

Assessment of the Seasonal Variation of Water Quality Parameters at Tamburawa Water Treatment Plant

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Abstract

Seasonal variation of physico-chemical water quality parameters (WQPs) for Tamburawa water treatment plant (WTP) has been evaluated using descriptive statistical analysis with the aid of Excel 2016 software, the study was conducted within the span of four hydrologic (year) cycle (four wet seasons and four dry seasons) using water sample been collected at Tamburawa WTP intake, on 19 WQP including water temperature, Turbidity, pH. Electrical conductivity, Alkalinity, Total Water Hardness, Free Carbon-dioxides, Calcium ion, Total suspended solids and total dissolved solids, nitrate and nitrite ions, Magnesium ion, Sulphate ion, Iron ion, Manganese ion, Fluoride ion, Chlorine ion and Aluminum ion. The results obtained shows Wide variation in average concentration of raw WQPs observed between the wet and dry seasons, where parameters including Turbidity and Total Suspended Solids are significantly higher in average concentration at wet seasons while Electrical Conductivity and Total Dissolved Solids are higher in average concentration during the dry seasons. Higher concentration of average Water Temperature and pH is also recorded in the wet and dry seasons respectively. Other parameters including Hardness, Calcium ion, SO₄ ion, Iron ion, Manganese ion, Fluoride ion, Nitrate ion, and Chlorine ion are averagely high in concentration during the wet seasons, while Magnesium ion is higher in dry seasons. Alkalinity and Nitrite ions are slightly higher in dry and wet seasons respectively. There is averagely no observed difference between wet and dry seasons in Al_{inf} concentration. All physico-chemical WQP were found be within the acceptable range of WHO/SON standards after treatment, indicating high efficiency of Tamburawa WTP in terms of drinking water production. These results will help in water quality management, decision making, policy adaptation, and risk management and strategies.

Keywords: WQPs, Seasonal Variation, WTP, Tamburawa, Wet Season, Dry Seasons

INTRODUCTION

Surface water quality has been identified as potentially vulnerable to long term (climate) changes as well as the short term (seasonal) variability of climate systems, phenomena which proved to have possesses the potentials of imposing additional pressure on the availability and accessibility of drinking water, both in quantity and quality if left unchecked (Chang, et al., 2015). International Panel on Climate Change (IPCC) has forecasted on its fifth report on climate change and water that; the world's average temperature will rise globally between 1.5 to 5.8 degrees Celsius (2.5 to 10.4 degrees Fahrenheit) between 1990 and 2100 (IPCC, 2007). The report precisely indicated that the global surface temperature increased by 0.74 °C, in the period between 1906 and 2005 and will continue to rise by an average of 0.2 °C per decade, a faster rate of warming very likely without precedent in the last 10,000 years, raising the risk of suffering from climate change towards the end of 21st century. Thus, it is unequivocal that long and short term climate induced variability effect on human is inevitable, with air temperature and precipitation (rainfall) as the lead drivers of such variations.

The potential impacts of the concurrent climate change and climate (seasonal) variability on water supply have received much attention in terms of availability and accessibility (Thorne and Fenner, 2009), but comparatively little is known about their concomitant effects on water quality. Nonetheless, it is recently estimated that in the next five decades, climate change and variability will severely affect the

quality and quantity of water resources for human consumption, (most especially drinking), and the availability of water in agriculture, resulting from the increase in the frequency of extreme events such as droughts and floods, thereby making policy adaptation very challenging (Murphy et. Al. 2014). Dams (reservoirs) represent hybrid systems of rivers and lakes (Chang, et al., 2015), and their water quality is not only influenced by human activities, but also by natural factors, such as the climate systems variability, hence, closed water basins, like lakes and reservoirs (Garg et al., 2010), are especially sensitive to climate systems variations, and many studies indicate that increases in water temperature are consistently associated with the increasing thermal stratification of such water bodies. Similarly, the duration for thermal stratification is projected to be prolonged due to the increased air temperature. Under these conditions, the periods of overturn that bring a fresh supply of oxygen to the deeper layers would also be prolonged, resulting to an increased nutrients load after thermal stratification (Zhu, et al., 2013). Moreover, shallow lakes are likely to be the most vulnerable to climate system variations, because water temperatures have an impact on internal lake processes like diffusion, mineralization and vertical mixing (Malmaeus et al., 2006). Therefore, stratification period of lakes would probably increase in summers by more than 90% in 2050 for lakes with short stratification period, (George et al. 2007). It is also predicted that shallow lakes will experience an epilimnion and

hypolimnion increase in temperature during summer (Jöhnk et al., 2008), although dam reservoirs may even respond more directly to weather variations (Mooij et al., 2005).

Nevertheless, deep lakes and dam reservoirs are the most sensitive to climate warming on a long period of time due to their greater heat storage capacity and will consequently show the highest winter temperatures (George et al., 2007). An increase in water temperature also have an impact on lakes chemical processes with increases in pH and greater in-lake alkalinity generation (Psenner and Schmidt, 1992). Depending upon site conditions and differences in climate (seasonal) variability pattern, the total nitrogen of a warmer climate zone that has decreased precipitation is observed to have increases, while total phosphorus and Chlorophyll-*a* decreases. Likewise, the sensitivities of reservoirs of different ages to climate change varies remarkably when reservoir's internal environment changes from an abiotic to a biotic ecosystem, such as lake (Duan et. Al. 2009). Therefore, empirical studies which assess the climate system variability impacts on reservoirs on a regional or climate system specific scale are needed to help determine the appropriate adaptation strategies for public water supply agencies/industries. (Kim et. Al. 2001).

Despite the fact that recently, several studies have and are still being conducted on evaluation of the impacts of climate change on water quality of freshwater ecosystems, such as natural lakes and streams, limited information is available for man-made ecosystems

such as dam reservoirs, and they are the major sources of public waters utilities in most of the developing countries. Good number of studies shows that the thermal stratification period of several lakes in Europe and Northern America have increased by about 2 to 3 weeks, and water temperatures have risen between 0.2 to 1.5 °C, which have significant influence on thermal stratification (Komatsu et al., 2007) and lakes' hydrodynamics (Bates et al., 2008). (Tibby and Tiller 2007) analyzed over 15 years of water quality monitoring data from three lakes from Western Victoria, Australia, and their relationship to climate (seasonal) variability. They found that there are strong correlations between climate system variability and water quality in these lakes of different sizes. Computer models also predicts an increase in ambient water temperature of European lakes to around 2 °C by 2070, although this rise in temperature will also depend on lake characteristics and seasonal variations (George et al., 2007, Malmaeus et al., 2006). However, similar information is mostly lacking for the streams, lakes and man-made reservoirs (Dams) from the developing countries, most especially the sub-Saharan African, hence needed.

Water quality in reservoir varies seasonally with high and low inflow precipitation during the wet and dry seasons, and high and low temperature during hot and cold seasons respectively, wind effect also plays a significant role. In tropical regions like northern Nigeria, reservoir water quality gets impacted with the seasonal variation of climate systems (Sawa, 2002). During rainy seasons, reservoirs

receives inflow of rain water from adjacent environment which carries along so many forms of pollutants including eroded soil sediments (Adamu et al. 2015), mineral nutrients and salts, human pathogens, dissolved organic carbon, agricultural pesticides, etc., whose inflow into reservoir exacerbates deterioration of water quality (Sulaiman. 2006), having adverse impact on human health and increases operating and maintenance cost of water treatment facilities (Murphy et. Al. 2014).

Paradoxically, where rain water inflow tends to be high, natural purification processes takes place through the process of dilution, where the inflow tends to be very low, the purification takes place by aeration, sedimentation, gas transfer and down flow filtration. Also, in dry seasons, reservoir pollution results from increase in temperature which promotes algal blooms, and also from bacterial and fungal growth. Purifications processes like gas and heat transfer, chemical conversions and metabolic reactions also follows depending on seasonality of the environment and weather condition, (peavey et, al. 1985).

Raw water from these reservoirs among other functions serves as sources of water to water treatment plants (WTP), which is usually collected at the intakes. In conventional water treatment process, series of procedural unit processes are often involved, these unit processes comprise of coagulation-flocculation, sedimentation-filtration, aeration, disinfection, heavy metals removal etc., Combination of two or more unit processes may be considered

depending upon the raw water quality, the anticipated treated water quality, and the costs of production. (Kalibbala, 2007).

Due to the complexities of the relationship between unit water treatment processes and other constraints involved in the treatment processes, which includes the continuous daily and seasonal variation of raw water quality, that often necessitates numerous water sampling, laboratory tests, and analyses for proper monitoring and evaluation, there is a need for water quality management policies and planning strategies to assist water treatment utility operators and managers in risk management and policy adaptation. Previous studies have acknowledged strong correlations between seasonal variability of climatic systems, water quality (Linden et al. 2004), and water treatment operations (Hurst et al. 2004).

PROBLEM STATEMENT

Although the effects of climate systems variability and associated risks on water availability have been broadly studied for many decades, and their implications for water resource management have been widely acknowledged, studies on the effects of these climate-related variability on water quality have only recently received attention (Whitehead et al., 2009). This created a disconnect between the connectivity of water quality and climate system variability on one hand and the elasticity of water quality parameters to changes in climate system variability on the other (Whitehead et al., 2009). While many

research focuses more on the implication of climate system variability on water quantity with respect to extreme events such as droughts and floods, little attention has been given to the effects of the same climate system variability on water quality, thus overlooking the anticipated risk these variations may pose to water treatment plant operations, policy adaptation, and drinking water production.

