria proliferation, which decrease after summer. Such behavior is shown with the amount of pseudomonas with a more visible change, whereas the amount of streptococci remains almost steady during all the seasons. Once again, Halim’s farm shows to be the most active and interesting farm to be studied. All the bacteriological data show a significant amount of change in the number of bacteria throughout the year. We focused especially on the work of such bacteria for the production of nitrites which could then be reduced. For that reason, the concentration of nitrites was studied in the four locations and it was indicated that the values were directly related to bacteria concentration. Halim’s farm showed the highest concentration amount of nitrites due to the highest bacterial activity in the basin. We shall therefore continue our investigation on this farm and extend it to the others since the results were identically to Halim’s farm. Additional measurements of total nitrogen and ammonia (Tables III and IV) confirmed this investigation. The principle sources of nitrogen compounds are (1) the nitrogenous compounds from plants and from animal origin, (2) sodium nitrate and (3) atmospheric nitrogen. All ponds are located in agriculture areas where the water and soil are polluted by the above mentioned sources of nitrogen. This can be observed in the highest values for total nitrogen during the summer season after the dry summer season and before any rain that may eliminate some of these pollutants. In fact all the values, compared to the French regulations and standards AFNOR show the high decomposition of organic compounds in the basin. Moreover the concentration of phosphates leads to confirm this study (Table V). Phosphorus is essential to the growth of algae and other biological organisms. There is presently much interest in controlling the amount of phosphorus compounds that enter surface waters. The most common forms of phosphorus that are found include orthophosphates, polyphosphate and organic phosphates. Although they are available for biological metabolism, they should not trespass standards above which it will become an overcharge which needs to be eliminated. Once the major properties of water have been investigated, it is worth to consider the productive qualities as well as the morphological parameters concerning Tilapia fish (Table VI and VII). First live weights were measured during five months and the results were not satisfying because these species may easily have 20% more live weight when raised in suitable farms. This is confirmed by all the morphological measurements that have been done: The comparison of fish bodies with international standards shows the fact that the excess of pollutants decreases the quality of fish production.

Table 1: Physical properties of matter in fish farms.

Parameters	Normal	Fish farms			
		Baacir	Al Chawi	Halim	El Khodar
Winter 2014					
Temperature,°C	18-27	17.3 ± 1.94	17.0 ± 1.70	16.9 ± 1.44	17.4 ± 1.08
Colour	3°	3.3 ± 0.03	3.5 ± 0.90	4.1 ± 0.67	3.1 ± 0.48
Transparency	1500 MM	500 ± 4.88	596 ± 3.51	440 ± 4.12	495 ± 7.82
Solid suspension	100 mgl^{-1}	244 ± 11.72	278 ± 7.14	347 ± 15.29	299 ± 11.8
Spring 2014					
Temperature,°C	18-27	25.7 ± 1.03	25.5 ± 0.97	25.0 ± 1.32	25.3 ± 1.00
Colour	3°	4.0 ± 0.04	4.1 ± 0.02	4.3 ± 0.02	4.1 ± 0.07
Transparency	1500 MM	734 ± 6.92	696 ± 5.11	621 ± 8.12	700 ± 0.07
Solid suspension	100 mgl^{-1}	176 ± 13.31	173 ± 8.39	199 ± 14.71	168 ± 7.9
Summer 2014					
Temperature,°C	18-27	26.6 ± 2.07	26.0 ± 1.19	26.8 ± 1.93	27.5 ± 2.00
Colour	3°	4.3 ± 0.07	4.0 ± 0.18	4.7 ± 0.27	4.2 ± 0.13
Transparency	1500 MM	514 ± 18.11	521 ± 21.33	417 ± 24.37	500 ± 14.4
Solid suspension	100 mgl^{-1}	193 ± 14.51	205 ± 11.82	278 ± 20.00	211 ± 13.7
Autumn 2014					
Temperature,°C	18-27	18.5 ± 1.03	18.0 ± 0.96	18.7 ± 1.09	18.1 ± 0.98
Colour	3°	3.0 ± 0.01	3.2 ± 0.09	3.9 ± 0.12	2.9 ± 0.11
Transparency	1500 MM	512 ± 3.84	521 ± 4.08	434 ± 5.03	528 ± 3.09
Solid suspension	100 mgl^{-1}	201 ± 11.94	288 ± 19.8	345 ± 23.3	246 ± 18.5

Table 2: Bacteriological content of water in fish farms.

