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Assessment of surface and groundwater quality for use in aquaculture in parts of northern Nigeria

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Abstract

In recent times, fish farming (aquaculture) has become a major source of income and a substitute for beef in many homes all over Nigeria because a kilogram of fish is cheaper especially the so call ice-fish compare to same kilogram of beef. As a result, many people have embraced fish farming and while some aquaculturist have recorded loss, only few got it right especially at the initial stage of the fish farming business. Some fish farm had average fish weighing a kilogram while others have average weighing less than half a kilogram due to many factors ranging from contamination of pond water from pile up of feeding stuff at bottom of the pond to the use of ground or surface water whose constituents or chemically controlled parameters have adverse effects on harvest in aquaculture. This study was carried out to ascertain the worth or not of surface and groundwater from parts of northern Nigeria for fish farming. Thirty seven surface and groundwater samples were collected during the peak of dry season and analyzed for physicochemical parameter, major and minor elements that can have adverse effects on fish farming using model V-2000 multi-analyte photometer, atomic absorption spectrophotometer, pH and conductivity meter. Some of the measurements were carried out in-situ, while others were carried out in the laboratory. Most of the samples (92%) analyzed indicate that they can be used efficiently for aquaculture, only few were observed to have some adverse effects on the intended use and these include pH, salinity, sodium contents and residual sodium carbonate which are closely related to the pH of water samples analyzed. It can be summarized that the studied water samples are generally good for aquaculture.

Keywords: Aquaculture, Adverse Effect, Physicochemical Parameter, Hydrochemistry

Introduction

Fish and other organisms with aquacultural potential survives only in water, therefore, it is no surprise that professional fish culturists state that "Water quality determines to a great extent the success or failure of a fish cultural operation" (Piper et al. 1982). Because water is an essential requirement for fish farming, it is only a properly prepared and planed aquaculturist that fully understands or put into consideration the quality and quantity of water available for the proposed enterprise that is assured of success. An experienced aquaculturist can judge whether the water is suitable for the proposed enterprise.

Location 1 falls between latitude 10° 10'N to 10° 31N' and longitude 11° 35'E to 12° 05'E covering an area of about 2250 km^2 (fig. 1). Geologically, it comprises of the tertiary basalt of the Biu plateau on the north, sedimentary sequence of Bryel and Zange grabens on the north-west and south-east respectively and is underlain by the crystalline basement of north-eastern Nigeria. Location 2 (fig.1) covered an area of about 159km^2 and falls within latitude 10° 34'to 10° 48N' and longitude 13° 17' to 13° 33E'. The area is covered by the Basement Complex rocks which consist of migmatites-gneiss, quartzite and other granitoids rocks of Precambrian age. The migmatites-gneiss rocks have undergone a weathering process that leads to the formation of laterite, gravels, sand, clays and silt materials. The granitoids mainly contain feldspars, biotites, and occasionally microcline. The granitoids, also called Older Granites, are products of the Pan African Orogeny (about 500 my ago). Water supply in the study area is mainly from a few hand-dug wells and an inadequate number of boreholes. Groundwater occur mainly in the weathered/fractured basement, and poor infiltration of surface water during the rainy season results in shallow water table conditions because of the low permeability characteristic of these rocks (Nur and Kujir, 2006.). A total of twelve water samples were collected from this area. Location 3 falls within

