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ASSESSMENT OF WATER QUALITY STATUS OF A TYPICAL CONSTRUCTED FISH POND IN NWRI, KADUNA

EDITH NWAKAEGO CHIMA, OMAGBEMI OMOLOJU YAYA, IFIE-EMI FRANCIS OSEKE, VINCENT CHIJIOKE UGBOAJA, KASSIM ABDULLAHI BABA, SEGUN PETER MICHAELS[1], TERRANG SAFIYA USMAN[1]

[1]National Water Resources Institute (NWRI) Kaduna, Nigeria.
[*]Corresponding author:
Department of Water Resources and Environmental Management
National Water Resources Institute (NWRI) Kaduna
E-mail address: edithnwakaego7@gmail.com
Tel: +2348071609879; +233504632043.

ABSTRACT

The National Water Resources Institute (NWRI) constructed a fish pond for the purpose of research. This study focused on the analysis of heavy metals and selected physiochemical parameters of the pond. The concentrations of some heavy metals such as zinc (Zn), iron (Fe), manganese (Mn), cadmium (Cd), chromium (Cr) and lead (Pb) were determined in water samples collected from source water (borehole) and fish pond water (constructed pond) and the results obtained were compared with WHO/EPA/NSDW standards. In addition to the heavy metals, some physiochemical parameters such as pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), salinity, chloride (Cl^-), alkalinity and hardness were also determined in the sampled waters to assess their suitability for fish production. Heavy metals concentration were determined using atomic absorption spectroscopy (AAS) while the analysis of the physiochemical parameters were carried out using standard methods. All the heavy metals studied were present in both samples. However, the weekly mean concentrations of these heavy metals are in the following order iron (1.005) > zinc (0.347) > manganese (0.116) > chromium (0.003) > cadmium (0.002) > lead (0.001) (source water) and iron (3.335) > zinc (2.665) > manganese (2.572) > chromium (0.077) > cadmium (0.061) > lead (0.051) mg/L (fish pond water), respectively. In the source water (SW) sample, the average concentrations of all the heavy metals analyzed were within the permissible limits of WHO/NSDW while the reverse was the case for fish pond water (FPW). Among all the heavy metals studied, iron had the highest concentrations in both the SW and FPW. This may have resulted from the geology of the area where the pond is located and the corrosion of steel/iron used in the borehole casing. In fish pond water samples, there is a significant difference in the concentrations of all the heavy metals (p>0.05) across the weeks with strong correlations in the levels of heavy metal concentrations and some physiochemical parameters. However, regular monitoring of these heavy metals is recommended due to their potential to bioaccumulate in different fish tissues to the detriment of fish consumers.

KEYWORDS: *Pond Water, Source Water, Heavy Metals, and Physiochemical Parameters.*

1.0 INTRODUCTION

Fish is one of the basic foods for humans and is widely consumed as animal protein (Ezeanya et al., 2015). As a result of its rising demand, more fish ponds are being developed throughout Nigeria by individuals, institutions, and organized groups (Adeyemi and Ugah, 2017; Collins, 2019). However, most fish farming operations are carried out incorrectly due to a lack of understanding of fish pond management, which causes fish to grow slowly or die suddenly (Adeyemi and Ugah, 2017; Collins, 2019). Fish production is often affected by the unfavorable physiochemical characteristics of the pond water parameters caused by poor construction and inadequate management of the ponds. Increased fish productivity can been achieved if physiochemical parameters like EC, alkalinity and hardness, pH, and others lie within the acceptable limits (Collins, 2019).

The fate and distribution of heavy metals directly depends on the physical and chemical properties of the water (Kamaruzzaman *et al.,* 2010). Sources of heavy metals in water resources include landfill leachate, metal-based pesticides and fertilizer applications in farmland, and domestic and industrial wastes. Additionally, in many cases, heavy metal source has been related to the type of animal feed used (Belias *et al*., 2003).