In situations where climate system variability has been acknowledged as an important regulatory factor capable of influencing water quality system management and water production utilities maintenance, management, and operations (Law et al. 2009), the impact mechanisms of such variability on water quality management and operations have still not been fully comprehended.

MATERIALS AND METHODS

THE STUDY AREA (New Tamburawa Water Treatment Plant):

The Tiga dam reservoir Latitude $11^{\circ} 26' 8.39''$ N, Longitude: $8^{\circ} 24' 5.39''$ E south eastern part of Kano city was constructed as a medium earth dam, completed in 1975. The reservoir is located some 70 km away from Kano city, it is a major reservoir along the tributary of Kano river, the main tributary of the Hadejia river. The reservoir has a total catchment area of 6,641 km², covers an area of 178 Km² with maximum capacity of nearly 2,000,000 cubic metres (71,000,000 cu ft). Water from the reservoir supplies the Kano River Irrigation Project as well as Kano metropolitan.

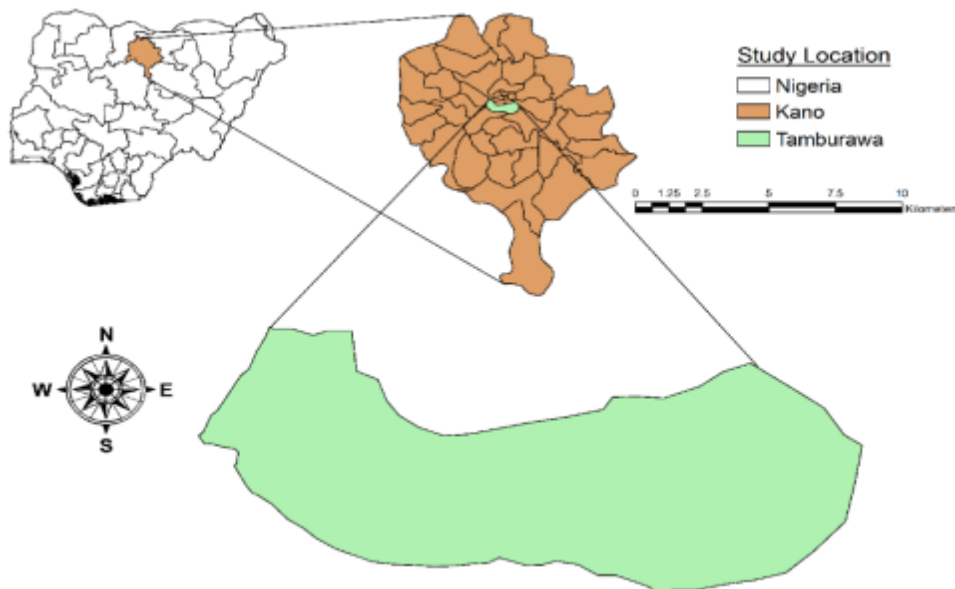


Figure 1 showing the location of Tamburawa water treatment plant

The construction of Tamburawa water treatment plants, named as old and new Tamburawa, water works commenced in the year 1986 with initial

capacity of 9.6 million liters of water, and was later upgraded to supply 20 Million litres, while the New Tamburawa water treatment plants

(WTP) which is an ultra-modern, world class water treatment plant constructed by Kano state government and completed 2008. The new Tamburawa Water Treatment Plant is a conventional WTP that has the capacity to deliver 150ML of potable water per day to the city of Kano and surrounding areas. The raw water is sourced from the Kano River downstream of Tiga dam, being carefully controlled at the spillways of the dam. The raw water intake pump station is sited on the south bank of the Kano River, before the confluence of the river with river Challawa, barricaded with concrete barrier to prevent the mixture of water from Tiga Dam with the Challawa river (which is heavily loaded with industrial pollution). Thus, the only anticipated source of pollution at the intake is that of agricultural waste from farmlands. The Tamburawa WTP utilises a

conventional treatment train involving aluminum coagulation-flocculation, dissolved air flotation with sand filtration (DAFF) and chlorination disinfection process, to produce potable water that would readily exceeds World Health Organisation's (WHO) minimum requirements for drinking water.

Pre-chlorine and pre-soda ash are dosed immediately after the inlet tower when required, while Powdered activated carbon (PAC) is added intermittently to respond to the issues of unacceptable taste and odor at the reservoir off take, Post-chlorine and post-soda ash are dosed before the treated water enters the contact tank. The WTP has a maximum capacity of 150ML/day and supplies to the Kano city and its surrounding environs, in addition to water supplied from Challawa and Watari water works.



Plate (1-6) pictorial view of Tamburawa water works

DATA COLLECTION:

Water Quality Data: The water quality parameters required for this study were generated through continuous monitoring of the water quality of Tiga (Dam) water reservoir, being controllably released into Kano river, collected and measured through the Tamburawa WTP intakes (plate). The physico-chemical water quality parameters are monitored on weekly basis for both raw and treated water samples, while operational parameters that are directly linked with WTP operations, and chemicals demand are measured during treatment operations (once or twice each day), depending upon the seasons and raw water quality (Turbidity particularly). Water samples were collected by grab sampling technique at the depth of 15cm below the water surface at the sampling points. Temperature, pH, electrical conductivity and total dissolved solids were measured onsite using thermometer, pH meter, electrical conductivity meter respectively. Other parameters including turbidity, total dissolved solids, total suspended solids, metals and non-metals were measured in the laboratory by chemical titration, photometric, spectrometric and other multi parameter water quality monitoring instruments accordingly. The water quality parameters that were frequently monitored (daily) at the Tamburawa WTP includes: water temperature, Turbidity, pH. Total suspended solids and total dissolved solids, whereas other parameters like alkalinity, water total hardness, free carbon dioxides, calcium hardness, nitrates, nitrite, etc are monitored over

regular intervals of weekly basis. Both parameters were measured and recorded concurrently to ensure correspondence during analysis.

Seasonal Water Quality Variation Assessment: Kano state used to have been identified with a very long dry season which extends from middle of October to late May, largely associated to a sparse rainfall pattern and low amount of rainfall in wet season, making reliance on its water resources for developmental and economic activities of the state very critical (Sani et. al, 2009). The water resources of the state are under severe stress due to poor climatic conditions and competing demands due to the state's rapid population growth (Garba et. al 2015). Climatic conditions in the region are such that there is high variability in both temporal and spatial distribution of rainfall over the basin causing a corresponding high variability in stream flow.

To ensure an established strategy for water quality management, analysis of past trend and study of present status of water quality parameters is very essential. Hence, descriptive statistical method of analysis was used for the assessment of seasonal changes in the reservoir water quality using Excel 2016 model, the physico-chemical water quality parameters collected from the monitoring station along the study area which extends to the range of four year cycles (four wet seasons and four dry seasons) were used to evaluate the variations of water quality of the study area at different seasons of the year. The analyses were carried out separately both on the wet and dry

seasons to establish the seasonality of the water quality variables, and then, compared with annual data, to establish the seasonality of the water quality parameters (WQP).

Assessment for the seasonal changes of water quality was carried out on the physico-chemical raw water quality parameters to establish the basis of this study. Descriptive statistical analysis summary results for the water quality of both annual, dry and wet seasons are presented in Tables 1, 2 and 3 respectively. While Table 1 shows the statistical analysis summary for the raw

water quality parameters on annual data, Table 2 shows the statistical analysis summary for raw water quality parameters during the dry seasons, and table 3 shows the statistical analysis summary for raw water quality parameters at wet seasons. Table 4 compares the mean concentration of physico-chemical water quality parameters between annual, wet and dry seasons.

Table 1: Descriptive Statistical Analysis Summary of Raw Water Quality Parameters at Tamburawa WTP (Annual Data)

Parameter	Minimum	Maximum	Mean	Range	Standard Deviation	Sample Variance
<i>WT_{inf}</i>	15.70	31.10	25.13	15.40	3.45	11.90
<i>Turb_{inf}</i>	62.00	1796.00	231.58	1734.00	242.54	58823.63
<i>pH_{inf}</i>	5.90	9.90	7.77	4.00	0.79	0.63
<i>E C_{inf}</i>	8.30	956.00	101.65	947.70	91.87	8439.33
<i>Alk_{inf}</i>	45.00	86.00	57.64	41.00	8.01	64.15
<i>Hardness_{inf}</i>	19.95	53.87	35.92	33.92	5.97	35.61
<i>Ca_{inf}</i>	5.40	39.65	10.43	34.25	2.78	7.74
<i>FREE CO_{2inf}</i>	4.00	8.00	6.59	4.00	1.06	1.12
<i>TDS_{inf}</i>	17.90	462.00	51.01	444.10	44.42	1973.17
<i>TSS_{inf}</i>	58.00	1530.00	223.81	1472.00	214.02	45805.61
<i>Mg_{inf}</i>	1.64	4.38	3.14	2.74	0.44	0.19
<i>SO_{4inf}</i>	0.00	8.00	1.26	8.00	0.97	0.93
<i>Fe_{inf}</i>	0.76	8.90	2.16	8.14	1.69	2.85
<i>Mn_{inf}</i>	0.00	4.03	1.04	4.03	0.87	0.76
<i>F_{inf}</i>	0.14	13.30	3.13	13.16	2.04	4.15
<i>NO_{3inf}</i>	0.40	12.90	3.67	12.50	2.86	8.19
<i>NO_{2 inf}</i>	0.01	0.07	0.03	0.06	0.01	0.00
<i>Cl_{inf}</i>	8.38	27.63	12.46	19.25	2.77	7.70
<i>Al_{inf}</i>	0.01	0.65	0.05	0.64	0.07	0.00