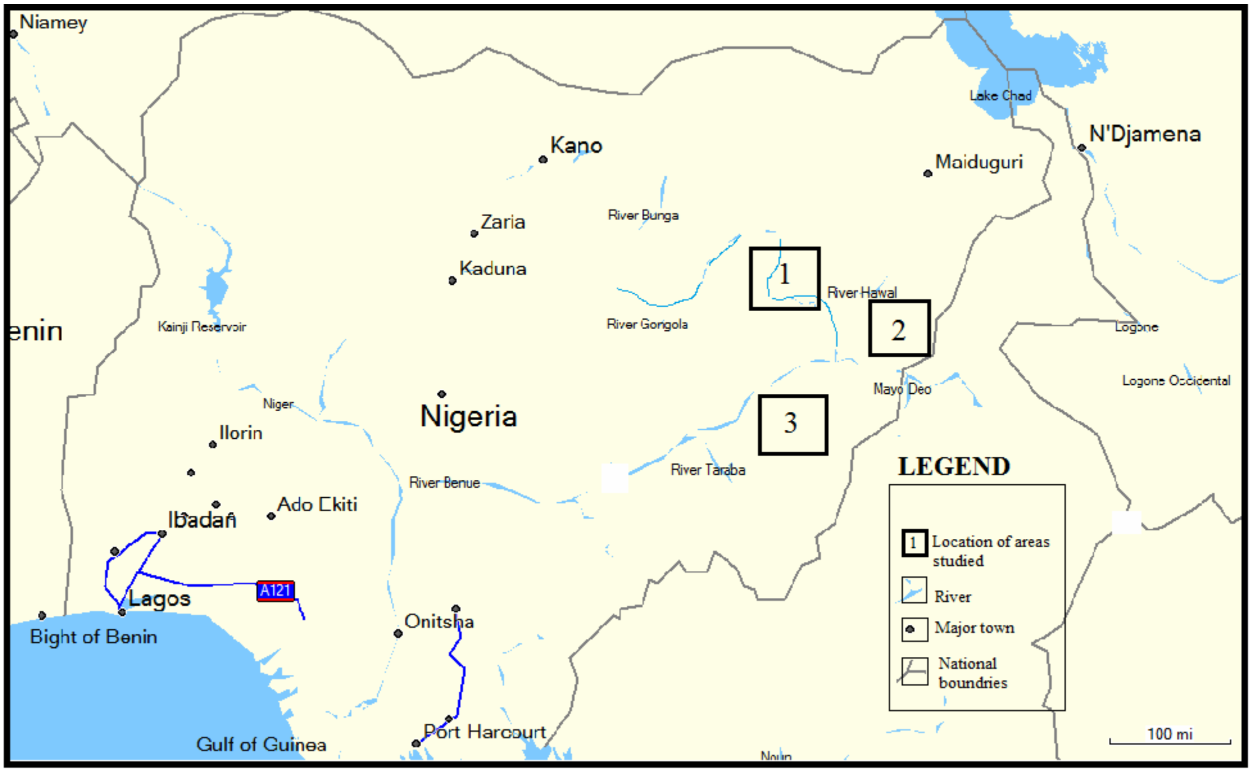

Fig. 1: Map of Nigeria showing locations of the studied areas (MapSource, 2006. Version 6.11.6)

longitude 11° 27' to 11° 50' and latitude 08° 48' to 09° 08' (fig. 1). The Geology of the area comprises the crystalline basement, represented by migmatite complex comprising of poorly foliated magmatic granite and lenses of banded gneiss. The migmatite gneiss has been intruded by quartz, pegmatite vein and by porphyritic granite. A total of eleven water samples were collected from the area for analysis.

There are two main categories of water supply for aquaculture, groundwater and surface water. Groundwater (also called well water, or spring water) often differs substantially from surface water in many characteristics. Groundwater is commonly considered the most desirable water source for aquaculture because, at a given site, it is usually consistent in quantity and quality, and free of toxic pollutants and contamination with predator or parasitic living organisms. Natural springs occur where groundwater emerges from rock stratum containing an aquifer. Because spring water has consistent and desirable temperature characteristics, not to mention the valuable fact that it may not be necessary to pump the water to the raceways, springs are the most common water supply for land based trout and salmon culture (land based as contrast with net pen culture in coastal waters).

The composition of water changes right from the time it falls from space, during infiltration into the subsurface through different geologic materials and in the saturation zones. The reactions of water with the environment and the natural chemistry can have an important bearing on human beings, livestock and even plants, therefore, a detailed analysis of major, minor and trace constituents of groundwater is an important step in reducing the risks that is associated with water especially for aquaculture on which this study focused.

There are no published articles regarding the suitability of waters from different sources for aquaculture in the study area. Arabi at al, (2010) studied some water samples from part of Adamawa State (location 2) but his study was restricted to use of these water sources for irrigation and house hold purposes. The objective of this study is to evaluate some physical and chemical qualities of water that are of importance to aquaculture (the business of fish farming). Although the quantity of water available is also of primary importance, only water quality factors are considered here.

Materials and Methods

All the water samples were collected between 8th to 16th April, 2009 from boreholes, springs and hand dug wells using standard sampling procedure and stored in low density polyethylene container after measurement for pH, conductivity, temperature and total dissolved solids were carried out using a Platinum Series portable pH and Conductivity meter (HACH make). After these measurements, samples were acidified, brought to the laboratory and refrigerated prior to analysis. Other recordings made in the field are coordinates of sampled points, elevation of sampled points and static water level in wells at each of the locations using GPS and a deep meter.

The analysis of Si, O_2, K and P was carried out using a CHEMetrics make Photometer Model V-2000. It is the most advanced portable analyzer which automatically tests pre-programmed analyte using CHEMetrics Vacu-vials self-filling, Na and K were analyzed with a corning flame photometer 410 while the other elements were analyzed with a Buck Scientific (Model 210) VGP Atomic Absorption Spectro-photometer. The results obtained were interpreted and evaluated using "AquaChem" version 2010.1.83 (a software package developed specifically for graphical and numerical analysis and modeling of water quality data equipped also with features that has a fully customized database of physical and chemical parameters and provides a comprehensive selection of analysis tools, calculations, and graphs for interpreting water quality data).

Results

The results of in-situ measurements of parameters such pH, conductivity and temperature is presented in table 1 and 2.

Analysis of some important chemical elements were carried out and presented in tables 4, 5 and 6. While hardness classification is presented in table 7, Piper diagram of water type are also presented together with Residual Sodium Carbonate (RSC).