In recent years, analysis of heavy metals has become of great interest to scientists (Mutlu and Kurnaz, 2018), due to their environmental persistence and ecological risks (Abbas *et al*., 2008; Walker *et al*., 2006). However, heavy metals such as copper, iron, manganese, nickel and zinc (essential elements) are beneficial to the body for the growth and functioning of living organisms while others like lead, arsenic, cadmium and chromium may be highly toxic and harmful even when they are present at small concentrations (Aladesanmi and Isaac, 2014; Mutlu and Kurnaz, 2018; Collins, 2019). The presence of these toxic and harmful heavy metals in aquaculture is of great concerns due to their ability to produce potential effects on biota including humans (Mutlu and Kurnaz, 2018; Showqi et al., 2018). Diseases such as gastrointestinal tract disorder, tumours, genetic and neurological malfunctions, and stuffiness of the neck, oedema of the eye and congestion of the nasal mucous membranes have been linked to the accumulation of some of these heavy metals (Adeyemi and Ugah, 2017). Hence, careful and regular monitoring of these heavy metals will greatly help provide information on the safety and status of these metals in fish farming ponds. The present study aimed to evaluate the weekly variations in some physiochemical parameters and the degree of heavy metal contamination in a typical constructed fish farming pond.

2.0 MATERIALS AND METHODS

2.1 DESCRIPTION OF STUDY AREA

The samples used in this work were collected from the National Water Resources Institute (NWRI), Kaduna constructed fish pond. The Fish Pond is situated at longitude 10°34′46″ N and latitude 007°25′12″ E (Figure 1). The pond is fed by the borehole drilled within the area where the pond is located. The effluent from the pond is used for irrigation purposes.

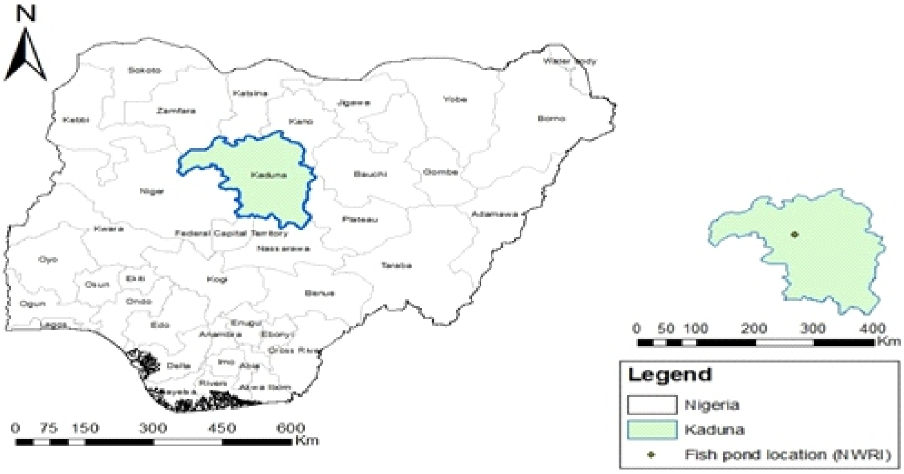

Figure 1: Map of Nigeria showing the study area in National Water Resources Institute, Kaduna

2.2 SAMPLING

A grab sampling method was employed in this study. Samples were collected from the constructed fish pond in the National Water Resources Institute (NWRI), Kaduna, Nigeria. Sampling was done every week in duplicate for five weeks. Samples were collected from both the source water (borehole) and fish pond water in a sterile clean plastic bottle. Before sampling, each sampling bottle was rinsed with distilled water and sampling water. Bottles used to collect samples for heavy metal analysis were pre-washed with 10% nitric acid and distilled water before collection. Later all samples collected were packed in a cooler with ice block and were taken to the laboratory for further analysis.

2.3 WATER QUALITY ANALYSIS

Among the water quality parameters studied were EC, pH, TDS, salinity, chloride turbidity, alkalinity and hardness, iron, zinc, manganese, lead, chromium and cadmium. The above mentioned parameters provide a comprehensive overview of the water quality in constructed fish ponds, highlighting potential environmental risks that could impact aquatic health and productivity.

2.3.1 ANALYSIS OF PHYSIOCHEMICAL PARAMETERS

After each sampling, parameters such as temperature, EC, pH, TDS, and turbidity were determined in situ with a multi-parameter water analysis kit. Titration with tetraoxosulphate (vi) acid was used to determine alkalinity while titration with EDTA was used for the determination of hardness using the Eriochrome black T indicator. Analysis of salinity and chloride were carried out using a HACH LANGE brand 6000 laboratory-type spectrophotometer (APHA, 1992).