Table 2: Descriptive Statistical Analysis Summary of Raw Water Quality Parameters at Tamburawa WTP (Dry Seasons)

Parameter	Minimum	Maximum	Mean	Range	Standard Deviation	Sample Variance
WT_{inf}	15.70	31.10	23.46	15.40	3.43	11.75
$Turb_{inf}$	62.00	237.00	113.50	175.00	43.32	1876.43
pH_{inf}	5.90	9.90	7.84	4.00	0.87	0.75
EC_{inf}	8.30	956.00	108.78	947.70	119.31	14235.18
Alk_{inf}	45.00	86.00	57.85	41.00	9.16	83.92
$Hardness_{inf}$	19.95	40.41	33.77	20.46	4.03	16.21
Ca_{inf}	7.21	11.72	9.91	4.51	0.98	0.96
$FREE\ CO2_{inf}$	4.00	8.00	6.34	4.00	1.10	1.20
TDS_{inf}	20.50	462.00	53.34	441.50	58.19	3385.53
TSS_{inf}	58.00	231.00	118.19	173.00	37.67	1418.88
Mg_{inf}	1.64	3.29	3.15	1.65	0.41	0.17
$SO4_{inf}$	0.00	2.00	1.00	2.00	0.38	0.14
Fe_{inf}	1.03	2.80	1.48	1.77	0.45	0.20
Mn_{inf}	0.00	1.68	0.44	1.68	0.51	0.26
F_{inf}	1.26	7.50	2.40	6.24	0.95	0.90
$NO3_{inf}$	0.40	12.90	3.10	12.50	2.33	5.42
$NO2_{inf}$	0.01	0.05	0.03	0.04	0.01	0.00
Cl_{inf}	8.38	12.84	11.46	4.46	1.21	1.45
Al_{inf}	0.01	0.65	0.05	0.64	0.10	0.01

Table 3: Descriptive Statistical Analysis Summary of Raw Water Quality Parameters at Tamburawa WTP (Wet Seasons)

PARAMETERS	Minimum	Maximum	Mean	Range	Standard Deviation	Sample Variance
WT_{inf}	17.61	31.00	27.15	13.39	2.15	4.63
$Turb_{inf}$	64.00	1796.00	374.78	1732.00	301.38	90832.76
pH_{inf}	6.10	9.50	7.69	3.40	0.69	0.48
EC_{inf}	20.20	259.00	92.99	238.80	36.74	1349.56
Alk_{inf}	45.00	70.00	57.39	25.00	6.38	40.71
$Hardness_{inf}$	22.45	53.87	38.54	31.42	6.85	46.98
Ca_{inf}	5.40	39.65	11.05	34.25	3.92	15.36
$FREE\ CO2_{inf}$	4.00	8.00	6.88	4.00	0.94	0.88
TDS_{inf}	17.90	106.40	48.19	88.50	16.24	263.58
TSS_{inf}	63.00	1530.00	351.90	1467.00	264.52	69971.99
Mg_{inf}	1.67	4.38	3.13	2.71	0.48	0.23
$SO4_{inf}$	0.00	8.00	1.57	8.00	1.31	1.73
Fe_{inf}	0.76	8.90	2.74	8.14	2.10	4.41
Mn_{inf}	0.06	4.03	1.54	3.97	0.80	0.64
F^{-}_{inf}	0.14	13.30	3.75	13.16	2.48	6.14
$NO3_{inf}$	0.40	11.20	4.15	10.80	3.19	10.21
$NO2_{inf}$	0.01	0.07	0.04	0.06	0.01	0.00
Cl^{-}_{inf}	8.88	27.63	13.31	18.75	3.40	11.55
Al_{inf}	0.01	0.10	0.05	0.09	0.03	0.00

Further statistical analysis was also carried out on the treated water produce at the Tamburawa water treatment plant within the span of this study period to investigate the concurrent seasonal changes of the treated water quality parameters, for the conformity of the drinking water production with WHO standards. Table 4 shows the summary statistical analysis of the treated and its conformity with the WHO standard.

While, Pearson's Correlation Analysis which is a probability-based cumulative distribution functions that differs from common statistical averages (like the descriptive statistical analysis) was further used to evaluate the seasonal correlations between the water quality parameters, in order to extract the parameters whose seasonal variation most significantly affects the water treatment operations of the study area.

Table 4: Statistical Analysis Summary for Treated WQP in Conformity with WHO Standard

PARAMETERS	Minimum Value		Maximum Value		Mean Value		Ranges		
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Desirable range
	Season	season	Season	Season	Season	season	Season	Season	
<i>WT_{inf}</i>	15.70	17.61	31.10	31.00	23.46	27.15	15.40	13.39	15 - 25
<i>Turb_{eff}</i>	0.00	0.00	5.00	7.20	0.78	1.35	5.00	7.20	<5
<i>pH_{eff}</i>	6.30	6.00	8.70	7.80	7.14	6.72	2.40	1.80	6.5 - 8.5
<i>E C_{eff}</i>	19.66	45.00	787.00	362.00	177.79	174.93	767.34	317.00	1000.00
<i>Alk_{eff}</i>	20.00	20.00	25.00	25.00	23.17	23.62	5.00	5.00	20-200
<i>Hardness_{eff}</i>	15.10	21.30	31.42	47.13	24.70	29.57	16.32	25.83	60 - 120
<i>Ca_{eff}</i>	5.47	7.20	9.01	27.03	7.70	8.40	3.54	19.83	75.00
<i>FREE CO₂_{eff}</i>	3.00	3.00	9.72	37.65	7.39	8.78	6.72	34.65	<50
<i>TDS_{eff}</i>	8.80	26.70	108.00	175.80	45.57	59.40	99.20	149.10	<300
<i>TSS_{eff}</i>	0.00	0.00	4.00	7.00	0.98	1.92	4.00	7.00	<25
<i>Mg_{eff}</i>	1.09	1.64	2.19	3.83	2.08	2.24	1.10	2.19	<30
<i>SO₄_{eff}</i>	10.00	12.00	29.00	56.00	18.12	31.51	19.00	44.00	<250
<i>Fe_{eff}</i>	0.03	0.01	0.22	0.23	0.08	0.10	0.19	0.22	<0.3
<i>Mn_{eff}</i>	0.00	0.00	0.07	0.09	0.03	0.04	0.07	0.09	<0.05-(0.4 MAC)
<i>F_{eff}</i>	0.04	0.04	0.53	0.67	0.12	0.20	0.49	0.63	<1.0
<i>NO₃_{eff}</i>	0.65	0.06	3.30	6.50	1.50	1.25	2.65	6.44	<10
<i>NO₂_{eff}</i>	0.00	0.00	0.03	0.03	0.01	0.01	0.03	0.03	<1.0
<i>Cl_{eff}</i>	16.78	10.88	56.26	75.01	26.89	28.43	39.48	64.13	<250
<i>Al_{eff}</i>	0.02	0.04	0.87	0.18	0.11	0.11	0.85	0.15	<0.2-(2.9 MAC)

RESULTS AND DISCUSSIONS

Seasonal Raw Water Quality Variation Assessment: The results of the seasonal variation assessment show wide variation in average concentration of raw water quality parameters observed between the wet and dry seasons, where parameters including *Turb_{inf}* and *TSS_{inf}* are significantly higher in wet seasons while *EC_{inf}* and *TDS_{inf}* are higher in concentration during the dry seasons. Higher concentration of average *WT_{inf}* and *pH_{inf}* is also recorded in the wet and dry seasons respectively. Other parameters including *Hardness_{inf}*, *Ca_{inf}*, *SO₄_{inf}*, *Fe_{inf}*, *Mn_{inf}*, *F_{inf}*, *NO₃_{inf}* and

Cl_{inf} are averagely high in concentration during the wet seasons, while *Mg_{inf}* is higher in dry seasons. *Alk_{inf}* and *NO₂_{inf}* are slightly higher in dry and wet seasons respectively. There is averagely observed difference between wet and dry seasons in *Al_{inf}* concentration.

The average variation in mean concentration of raw water quality parameters are presented in figure (2 and 3). While, the trends of the seasonal variation of the physico-chemical water quality parameters are presented in figure 4 (a-s) using box and whisker plots.