Discussion

Temperature

Sometimes called poikiothermic, most fish are ectothermal, meaning that their body temperature is the same as the surrounding water (tuna and a few other species have body temperatures somewhat higher than the surrounding water, but are not homothermal, that is they do not have constant body temperature such as mammals or birds). The body temperature of a eurythermal (wide range of temperature adaptation) fish like largemouth bass may range from near freezing to nearly 90°F. It is important to note that intrinsic differences exist in adaptation of fish to water temperature. In regards to their temperature tolerance, fish are categorized as coldwater, coolwater, warmwater, and tropical. Most tropical fish, such as tilapia, die when temperatures are less than 50°F (10°C), and most salmonids (trout and salmon) die when temperatures exceed 80°F (25.7°C). Channel catfish, which are called warmwater fish, survive from near freezing to about 90°F (32.2°C). Temperature recorded for samples from location1, 2 and 3 ranges from 28.2^{0}C to 32.4^{0}C, 27^{0}C to 32.7^{0}C and 29.8^{0}C to 32.5^{0}C, respectively. This indicate base on temperature and the species of fish grown in Nigeria which are mostly the cat fish and tilapia, the water samples analyzed has tolerable temperature for aquculture.

Table 1: Physico-chemical and other measurements carried out in-situ at study location 1

S/N	SAMPLE ID	COORDINATES LATITUDE	LONGITUDE	ELEV (m)	S.W.L (m)	H-HEAD (m)	PH	COND. (μs/cm)	TEMPT. (˚C)	TDS (mg/L)
1	BH01GB	09°44.176´	11°59.862´	169.47	5	164.47	6.55	384	31.2	185.3
2	BH02GB	10°36.750´	12°11.475´	757.73	10.79	746.94	6.92	1,271.0	28.2	628
3	OW03BG	10°21.645´	11°58.216´	312.12	2.38	309.74	5.68	71.8	28.5	33.8
4	OW04GB	10°13.370´	12°03.141´	259.69	3.54	256.15	6.59	197.1	30	94.3
5	BH05GB	09°33.746´	12°00.463´	188.37	6.25	182.12	7.24	779	32.4	380
6	OW06GB	10°17.853´	11°59.704´	368.81	5.33	363.47	7.45	281	31.2	135
7	BH07GB	10°30.167´	11°50.628´	350.83	11.89	338.94	6.81	1,155.0	31.3	569
8	BH08GB	10°23.045´	11°41.760´	306.02	25.91	280.11	6.85	699	31	340
9	SP09GB	10°19.688´	11°44.793´	294.13	0	294.13	6.87	142.1	28.5	67.7
10	OW10GB	10°19.934´	11°44.315´	295.96	2.5	293.46	6.39	684	29.1	333
11	OW11GB	10°16.679´	11°45.933´	254.81	11.03	243.78	6.59	1,206.0	29.5	595
12	ST12GB	10°15.199´	11°42.219´	261.21	0	261.21	6.15	101.7	29.4	48.2
13	OW13GB	10°18.571´	11°39.2025´	299.92	6.89	293.04	6.54	220	29.8	105.3
14	BH14GB	10°20.710´	11°36.656´	241.1	10.67	230.43	6.58	3,250.0	30.7	1,667.

Table 2: Physico-chemical and other measurements carried out in-situ at study location 2

S/N	SAMPLE ID	COORDINATES LATITUDE	LONGITUDE	ELEV (m)	S.W.L (m)	H-HEAD (m)	PH	COND. (µs/cm)	TEMPT (˚C)	TDS (mg/L)
1	BH01GM	10°38.835´	13°26.722´	548.34	18.32	530.02	6.91	424.0	32.70	246.00
2	SP02GM	10°38.811´	13°27.438´	549.86	-	549.86	6.10	394.4	27.00	196.5
3	BH03GM	10°38.896´	13°28.385´	561.14	20.42	540.72	6.69	347.0	31.20	199.0
4	BH04GM	10°37.347´	13°29.250´	600.76	16.46	584.30	7.16	312.0	30.50	172.0
5	ST05GM	10°34.639´	13°31.336´	649.83	-	649.83	6.11	419.6	31.00	211.3
6	BH06GM	10°38.757´	13°32.902´	642.52	17.98	624.54	6.46	375.0	30.00	179.1
7	BH07GM	10°44.875´	13°25.090´	461.47	3.38	458.08	6.62	310.0	28.60	137.4
8	OW08GM	10°34.909´	13°20.417´	510.24	1.89	508.35	6.25	263.6	26.00	133.6
9	OW09GM	10°47.285´	13°26.248´	456.29	9.33	446.96	6.38	319.0	29.60	164.5
10	OW10GM	10°44.240´	13°29.003´	510.54	13.35	497.19	6.06	342.0	30.00	164.8
11	BH11GM	10°43.024´	13°29.616´	534.01	11.55	522.46	7.05	372.0	30.00	198.0
12	OW12GM	10°42.060´	13°30.823´	544.37	1.86	542.51	6.44	309.4	30.60	155.9

Table 3: Physico-chemical and other measurements carried out in-situ at study location 3