2.3.2 HEAVY METAL ANALYSIS

The analysis of heavy metals such as iron, zinc, manganese, lead, chromium and cadmium was conducted according to a method described by Adeyemi and Ugah (2017). To digest the samples for heavy metal analysis, 10 mL of nitric acid was added to a beaker containing 100 mL of acid-preserved sample. The latter was brought to a slow boil and allowed to evaporate under a hot plate to 15 mL volume followed by heating and the addition of concentrated nitric acid until a light-coloured clear solution appeared indicating complete digestion. The volume was made up to 100 mL by the addition of distilled water. The samples were filtered, and the filtrate was used for heavy metal analysis using Atomic Absorption Spectrometry (AAS)

(Thermo Scientific SOLAAR S series)

2.4 STATISTICAL ANALYSIS

Graphical, mean, standard deviations, correlation matrix and p-values for the five weeks sampling period were calculated using Microsoft Office Excel 2016 and SPSS. Correlation matrix was used to assess the relationship between physiochemical parameters and the heavy metal concentrations. However, the criteria for a good correlation coefficient ranges from 0.5 – 1.0 while $R^2 = 1.0$ is considered a perfect correlation. The confidence interval is at 5%.

3.0 RESULTS AND DISCUSSION

3.1 Physiochemical parameters

Tables 1 and 2 shows the weekly distribution of the selected physiochemical parameters of both the source water and fish pond water samples. According to the results, all the physiochemical parameters analyzed in the source water were found to be within the acceptable level of WHO/NSDW/EPA. The highest and lowest pH values were obtained as 7.8 and 7.3 (source water) and 7.4 and 7.1 (fish pond water), respectively. More so, the mean pH values observed in the source water and fish pond water were 7.54 and 7.24. These results shows that the pH of the source water and fish pond water were both within the WHO acceptable limits of 6.5-8.5 (Collins, 2019). EC describes the ionic concentrations of water (Bhatnagar and Devi, 2013). The result from this study shows that the average values for EC (Tables 1 and 2) were 79.7 (source water) as against 100 (NSDW, 2007) and 281.2 (fish pond water) as against 300 µS/cm (Collins, 2019). These results were within the permissible limits. The measured salinity were from 4.87-53.2 with an average value of 26.38 (source water) and 30.92-355 with an average value of 103.82 mg/L (fish pond water), respectively. According to Jamabo (2008), salinity is a measure of all electrically charged ions and its increased concentration can affect fish growth. An increase in pond water salinity can occur during water exchange (Bhatnagar and Devi, 2013). The minimum and maximum TDS levels recorded in fish pond water were between 126 and 151 mg/L. These results fell within the EPA (1999) acceptable limits of 500 mg/L (Adeyemi and Ugah, 2017). The alkalinity of water is simply a measure of its capacity to neutralize acids at a certain pH (Mutlu and Kurnaz, 2018). The increase in alkalinity may be due to the decomposition of organic matter, evaporation and concrete blocks (Bhatnagar and Devi, 2013). According to Mutlu and Kurnaz (2018), alkalinity from 30-500 mg/L is acceptable for fish production. In this study, the fish pond water's total alkalinity ranges between 122 and 1500 mg/L with an average value of 507.4 mg/L. Therefore, considering the average concentration of fish pond water alkalinity (507.4 mg/L), there was a slight increase in the alkalinity. However, high alkalinity can cause physiological stress to aquatic life (Mutlu and Kurnaz, 2018). From these results, it can still be said that the fish pond water's alkalinity is suitable for fish production as its concentration levels has not exceeded the WHO permissible level of 600mg/L (Collins, 2019). Besides alkalinity, chloride level is another vital parameter in water quality. Chloride is very essential to fish in maintaining osmotic balance. The minimum and maximum values of chloride for the five-week sampling periods for both the source water and fish pond water were from 2.95-32.24 mg/L and 18.74-215.18 mg/L while the mean values for both the source water and fish pond water were determined to be 15.98 mg/L and 62.93 mg/L, respectively. A Study by Stone and Thomforde (2004) suggested that the acceptable level of chloride is between 60 and 100mg/L for catfish production. However, chloride level above 100 mg/L is a problem since they can cause damage to fish gills. Hardness is used to describe the presence of dissolved minerals such as sulphates, nitrates, chlorides and bicarbonates of magnesium and calcium (Collins, 2019). The results obtained from this study shows that the minimum and maximum values of hardness for both the source water and fish pond water ranges from 3-45 with an average value of 20.8 and 40-220 with an average value of 83 mg/L. According to Santhosh and Singh (2007), hardness from 30-180 mg/L is adequate for fish culture. On the aspect of fish pond water, the 83 mg/L average value was very low compared to a standard value of 600 mg/L (Collins, 2019). Low levels of hardness may cause stress on the fish due to insufficient magnesium and calcium required for scale and strong bone formation. Fish pond water turbidity value varied from 55-93 NTU with a mean value of 64 NTU. Meanwhile, high turbidity levels can impair light absorption into the pond. The result of this analysis reveals that the water from the pond will become warmer and lose its ability to hold oxygen. It can also reduce the photosynthesis and oxygen supply within the pond. This condition is not suitable for fish growth and production.