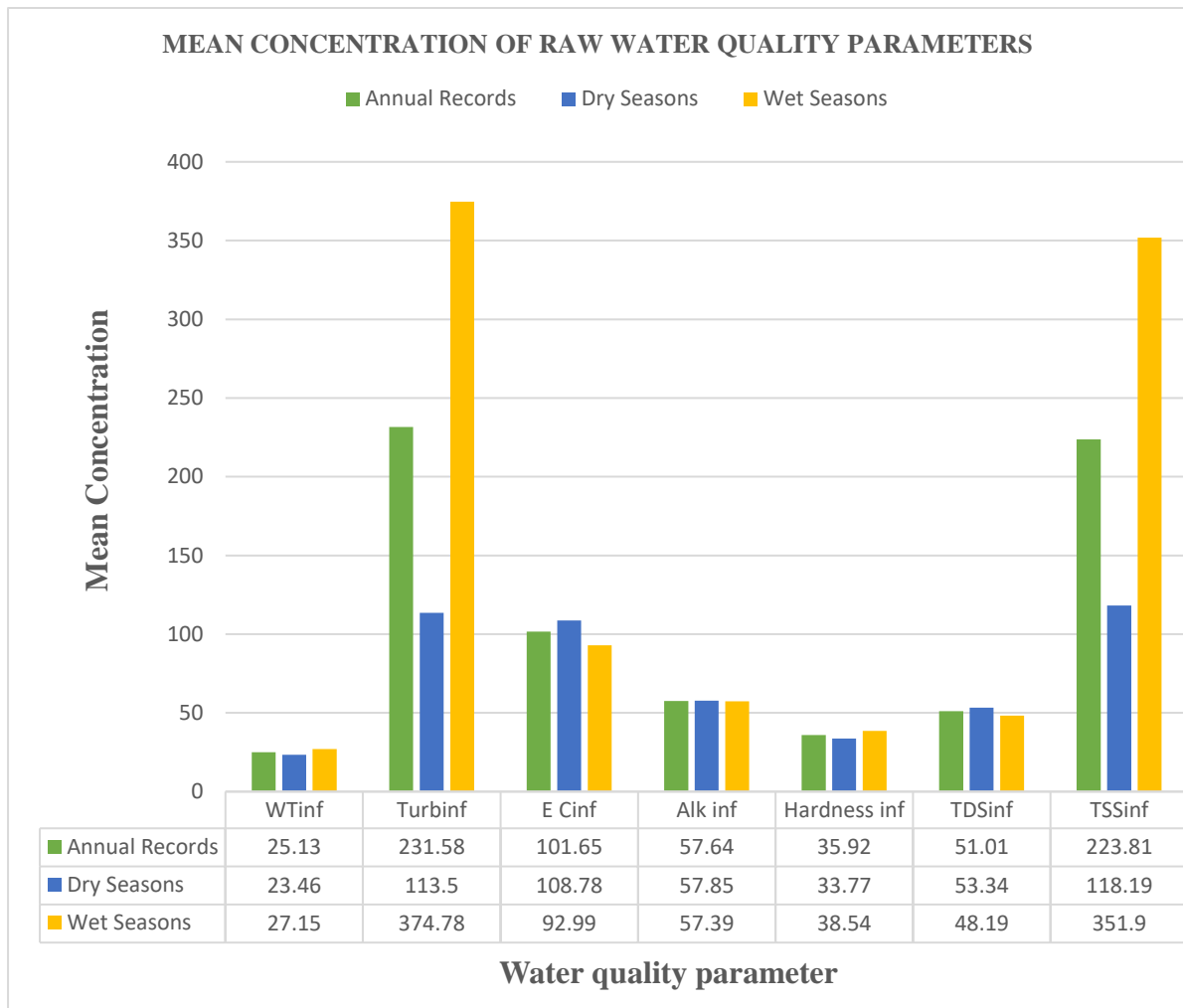


Figure 2 Seasonal variation of raw water quality parameters (mean concentration)

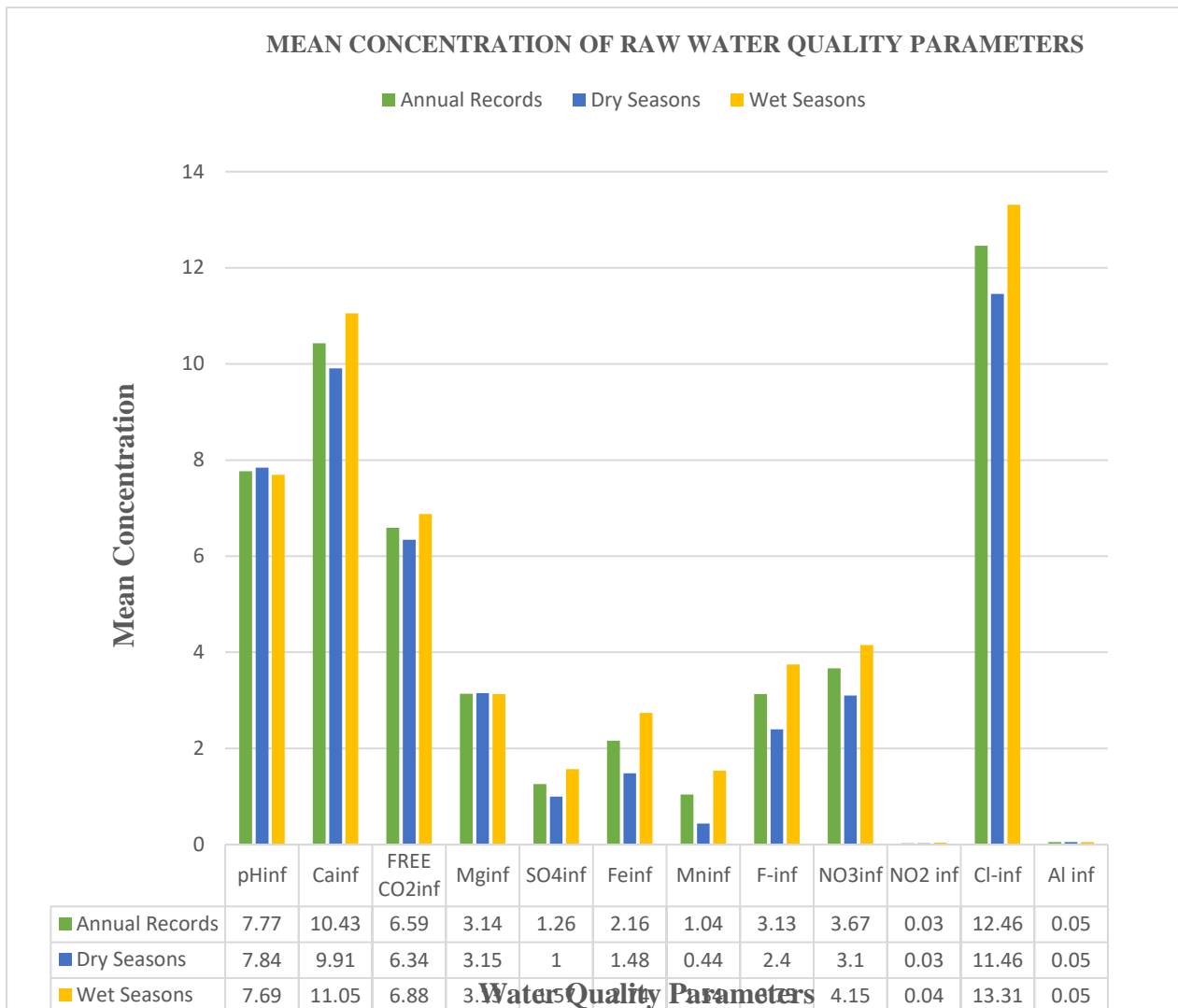


Figure 3 Seasonal variation of raw water quality parameters (mean concentration)

Higher average raw water temperature (WT_{inf}) of $27.15^{\circ}C$ was recorded at wet seasons, with lowest value ($15.70^{\circ}C$) recorded during the dry seasons, and the highest ($31.1^{\circ}C$) at wet seasons. Average water turbidity ($Turb_{inf}$) is recorded to be higher (374 NTU) during the wet seasons, with highest value (1796 NTU) recorded at wet season while lower recorded (62NTU) in dry season.

The higher average concentration of turbidity during the wet seasons can be linked to the high inflow of runoff water that is generally associated with

the soil erosion of adjacent farm lands within the entire catchment area of the Kano river, this coupled with continues agricultural activities leading to the loses of soil and subsequent deposition into the water as it travels. Likewise, the increase in average concentration of other parameters like total suspended solids, calcium, sulphate, iron, manganese, fluoride, nitrogen nitrate, nitrogen nitrite, and chloride ions etc., can all be linked with soil degradation and deposition in the water resulting from either farming activities, soil erosion as the rain falls, and/or resuspension of mineral deposits

present in the water bodies. In the dry seasons excessive water evaporation related to the climate of Kano region can be attributed to the higher average concentration of parameters like the magnesium ions, total dissolved solids, electrical conductivity etc.

In the dry seasons more than 50% of all the temperature record for all the seasons falls below 25°C with minimum and maximum values as 15 °C and 31 °C respectively, whereas in the rainy seasons more than 50% of the temperature records in all the four seasons are above 25°C with minimum and maximum values as 17 °C and 31 °C respectively (Figure 4a). In the case

of turbidity most of the values falls below 120 NTU in the dry seasons with minimum and maximum values as 62NTU and 237NTU respectively, while in rainy seasons more than half of the values are above 250 NTU with the minimum and maximum values recorded as 64 and 1796NTU respectively (Figure 4b).