S/N	SAMPLE ID	COORDINATES LATITUDE	LONGITUDE	ELEV (m)	S.W.L (m)	H-HEAD (m)	PH	COND. (µs/cm)	TEMPT. (˚C)	TDS (mg/L)
1	BH01MK	08°54.965´	11°42.586´	2,378.35	10.36	2,367.99	6.85	576	31.2	280
2	ST02MK	08°51.728´	11°41.741´	5,010.00	-	5,010.00	7.29	194.8	32.5	93.2
3	BH03MK	08°49.989´	11°41.869´	540.11	9.14	530.96	6.95	286	29.8	137.4
4	BH04MK	08°53.486´	11°34.673´	508.1	10.36	497.74	7.23	599	30.3	291
5	BH05MK	08°56.649´	11°30.701´	515.42	11.77	503.65	6.2	138.1	30.4	65.8
6	BH06MK	09°04.129´	11°31.910´	270.05	10.79	259.26	6.69	518	31.4	251
7	BH07MK	09°02.000´	11°36.299´	387.71	8.08	379.63	7.06	654	30.4	318
8	BHO8MK	08°58.535´	11°37.529´	446.53	8.14	438.39	6.58	203	30.4	96.9
9	BH09MK	08°59.687´	11°45.332´	500.48	8.69	491.8	6.48	201	29.9	96.2
10	ST10MK	09°07.264´	11°40.034´	361.8	-	361.8	6.23	90.4	31.4	42.8
11	OW11MK	09°06.675´	11°38.846´	407.52	5.82	401.7	7.85	470	30.8	227

Table 4: Mineral and fluid properties of water samples from location 1

S/N	SAMPLE ID	Na (mg/l)	O_2 (mg/l)	Fe (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	Water type	Salinity
1	BH01GB	16.3±0.02	6.24±0.80	0.14±0.02	27.2±2.01	0.54±0.01	54±0.21	37±0.21	Na-Cl	low
2	BH02GB	36.4±0.12	6.0±0.01	0.23±0.21	53±1.3	0.50±0.01	9.8±0.05	104.7±0.71	Na-Cl	Medium
3	OW03BG	29.7±0.022	7.73±0.62	0.74±0.12	25±0.2	0.01±0.001	3.60±0.01	93.4±0.25	Na-Cl	Medium
4	OW04GB	17.7±0.14	6.77±0.62	0.81±0.15	34±3.5	0.12±0.001	9.8±0.21	98. ±0.51	Ca-Cl	Medium
5	BH05GB	52±0.11	6.03±0.32	0.13±0.12	65±0.95	0.26±0.01	22.96±0.31	125±0.32	Na-Cl	Medium
6	OW06GB	36.4±0.25	6.55±0.53	0.59±0.23	76±1.9	0.14±0.001	11.84±0.18	117±0.66	Na-Cl	Medium
7	BH07GB	32.9±0.21	6.14±0.53.	0.04±0.25	47±2.1	0.8±0.002	99.68±0.54	158±0.85	Ca-Cl	Medium
8	BH08GB	36.4±0.32	5.84±0.32	0.41±0.32	21.2±0.52	0.31±0.01	45.55±0.31	123±0.32	Ca-Cl	Medium
9	SP09GB	28.3±0.57	6.03±0.52	3.01±0.25	63.8±0.25	0.01±0.001	2.86±0.62	104.3±0.61	Ca-Cl	Medium
10	OW10GB	33.5±0.52	6.47±0.51	0.06±0.51	72.01±2.1	0.09±0.01	8.72±0.21	113.2±0.34	Na-Cl	Medium
11	OW11GB	35.2±0.21	6.44±0.11	0.13±0.31	56.3±1.3	0.82±0.001	56.28±0.51	197.6±0.61	Ca-Cl	Medium
12	ST12GB	16.7±0.21	6.19±0.61	2.28±0.63	76.3±1.2	0.01±0.001	0.40±0.01	103.2±0.21	Ca-Cl	Medium
13	OW13GB	21.9±0.32	6.05±0.22	4.1±0.11	62±.23	0.21±0.01	13.16±0.31	104.5±0.61	Ca-Cl	Medium
14	BH14GB	93.8±0.02	5.9±0.32	0.18±0.01	106.5±1.2	2.75±0.03	142.6±0.71	174.4±0.61	Ca-Cl	High