Table 1: Weekly record of the physiochemical parameters of source water to the pond

S/N	Parameter	W1	W2	W3	W4	W5	Average concerns and STDV.
1	pH	7.3	7.5	7.6	7.8	7.6	7.56±0.16
2	Turbidity (NTU)	3	7	9	6	2	5.40±2.58
3	TDS (mg/L)	32.3	66.8	31.4	31.9	34.3	39.34±13.77
4	EC (µS/cm)	65.1	133.9	63.4	65.3	70.8	79.70±27.21
5	Salinity (mg/L)	16.09	4.87	30.92	26.8	53.2	26.38±16.18
6	Chloride (mg/L)	9.75	2.95	18.74	16.24	32.24	15.98±9.80
8	Hardness (mg/L)	16	3	20	20	45	20.80±13.61
8	Alkalinity (mg/L)	26	20	30	345	450	174.20±185.35

Table 2: Weekly record of the physiochemical parameters of the fish pond water

S/N	Parameter	W1	W2	W3	W4	W5	Average Concs and STDV.
1	pH	7.1	7.3	7.2	7.4	7.2	7.24±0.10
2	Turbidity (NTU)	56	56	55	60	93	64.00±14.60
3	TDS (mg/L)	151	140	126	146	140	140.60±8.38
4	EC (µm/cm)	304	280	251	291	280	281.20±17.50
5	Salinity (mg/L)	46.6	35.05	30.92	51.55	355	103.82±125.81
6	Chloride (mg/L)	28.24	21.24	18.74	31.24	215.18	62.93±76.26
7	Hardness (mg/L)	54	41	40	220	60	83.00±68.92
8	Alkalinity (mg/L)	138	124	115	660	1500	507.40±537.77

3.2 Heavy Metals

Figure 1-6 shows the weekly concentrations of the three essential micro-elements (zinc, iron and manganese) and three toxic heavy metals (cadmium, chromium and lead) in both source water and fish pond water samples. The weekly mean values of these heavy metals in source water were in this order iron (1.005) > manganese (0.116) > zinc (0.347) > cadmium (0.002) > chromium (0.003) > lead (0.001) while that of the fish pond water were in this order iron (3.335) > zinc (2.665) > manganese (2.572) > chromium (0.075) > cadmium (0.061) > lead (0.051) (Figure 1-6) respectively. All the heavy metal values for the source water samples were within the permissible limit of the NSDW except iron (Table 3). This may have resulted from the geology of the area where the pond is located and from the corrosion of steel/iron used in the borehole casing. Though trace metals are vital to the health of living organisms, they can be toxic when tolerable limits are exceeded (Ritter et al., 2002). Therefore, the borehole has to be treated to reduce the iron concentration to the permissible limit before it can be used as a source of water for the fish pond. All the heavy metals examined in the fish pond water exceeded the permissible limits of WHO (Table 3). The average concentrations of the three toxic heavy metals detected in fish pond water samples were cadmium (0.061), chromium (0.075) and lead (0.051) mg/L respectively. However, concentrations of lead and cadmium above 0.01 and 5 mg/L are considered indications of pollution and have been documented to be toxic and can lead to aquatic life mortality (Mutlu and Kurnaz, 2018). Also, from the fish pond water's results as can be seen from weeks 1-5, iron was detected at concentrations higher than other metals (Fig 1-6). The high levels of these heavy metals are of great concern since they can bioaccumulate in different tissues of the fish and become detrimental to the fish consumers (Collins, 2019).