Raw water pH also slightly varies in wet and dry seasons (Figure 4c), the raw water pH ranges between 5.9 to 9.9 in the dry seasons, and 6.1 to 9.5 in the wet seasons. Yet, higher percentage of the pH values in both dry and wet seasons are within the WHO recommended range of 6.5 to 8.5

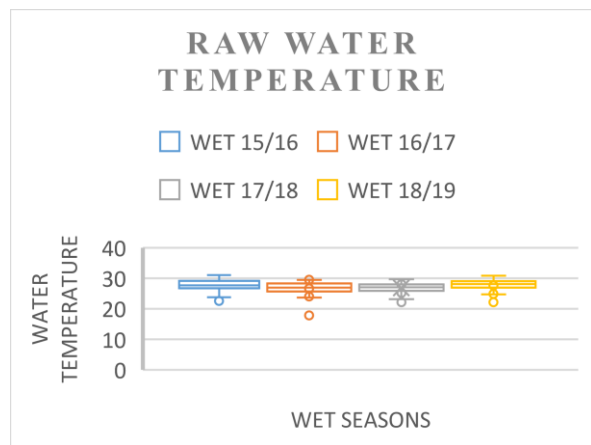
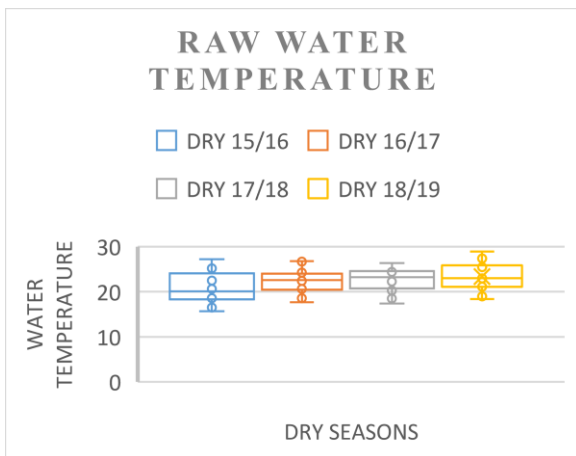


Figure 4a Seasonal variations of raw water temperature

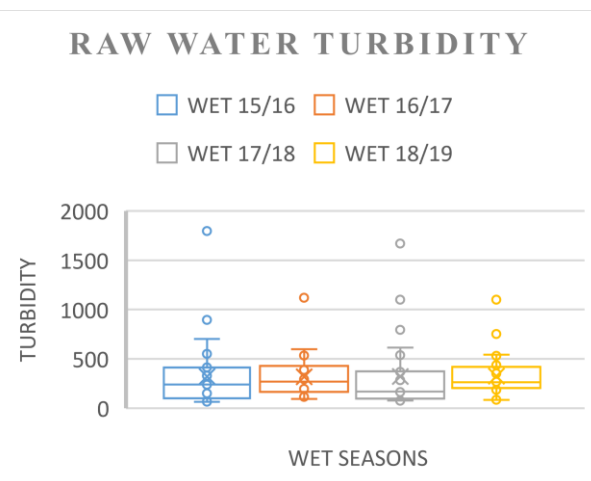
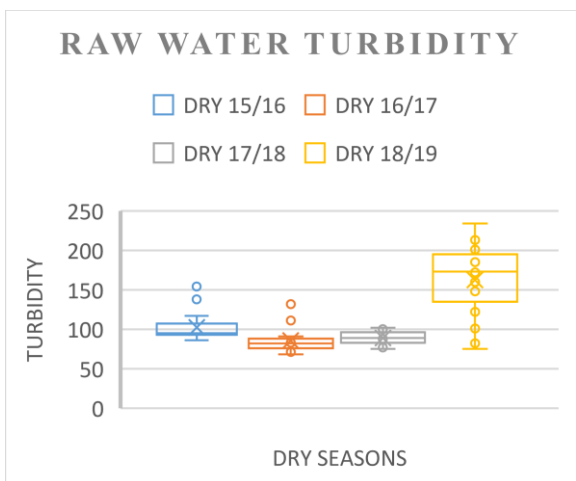


Figure 4b Seasonal variations of raw water turbidity

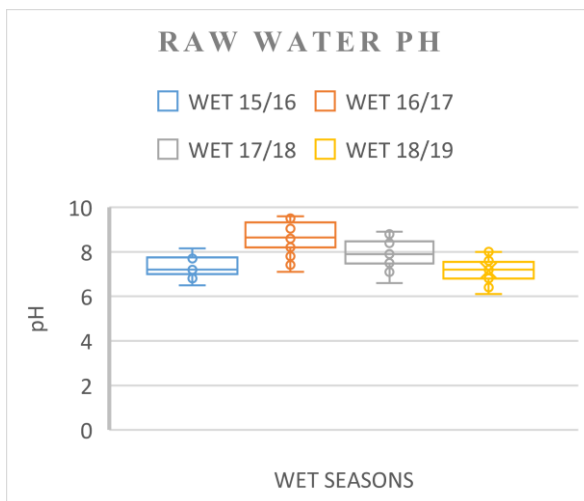
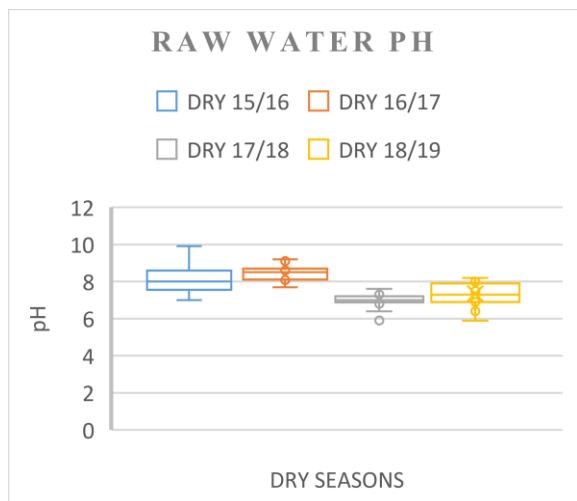


Figure 4c Seasonal variations of raw water pH

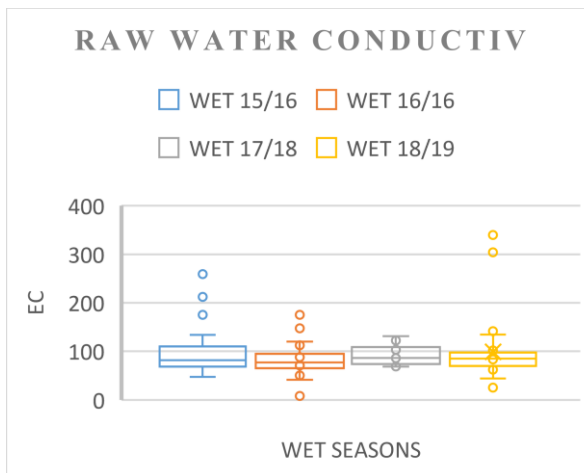
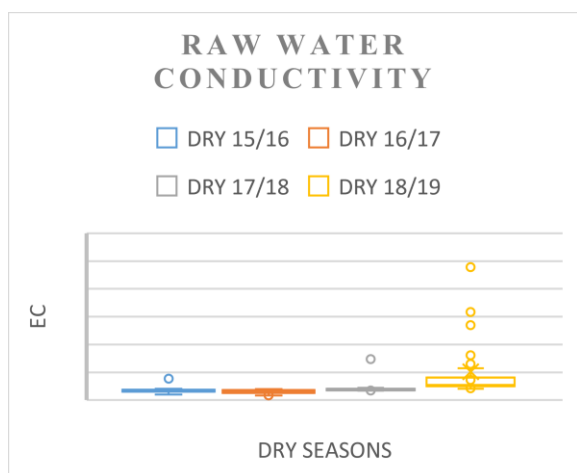


Figure 4d Seasonal variations of raw water conductivity

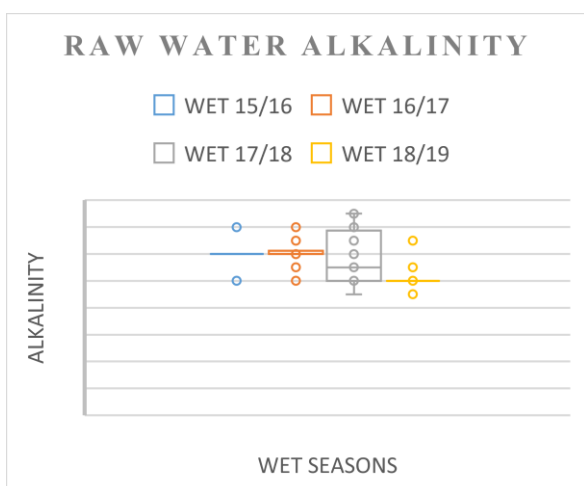
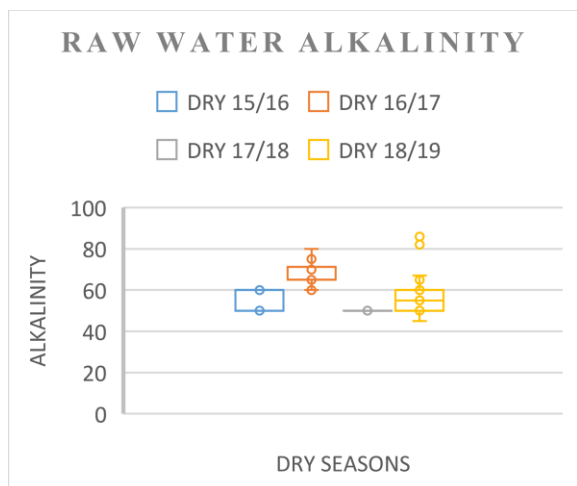