Table 5: Mineral and fluid properties of water samples from location 2

S/N	SAMPLE ID	Na (mg/l)	O_2 (mg/l)	Fe (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	Water type
1	BH01GM	30.7±0.02	6.23±0.21	0.15±0.01	35.2±0.21	0.25±0.01	48.96±0.21	113.60±0.08	Ca-Cl
2	SP02GM	27.3±0.12	6.65±0.32	5.64±0.12	65.01±0.28	0.02±0.00	0.80±0.01	123.5±0.51	Ca-Cl
3	BH03GM	24.6±0.022	7.64±0.31	8.06±2.51	167±0.51	0.10±0.01	30.16±0.62	99.4±0.61	Ca-Cl
4	BH04GM	28.3±0.14	5.98±0.31	0.28±0.21	173±2.5	0.12±0.01	26.70±0.52	87.21±0.32	Na-Cl
5	ST05GM	33.6±0.11	7.29±0.14	5.79±0.12	24.03±0.61	0.12±0.001	3.28±0.03	132±0.91	Ca-Cl
6	BH06GM	31.0±0.25	5.85±0.051	0.32±0.021	54.01±0.09	0.19±0.02	5.10±006	109±0.80	Ca-Cl
7	BH07GM	27.3±0.21	6.49±0.36	3.60±0.012	13.7±0.13	0.07±0.001	7.60±0.21	89.62±0.51	Ca-Cl
8	OW08GM	16.0±0.32	5.92±0.21	7.03±0.21	40.0±0.66	0.09±0.01	6.80±0.07	79.4±0.32	Ca-Cl
9	OW09GM	27.3±0.57	6.41±0.41	0.14±0.01	39.02±0.32	0.25±0.003	15.36±0.09	93.4±0.21	Na-Cl
10	OW10GM	23.1±0.52	6.16±0.08	0.25±0.01	46.33±0.65	10.60±0.05	10.72±0.12	92.740±0.11	Ca-Cl
11	BH11GM	27.0±0.21	6.86±0.012	4.23±0.21	74.31±0.07	0.27±0.01	21.3±0.05	107±0.51	Ca-Cl
12	OW12GM	24.4±0.21	6.46±0.04	0.98±0.01	37.01±0.62	0.00	3.76±0.03	93.6±0.91	Ca-Cl

Table 6: Mineral and fluid properties of water samples from location 3

S/N	SAMPLE ID	Na (mg/l)	O_2 (mg/l)	Fe (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	Water type
1	BH01MK	29.6±0.07	6.08±0.41	0.17±0.18	94.3±0.51	0.73±0.01	35.00±0.56	123.5± 0.91	Ca-Cl
2	ST02MK	56.4±0.02	6.14±0.12	0.02±0.001	72.4±0.61	1.75±0.021	6.08 ±0.02	143.00±0.32	Na-Cl
3	BH03MK	37.2±0.025	5.72±0.17	0.02±0.003	66.32±0.21	0.04±0.001	31.00 ±0.61	119.0±0.85	Ca-Cl
4	BH04MK	3407±0.04	5.81±0.12	0.04±0.001	84.3±0.23	0.27±0.01	37.00 ±0.21	123.5±0.32	Ca-Cl
5	BH05MK	33.5±0.03	6.03±0.23	0.37±0.002	67.3±0.21	0.04±0.001	36.00±0.03	109.7 ±0.92	Na-Cl
6	BH06MK	38.9±0.025	5.81±0.011	0.02±0.001	76.4±0.91	0.23±0.001	20.80±0.51	118.00 ±0.14	Na-Cl
7	BH07MK	33.4±0.05	5.91±0.12	0.013±0.005	109.3±0.23	0.33±0.021	56.90 ±0.36	110.8 ±0.51	Ca-Cl
8	BHO8MK	27.6±0.031	6.18±0.05	0.42±0.03	96.2±0.22	0.03±0.001	5.60 ±0.51	121.7 ±0.36	Ca-Cl
9	BH09MK	38.6±0.051	6.14±0.23	0.25±0.011	79.31±0.31	0.08±0.01	12.9. ±0.08	108.3 ±0.28	Na-Cl
10	ST10MK	29.7±0.011	5.95±0.067	2.03±0.01	76.5±0.22	0.01±0.001	17.80±0.12	107.3 ±1.20	Ca-Cl
11	OW11MK	26.5±0.021	6.05±0.21	1.15±0.01	89.6±0.91	0.15±0.01	46.7 ±0.31	114.0 ±0.61	Ca-Cl