Table 3: Average heavy metal concentrations of both the source water and pond water and standard values

PARAMETERS (mg/L)	SOURCE WATER	NSDW	POND WATER	WHO Standard (Issn, 2017)
Cadmium	0.002	0.003	0.061	0.01
Chromium	0.003	0.05	0.075	0.1
Lead	0.001	0.01	0.051	0.01
Zinc	0.347	3.00	2.665	1.0
Iron	1.005	0.3	3.335	0.3
Manganese	0.116	0.2	2.572	1.0

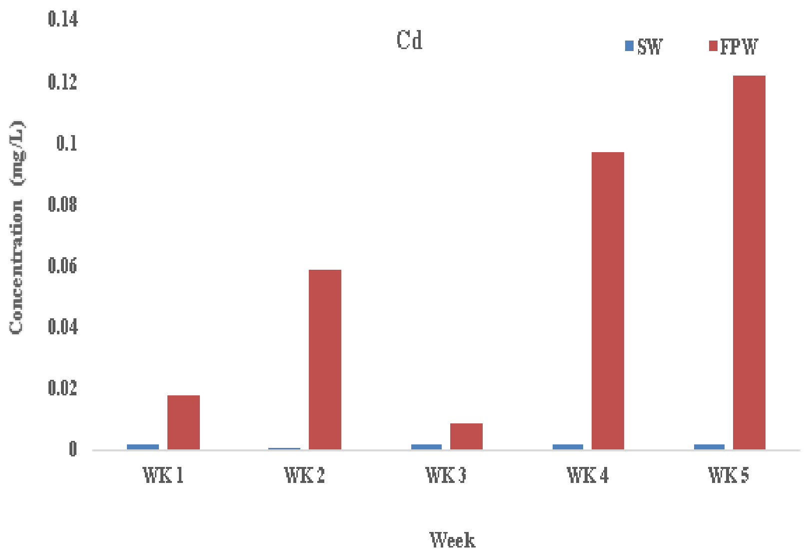

Fig 1: Average concentrations of cadmium in pond source water (borehole) and the pond water samples

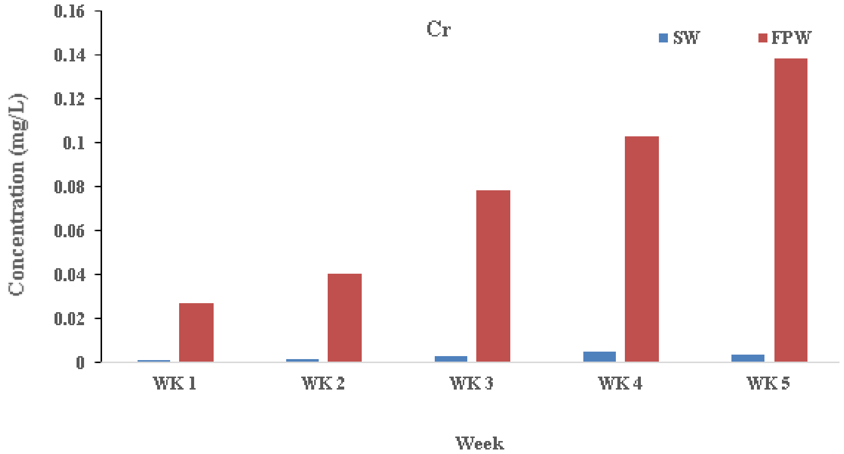

Fig 2: Average chromium concentrations in pond source water (borehole) and the pond water samples