Parameters	Colony forming unit/100mL	Fish farms			
		Baacir	Al-Chaui	Halim	Al Khodar
Winter 2014					
Total Coliforms	*CFU*	2.3 ± 0.11	1.1 ± 0.09	2.7 ± 0.07	1.3 ± 0.08
Streptococci	*CFU*	1.0 ± 0.01	1.3 ± 0.04	2.0 ± 0.01	2.2 ± 0.02
Pseudomonas	*CFU*	14.5 ± 1.34	9.6 ± 0.84	14.4 ± 0.72	10.3 ± 1.00
Spring 2014					
Total Coliforms	*CFU*	3.2 ± 0.24	3.0 ± 0.11	3.4 ± 0.28	3.1 ± 0.30
Streptococci	*CFU*	0.9 ± 0.03	1.3 ± 0.01	2.0 ± 0.02	2.3 ± 0.03
Pseudomonas	*CFU*	7.2 ± 0.24	6.1 ± 0.19	9.5 ± 0.11	3.8 ± 0.32
Summer 2014					
Total Coliforms	*CFU*	5.2 ± 0.44	6.1 ± 0.40	7.0 ± 0.47	6.9 ± 0.54
Streptococci	*CFU*	2.0 ± 0.21	1.2 ± 0.19	2.5 ± 0.22	1.9 ± 0.09
Pseudomonas	*CFU*	9.5 ± 0.42	11.0 ± 1.10	14.9 ± 1.00	12.1 ± 0.94
Autumn 2014					
Total Coliforms	*CFU*	3.3 ± 0.22	2.8 ± 0.17	3.9 ± 0.28	3.7 ± 0.28
Streptococci	*CFU*	1.8 ± 0.14	1.2 ± 0.17	2.1 ± 0.11	1.3 ± 0.09
Pseudomonas	*CFU*	5.4 ± 0.34	5.0 ± 0.22	7.5 ± 0.17	7.5 ± 0.47

Table 3: Amount of total nitrogen in water, Halim fish farm.

Concentration mgl^{-1}	Season			
	Winter 2014	Spring 2014	Summer 2014	Autumn 2014
Morning				
Inlet	1.055 ± 0.0910	4.960 ± 0.2350	5.790 ± 0.3870	1.114 ± 0.0925
Afternoon				
Inlet	1.190 ± 0.1070	4.670 ± 0.2750	6.040 ± 0.4250	1.252 ± 0.0910
Evening				
Inlet	1.268 ± 0.0963	5.450 ± 0.3740	5.600 ± 0.3720	1.070 ± 0.0324

Table 4: Ammonia concentration in water, Halim fish farm.

Concentration mgl^{-1}	Season			
	Winter 2014	Spring 2014	Summer 2014	Autumn 2014
Morning				
Inlet	2.58 ± 0.173	1.41 ± 0.092	2.88 ± 0.178	1.51 ± 0.095
Afternoon				
Inlet	2.88 ± 0.095	1.45 ± 0.075	2.98 ± 0.011	1.47 ± 0.029
Evening				
Inlet	2.89 ± 0.010	1.32 ± 0.024	3.13 ± 0.311	1.60 ± 0.095

Table 5: Amount of total phosphates in water, Halim fish farm.

Concentration mgl^{-1}	Season			
	Winter 2014	Spring 2014	Summer 2014	Autumn 2014
Morning				
Inlet	296.70 ± 23.701	385.33 ± 20.074	410.64 ± 32.284	316.19 ± 21.692
Afternoon				
Inlet	299.74 ± 17.317	324.24 ± 22.634	411.93 ± 20.711	366.77 ± 27.321
Evening				
Inlet	312.12 ± 21.074	401.75 ± 31.278	424.01 ± 37.156	383.57 ± 20.963

Table 6: Productive qualities of total fish.

Parameters	Values, grams
Live weight In the beginning	 10.0012 ± 0.3012
In 15 days	17.0085 ± 0.9150
In 60 days	62.2420 ± 2.0210
In 120 days	135.8015 ± 7.1025
At the end (150 days)	167.1062 ± 10.1601

Table 7: Morphological parameters of growth and development of fish.

Measurement	% of growth
Body length	69.21 ± 3.27
Maximum weight	24.60 ± 1.04
Post dorsal	41.57 ± 2.96
Tail stem length	20.00 ± 1.08
Spinal fin length	12.83 ± 0.96
Anal fin length	14.31 ± 1.01
Anal fin height	8.75 ± 0.32
Length of chest fin	12.07 ± 1.12
Length of belly fin	16.00 ± 0.27
Length of a head	12.02 ± 1.11

4. Conclusions

Water, especially in the summer season in Lebanese fish farms is subjected to many factors that may increase its ability to enhance bacterial activity. The differences in values from morning until evening depend upon chemical concentrations resulting from decomposition of organic compounds as well as minerals already existing in water source. The four Tilapia fish farms investigated show an excess of some parameters and chemicals that affect directly the quality of fish production. Baacir, Al Chawi, Halim and Al Khodar farms show similar variations of solid suspension and nitrites, and the higher values were obtained by the study on Halima's farm. This phenomenon affected the morphological parameters of fish where, according to standards, the quality of Tilapia fish decreases function of time passed in such farms and the need to exchange water becomes crucial. Moreover, exchanging water causes an important variation of temperature, this certainly leads to a disturbance in fish environment and it will look like that fish are moved from a basin to another. Furthermore the exchange of water eliminates most of phytoplanktons and microorganisms that are biological food for fish. Finally it is concluded that these farms are in an urgent need to obtain good water with all the biological nutrients, at the same temperature, without any excess of non-desirable compounds.

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