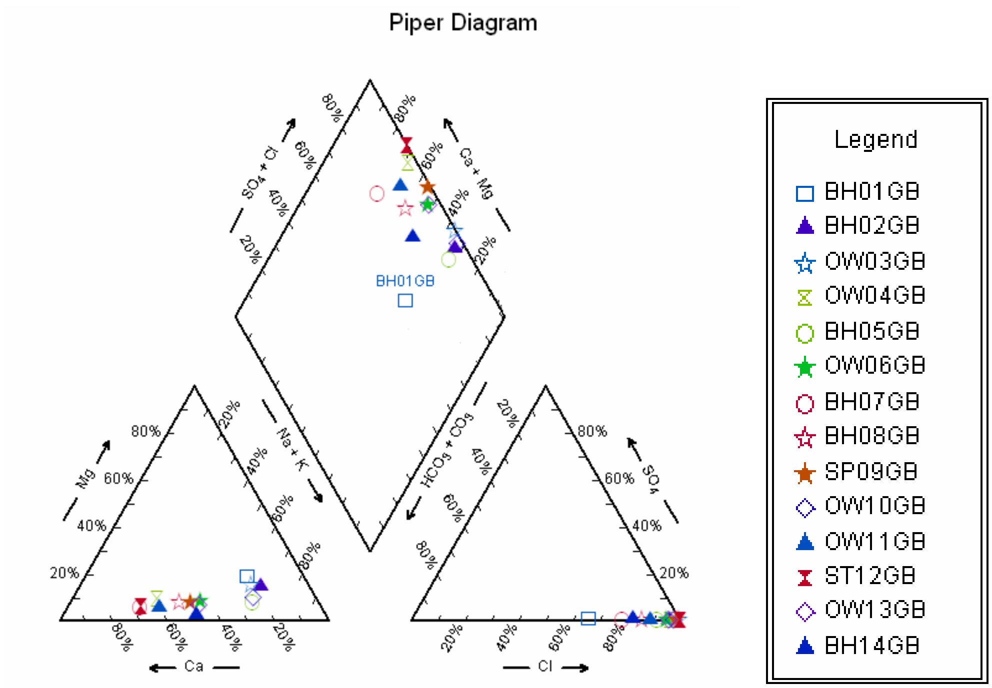

Fig. 2: Piper diagram for water samples from location 1

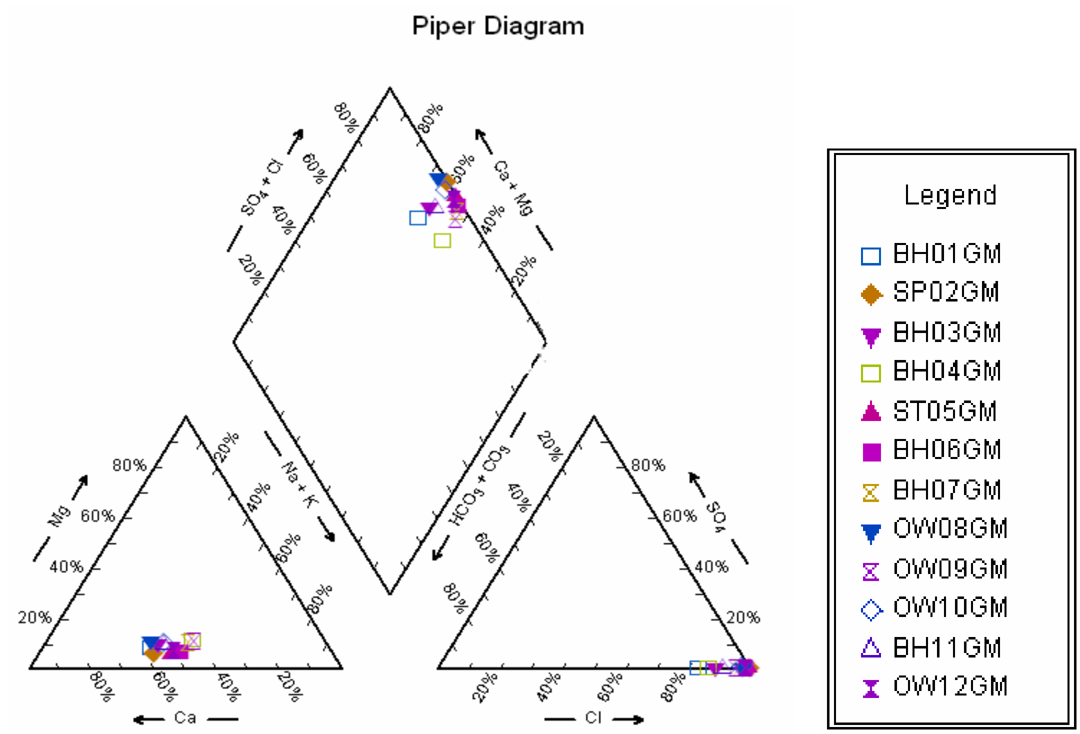

Fig. 3: Piper diagram for water samples from location 2

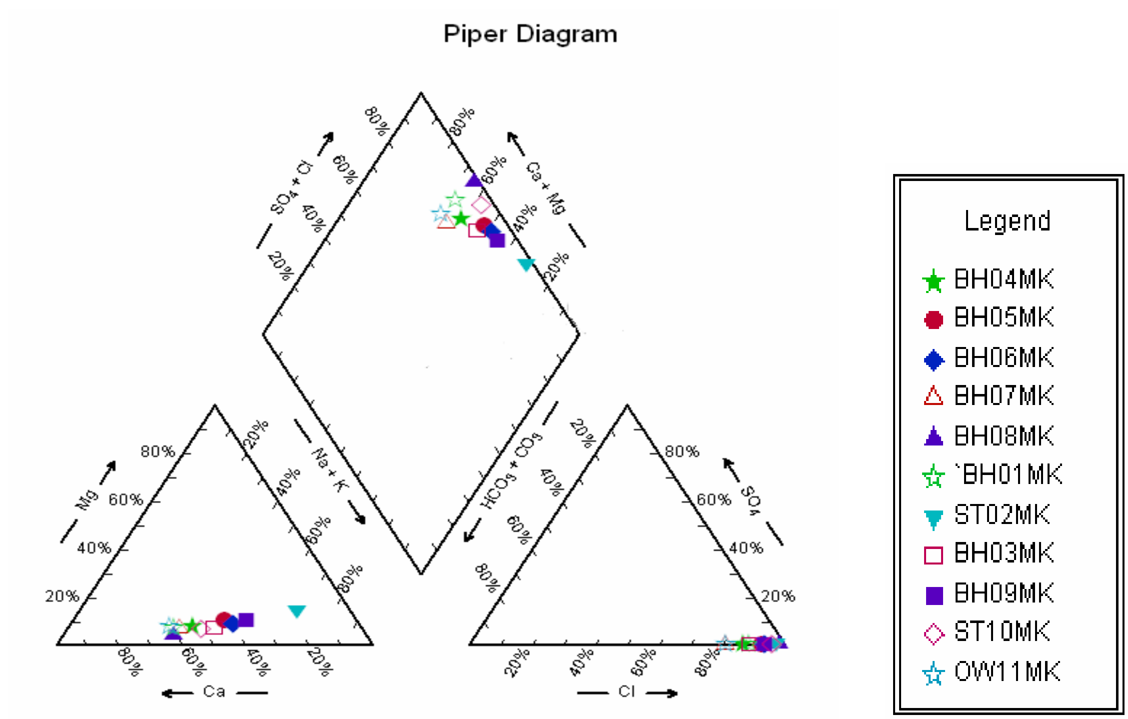

Fig. 4: Piper diagram for water samples from location 3

Table 7: Classification of water hardness (Sawyer and Mc Carty, 1967)

Hardness range (mg/l of $CaCO_3$)	Water classification
0 – 75	Soft
75 – 150	Moderately hard
150 – 300	Hard
>300	Very hard

The only stage temperature can affect these fish species may be during transportation of fingerlings where temperature variation are not kept steady which results in temperature shock. Temperature shock, which will stress or cause high mortality of fish, occurs when fish are moved from one environment to another without gradual acclimation ("tempered") to the other temperature. Boyd (1990) reported that 0.2°C/minute (12°C/hour) can be tolerated "provided the total change in temperature does not exceed a few degrees.

Dissolved Oxygen (DO)

Oxygen is the first limiting factor for growth and well-being of fish. Fish require oxygen for respiration, which physiologists express as mg of oxygen consumed per kilogram of fish per hour (mg O2/kg/h). The respiratory rate increases with increasing temperature, activity, and following feeding, but decreases with increasing mean weight. Here are several important implications of these physiological facts for aquaculture:

- At a given temperature, smaller fish consume more oxygen per unit of body weight than larger fish; or said in another way, for the same total weight of fish in a tank, smaller fish require more oxygen than larger fish
- Actively swimming fish consume more oxygen than resting fish. In raceways, high exchange rates will increase energy expenditures for swimming, and oxygen consumption.
- Oxygen consumption of fish will increase after feeding; multiple feedings per day (3 or more) will result in less variation in oxygen demand than 1 to 2 feedings per day.