Figure 4e Seasonal variations of raw water alkalinity

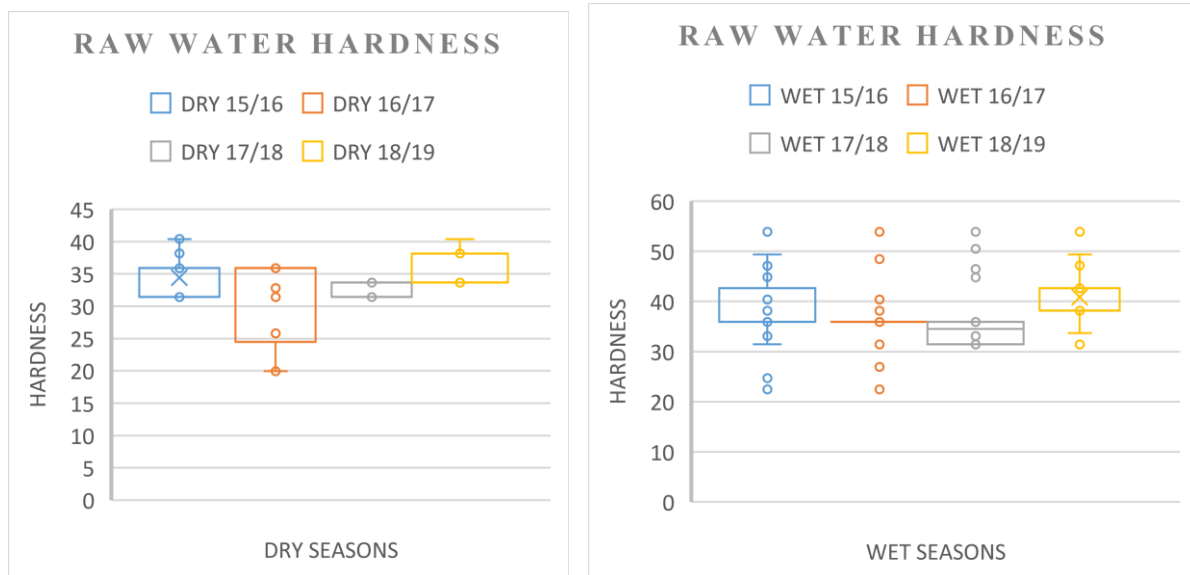


Figure 4f Seasonal variations of raw water hardness

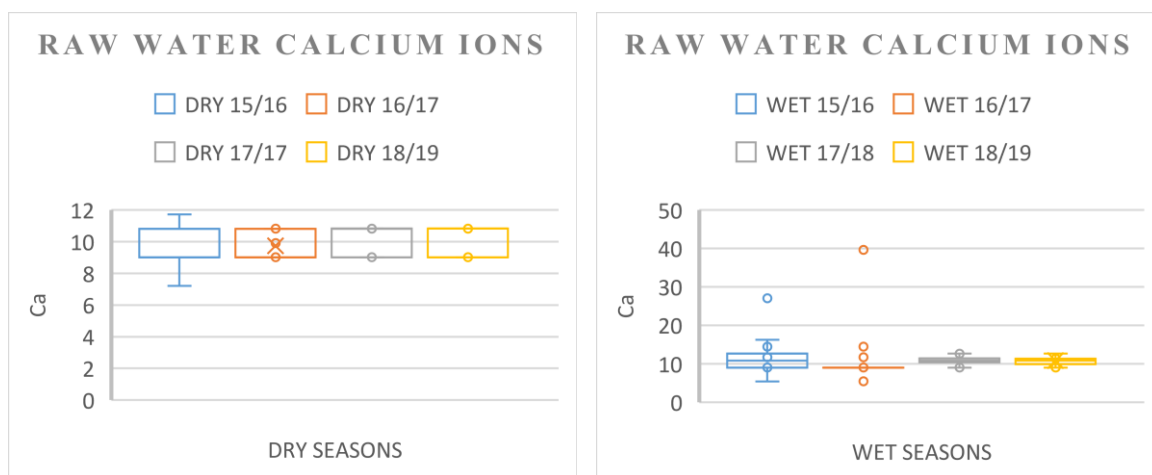


Figure 4g Seasonal variations of raw water calcium ions

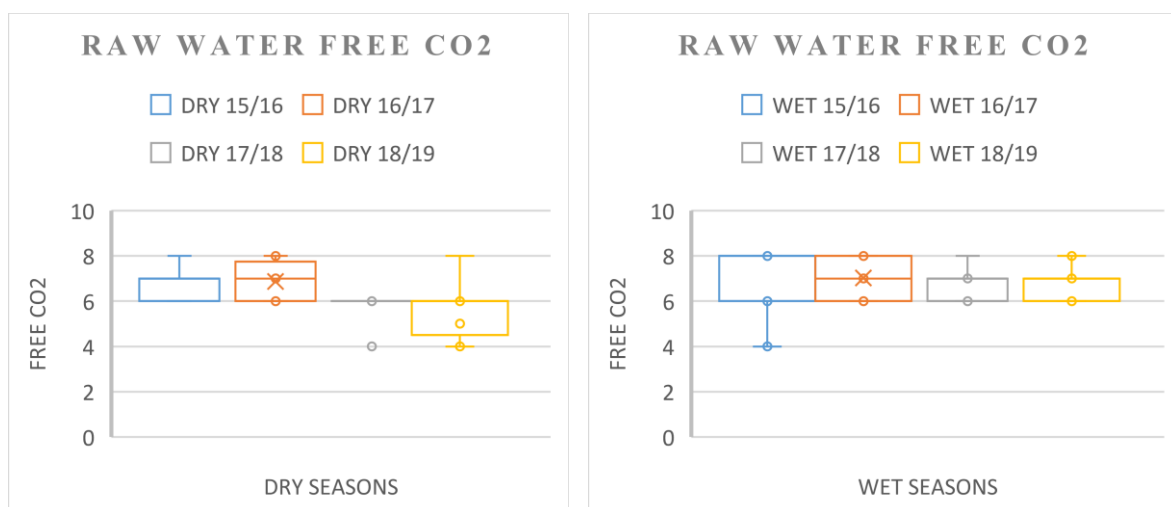


Figure 4h Seasonal variations of raw water free carbon dioxides

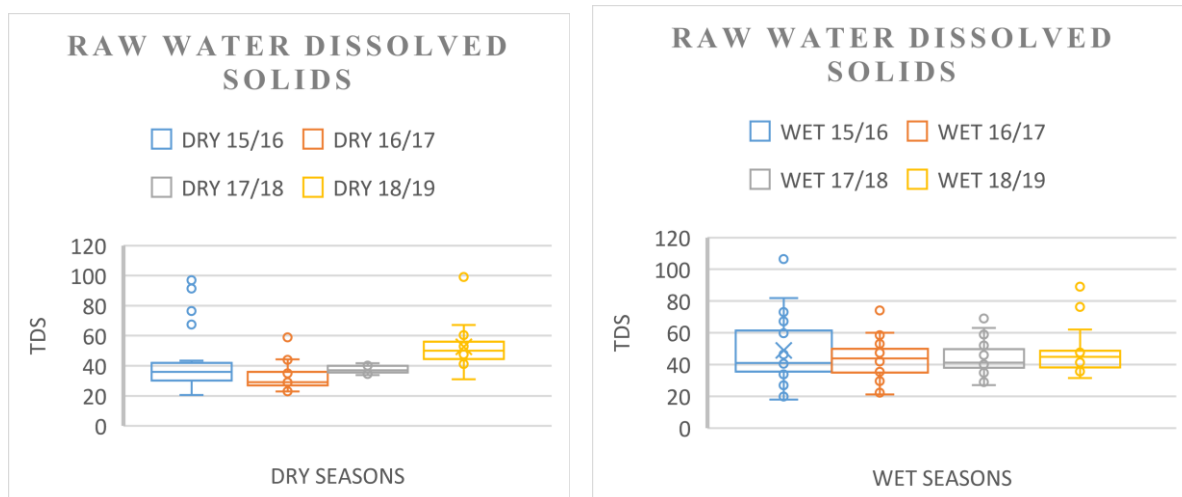


Figure 4i Seasonal variations of raw water total dissolved solids

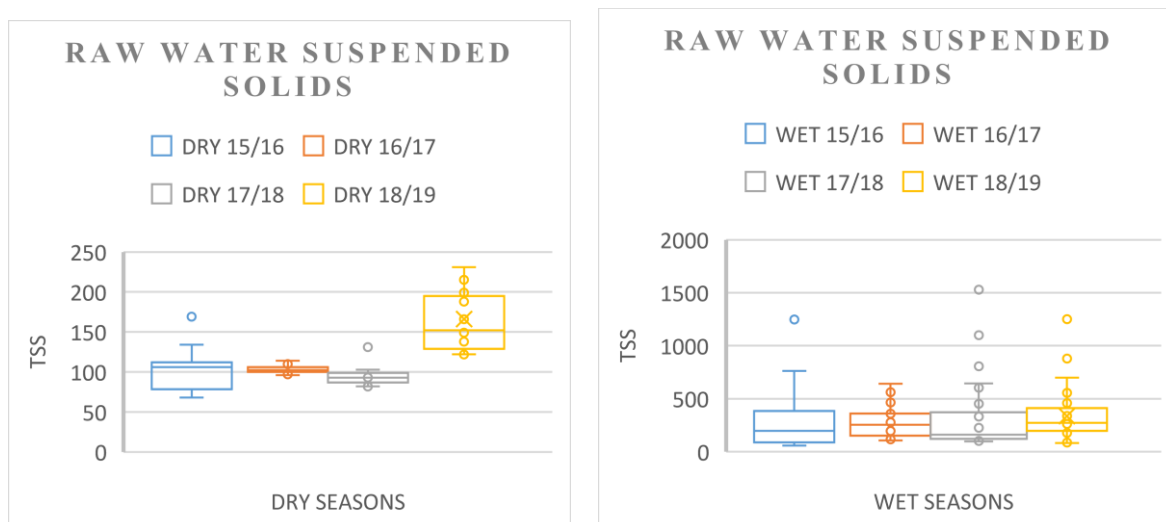


Figure 4j Seasonal variations of raw total suspended solids

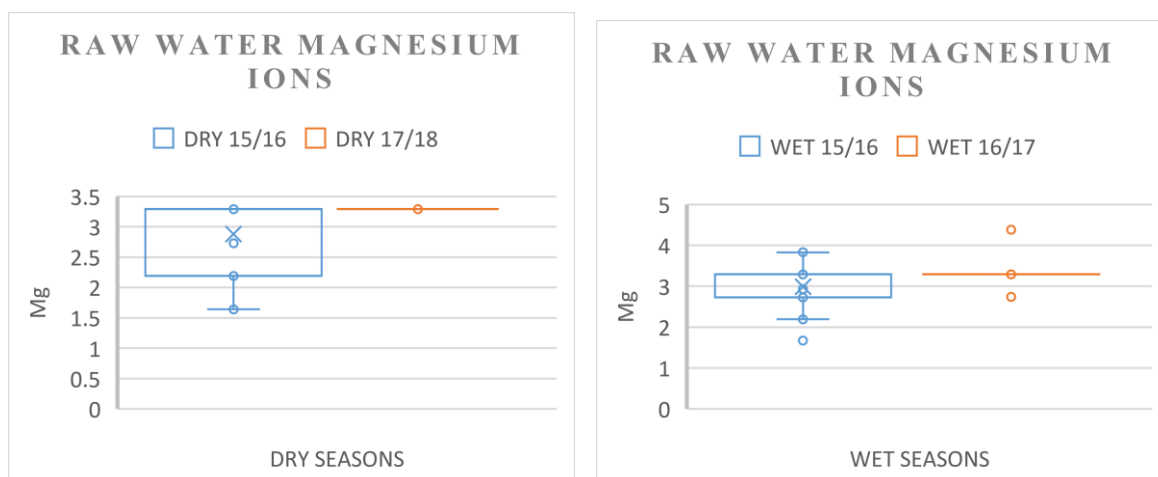


Figure 4k Seasonal variations of raw water magnesium ions

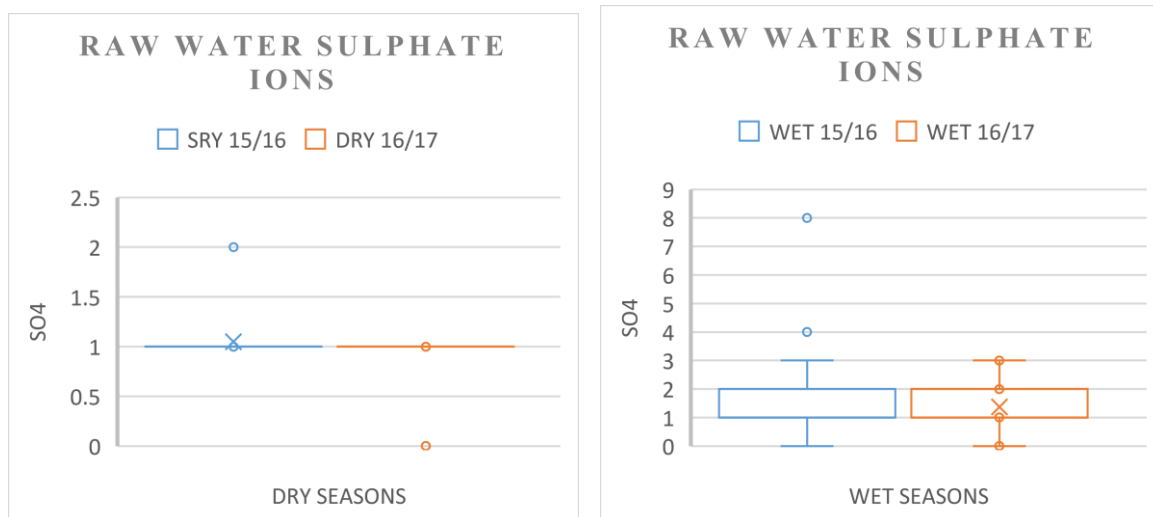


Figure 4l Seasonal variations of raw water sulphate ions