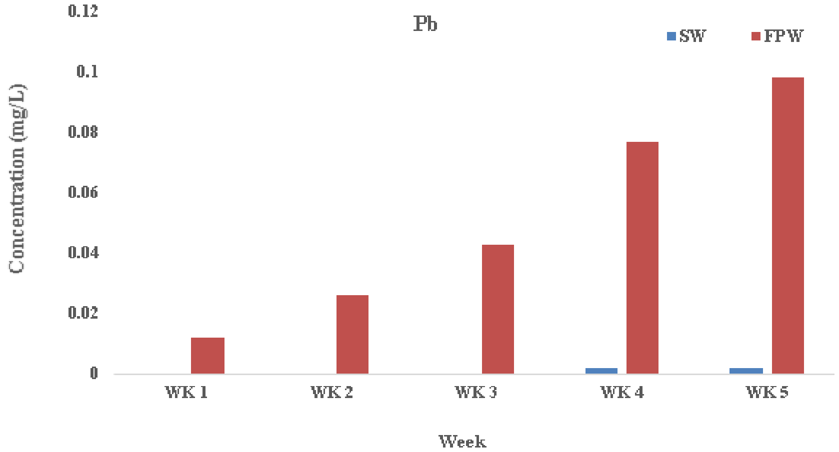

Fig 3: Average lead concentrations in pond source water (borehole) and the pond water samples

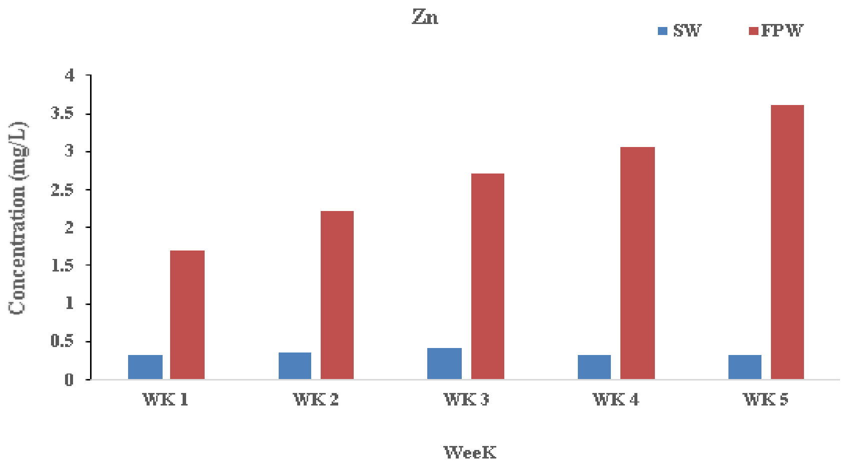

Fig 4: Average zinc concentrations in pond source water (borehole) and the pond water samples

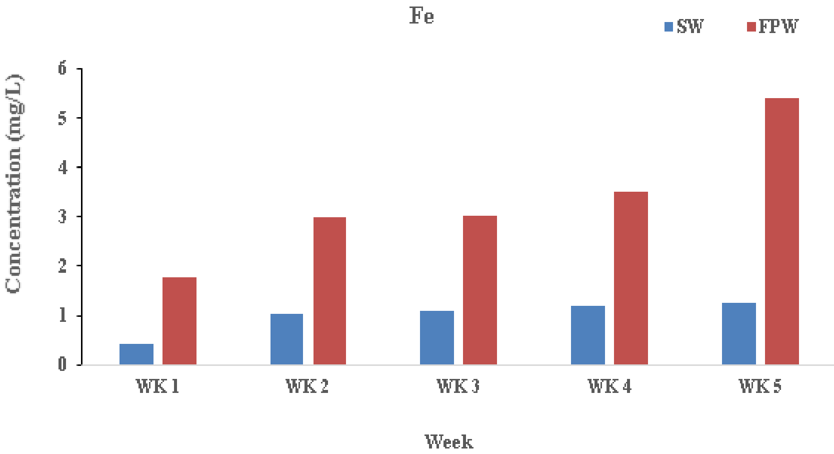

Fig 5: Average iron concentrations in pond source water (borehole) and the pond water samples