In ponds, the major source of oxygen is from algal photosynthesis and from wind mixing the air and water. If a tank is stocked with fish, over several weeks of a growth cycle, the fish will grow, reducing their consumption rate (inverse OC-fish size relationship), but the density (pounds/cubic ft^3) will increase. Flow to the tank will have to be increased or the population divided to handle the larger oxygen demand. The oxygen consumption rate of fish of different species ranges range from 200-500 (mg O2/kg/h).

A common generalization about oxygen requirements for aquaculture is that the minimum DO should be greater than 5 mg/L for growth of warmwater fish and 6 mg/L coldwater fishes at their optimum temperature. Thus, for a raceway or circular tank, oxygen of the effluent water should be at least 5 mg/L. The oxygen available for fish (AO) is the difference between the inflow (O2) and outflow (O2) oxygen concentration. If the outflow must be no less than 5 mg/L, then the inflow must be higher than that for fish to have any oxygen for respiration. At a temperature of 60°F (15.5°C), oxygen saturation would be about 9.6 mg/L at 1000 feet, which would provide about 4.6 mg/L of AO for fish respiration (9.6-5.0 = 4.6 mg/L). The oxygen requirement for 100 kg (220 lb.) of fish that consume 300 mg O2/kg/h would be 30,000 mg O2/h (100 kg fish x 300 mg/kg/h). The oxygen demand recorded in samples from locations 1, 2 and 3 ranges from5.84mg/l to 7.73mg/l, 5.85mg/l to 7.64mg/l and 5.72mg/l to 6.18mg/l, respectively. Therefore, base on oxygen demand the water samples studied can be used for aquaculture for either warmwater (at least 5mg/l) fish or even coldwater (6mg/l) fish at their optimum temperature.

pH, Carbon Dioxide (CO2) and Alkalinity

The pH of water is an index of hydrogen ion (H^+) activity of water. The pH scale (range from 0 to 14) is logarithmic (base 10), an important fact to remember because a drop of 1 pH unit indicates a 10 fold increase in hydrogen ions (H^+) present in water. A pH value may fall anywhere on a scale from 0 (strongly acidic) to 14 (strongly basic or alkaline), with a value of 7 representing neutrality (10-7 moles/liter of H^+ ions).

The pH of most productive natural waters that are unaffected by pollution is normally in the range of 6.5 to 8.5 at sunrise, typically closer to 7 than 8. Diurnal variation is related to photosynthesis:

$$(1) \qquad CO_2 + H_2O \overset{\text{Chlorophyll}}{\underset{\text{Sunlight}}{\Leftrightarrow}} C_6H_{12}O_6 + O_2$$

The controlling factor for pH in most aquacultural facilities is the relationship between algal photosynthesis, carbon dioxide (CO_2), and the bicarbonate ($HC0^{3-}$) buffering system:

$$(2) \qquad CO_2 + H_2O \Leftrightarrow H_2C0_3 \Leftrightarrow HC0_3^- + H^+$$

At night, respiration by bacteria, plants, and animals results in oxygen consumption and carbon dioxide production, the reaction in formula (2) goes from left to right, first producing carbonic acid (H_2C0_3), then bicarbonate $HC0^{3-}$ and H^+ ions; the increase in H^+ causes the pH to drop. During sunlight, respiration continues, but algae use CO_2 for photosynthesis, formula (1); the reaction of formula (1) goes from right to left, reducing the abundance of H^+ ions, and pH goes up. In productive ponds, especially those with low alkalinity, the daytime pH may reach 10, which can be lethal to young fish, especially hybrid striped bass.

Fish can die also from pH shock, a consequence of a sudden change in pH (1.7 pH units) that may occur when moving fish from pond to tank, or tank to pond. Toxicity of other compounds to fish, especially ammonia and chlorine, are affected by pH. pH values recorded for samples from locations 1, 2 and 3 ranges from 6.15 to 7.45, 6.06 to 7.16 and 6.25 to 7.85, respectively. This shows that all the water samples analyzed have pH value that supports aquaculture.

Water type

Based on the analysis carried out, water samples from the area studied were categorized into two water types, Ca-Cl and Na-Cl types (Calcium and Sodium water types). Both water types has no effect on fish farming, calcium is the most abundant of alkaline earth metal and a major constituent of vast common rock minerals. Sources of calcium (Ca^{2+}) are calcite, aragonite, dolomite, gypsum, anhydrite, fluorite, plagioclase, pyroxene and amphibole (Brian, et al. 1980).

Sources of sodium are halite, sea spray, some silicate and rare minerals such as plagioclase, plagioclase variety of albite and nepheline. Most sodium results from natural ion exchange. Sodium and potassium are common constituents of natural waters with sodium being more prevalent than potassium.

Hardness

Hardness is the sum of Ca^{2+} and Mg^{2+} concentrations expressed in terms of mg/l of calcium carbonate:

Hardness = 2.5 Ca (mg/l) + 4.1 Mg (mg/l) (Fournier, 1981) Calcium and magnesium form an insoluble residue with soap. The degree of hardness in water is commonly based on the classification listed in table 5(Sawyer and Mc Carty, 1967).

Most of the groundwater sample analyzed from location 1 had hardness value ranging from 0.65 to 74.5mg/l except sample BH07GB and BH14GB which has hardness value of 163.07 and 221.48 respectively. Hardness value below 75mg/l indicate that the samples analyzed are soft water indicating that twelve of the fourteen water samples analyzed are soft water while the remaining two are hard water.

All groundwater samples from location 2 had hardness value ranging from 9.31–80.09 mg/l with average value of 24.61mg/l. From these values, only one had hardness value greater than the set standard of 75mg/l for drinking purpose, this is recorded in sample BH01GM and the recorded value is 80.09mg/l.

All groundwater samples analyzed from location 3 recorded hardness value ranging from 9.16 – 93.08mg/l and from this value, ten of the eleven samples analyzed had hardness below 75mg/l indicating that the water in the study area are soft water except sample BH07MK which has hardness value of 93.08mg/l indicating moderately hard water.

Base on hardness values, all the water samples analyzed are also good for aquaculture.

Residual Sodium Carbonate (RSC)

Residual Sodium Carbonate (RSC) value considers the bicarbonate content of the water. High concentration of bicarbonate leads to an increase in pH value of water which aids dissolution of the organic matter. Almost all the water samples analysis has residual sodium carbonate values of < +1.25 which means that RSC values of the studied water samples do not affect aquaculture.

Conclusion

Generally, the qualities of the studied water samples are good for aquaculture. The quality water can varies considerably between surface and groundwater sources, and between sources at different geographical locations. Groundwater is considered the most desirable source of supply, because it has more consistent diurnal and seasonally in qualities than surface water, and much less likely to be contaminated by pathogens or fish. Fish can use some water supplies considered impaired for human use. Water quality affects affect growth and well-being of fish, therefore, water quality should be of great importance to the aquaculturist.

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