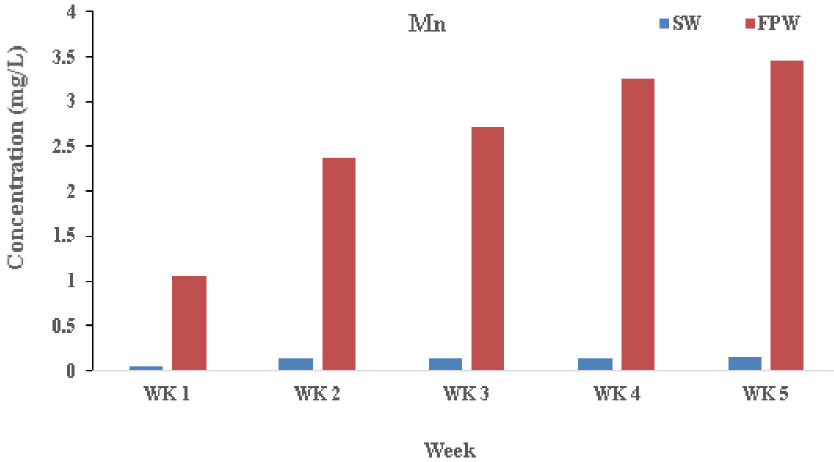

Fig 6: Average manganese concentrations in pond source water (borehole) and the pond water samples

Table 4: Correlation test between physiochemical parameters and heavy metals concentrations of pond water samples

Parameters	*pH*	*Turbidity*	*TDS*	*EC*	*Salinity*	*Cl^-*	*Hardness*	*Alkalinity*	*Cd*	*Cr*	*Pb*	*Zn*	*Fe*	*Mn*
pH	1													
Turbidity	-0.11	1												
TDS	0.00	0.02	1											
EC	-0.05	0.02	1	1										
Salinity	-0.18	1	0.01	0.02	1									
Chloride	-0.18	1	0.01	0.02	1	1								
Hardness	0.74	-0.05	0.38	0.34	-0.12	-0.12	1							
Alkalinity	0.11	0.96	0.10	0.09	0.94	0.94	0.23	1						
Cd	0.51	0.77	0.26	0.23	0.72	0.72	0.47	0.88	1					
Cr	0.31	0.79	-0.24	-0.27	0.75	0.75	0.37	0.89	0.77	1				
Pb	0.40	0.79	-0.12	-0.15	0.75	0.75	0.46	0.91	0.85	0.99	1			
Zn	0.39	0.76	-0.32	-0.35	0.72	0.72	0.34	0.85	0.77	0.99	0.98	1		
Fe	0.26	0.90	-0.24	-0.26	0.87	0.87	0.12	0.92	0.84	0.92	0.92	0.94	1	
Mn	0.62	0.57	-0.41	-0.44	0.52	0.52	0.41	0.69	0.74	0.90	0.90	0.95	0.87	1

Table 4 shows the correlation coefficient between physiochemical parameters and heavy metal concentrations in the studied fish pond water. It is interesting to note that when the EC is highest, the value of TDS is also highest and when EC is lowest, the TDS is also lowest. Similar relationships also existed between chloride and salinity, turbidity and salinity and, turbidity and chloride (Table 1 and 2).

To examine the relationship between these parameters, a correlation test was carried out and the results shows a good correlation between chloride and salinity (as 1), turbidity and salinity (as 1), turbidity and chloride (as 1) and TDS and EC (as 1). There is also a strong correlation between all the heavy metals and some of the physiochemical parameters such as turbidity, salinity, alkalinity and chloride. The perfect correlations between these parameters reflect their interconnected nature in the aquatic environment. Changes in one parameter often influence the others, making them valuable indicators for assessing water quality in constructed fish ponds. Understanding these relationships is essential for effective pond management and environmental monitoring.

6.0 CONCLUSION

Good water quality is very important for fish growth and survival. In this study, the quality of the source water was found to meet the WHO and Nigerian requirements (except for iron) as compared to that of the fish pond water which continued to have increasing level of deterioration in all parameters studied as the days go by. The high concentration of iron in source water implies that the borehole (source water) must be treated to reduce the iron concentration to the acceptable range before it could be used as source water to the fish pond. The increased concentrations of heavy metals above the permissible limit in the fish pond water are not desirable and beneficial for fish and human health. We recommend that the fish pond water must be routinely tested and renewed from time to time to keep the quality close to what is required for healthy production of fish. Further studies are needed to adequately give a time interval from when water is renewed to just when the deterioration is significant enough for intervention.

7.0 ACKNOWLEDGEMENT

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