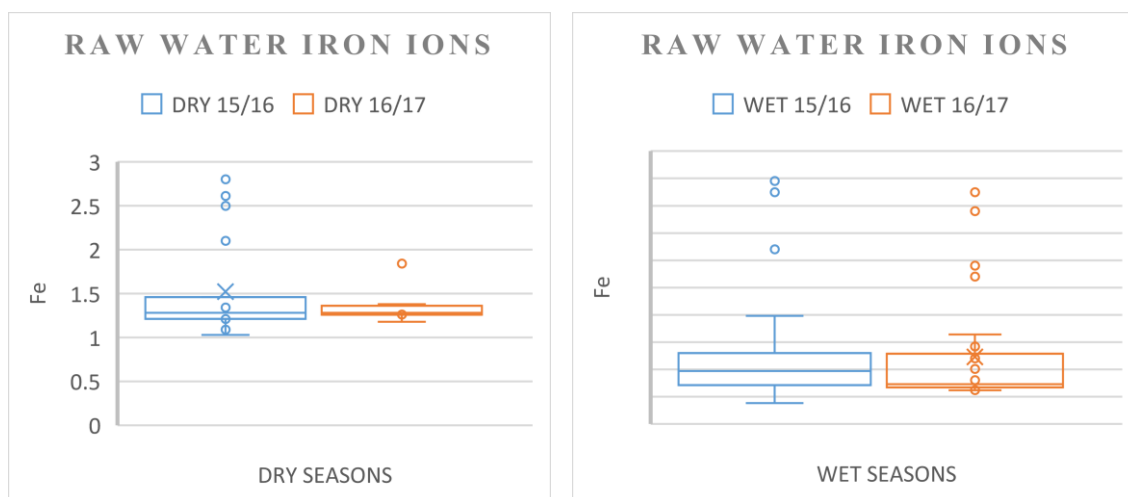


Figure 4m Seasonal variations of raw water iron ions

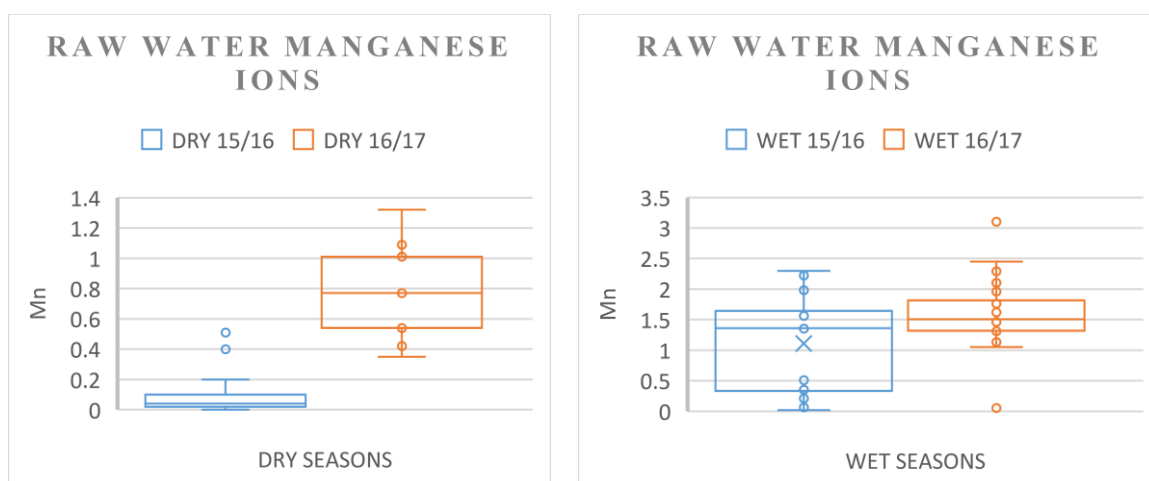


Figure 4n Seasonal variations of raw water manganese ions

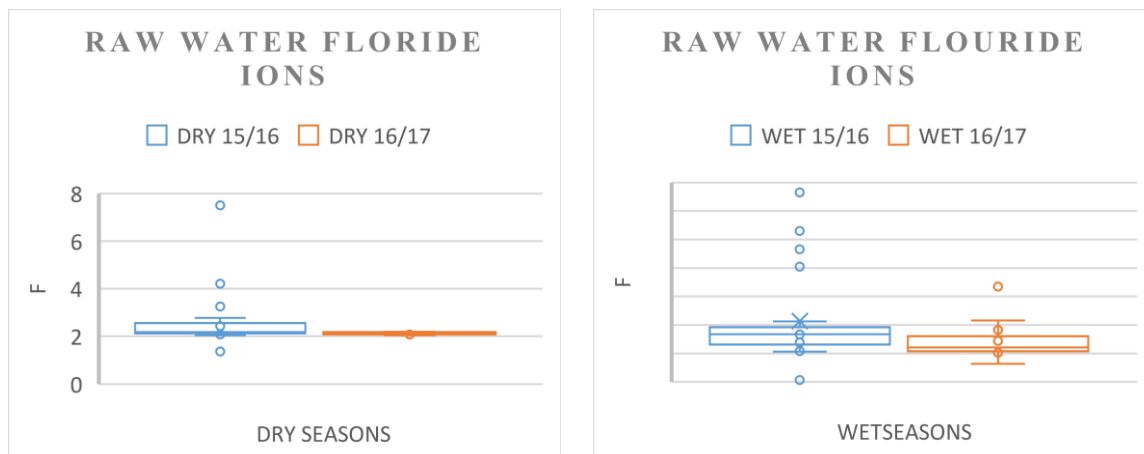


Figure 4o Seasonal variations of raw water flouride ions

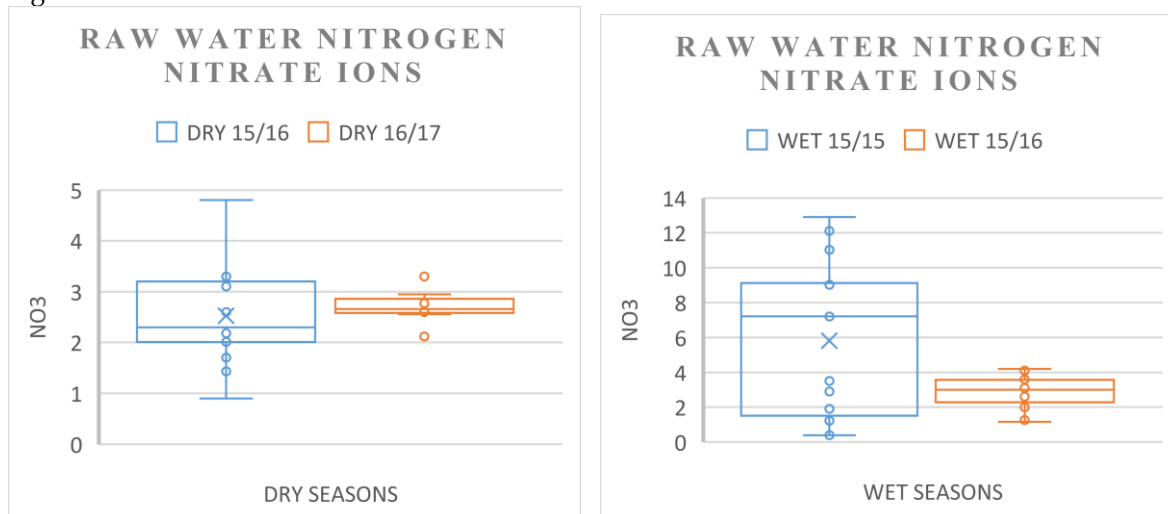


Figure 4p Seasonal variations of raw water nitrogen nitrate ions

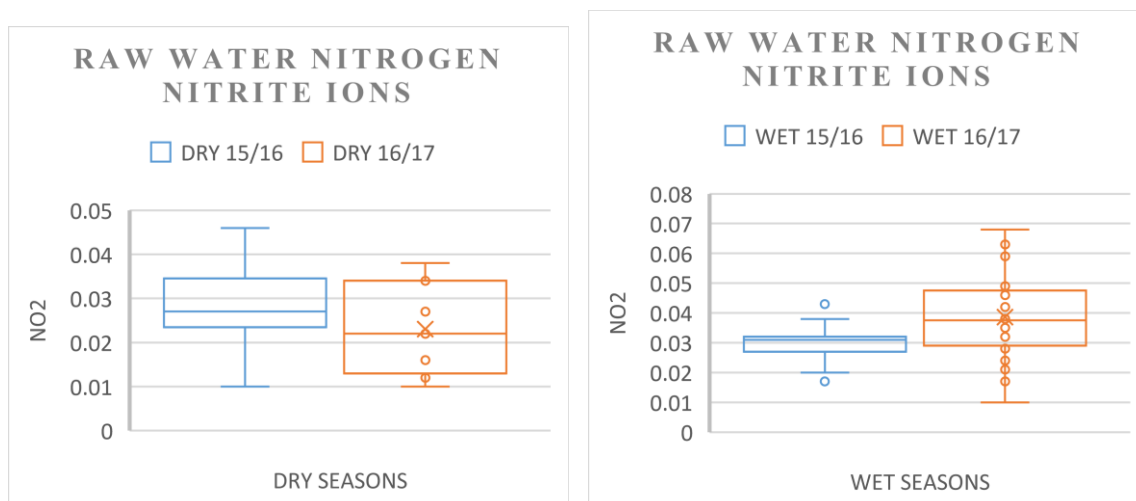


Figure 4q Seasonal variations of raw water nitrogen nitrite ions

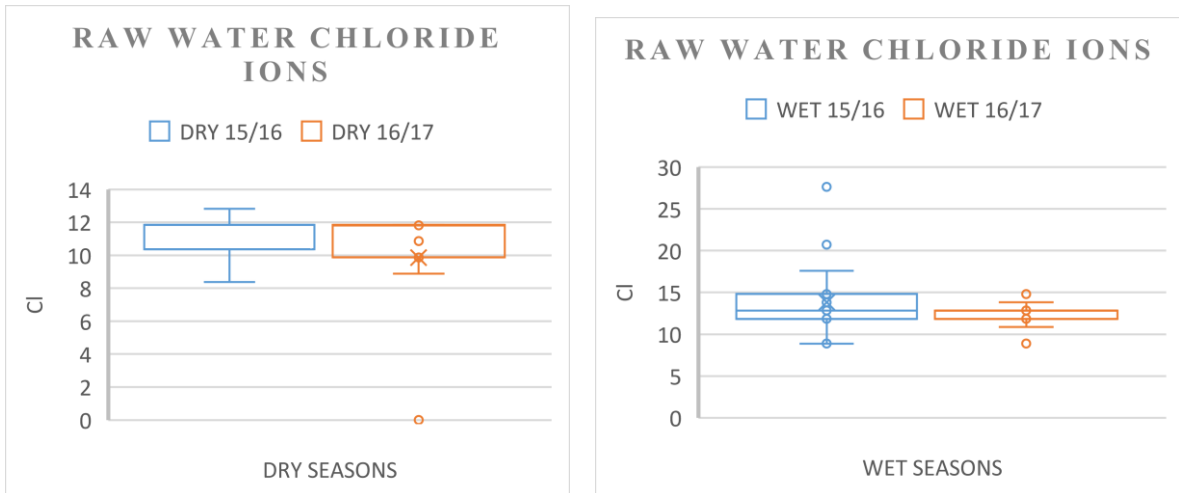


Figure 4r Seasonal variations of raw water chloride ions

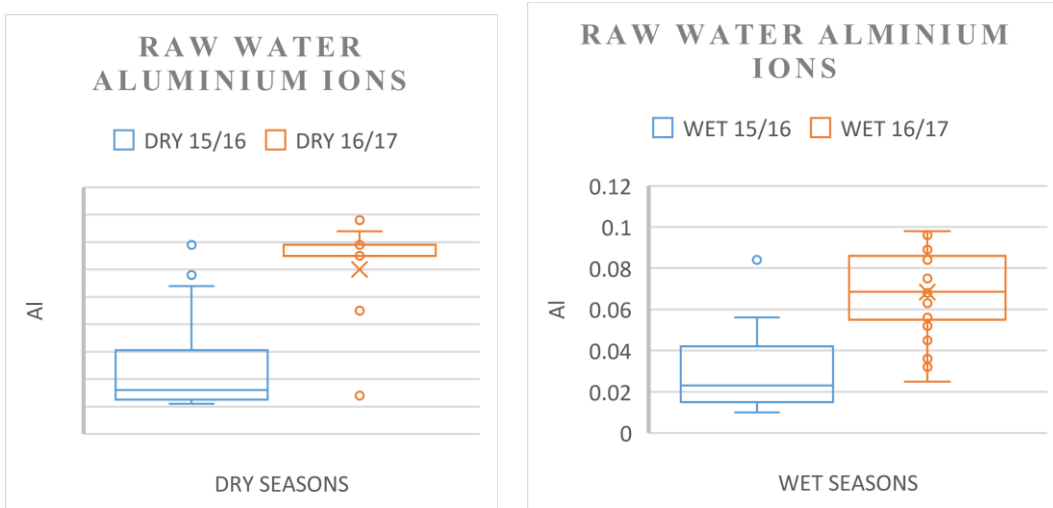


Figure 4s Seasonal variations of raw water aluminium ions

Other parameters including Alkalinity, water hardness, Calcium ion, Free carbon dioxide, magnesium ions, sulphate ion, Iron ion, Manganese ion, fluoride ion, Nitrogen nitrate and Nitrogen nitrite ions, and chloride ion shows slight variation in their average concentration between dry and wet season, and both their maximum values fall below WHO recommended ranges in either of the seasons (Figure 4 (e-r)). Aluminum ion shows no variation in average concentration between wet and dry seasons (Figure 4s), while electrical conductivity indicates noticeable variation in

average concentration between wet and the dry seasons (Figure 4d). The wide variation in concentration of electrical conductivity is recorded in the dry seasons, having lower value of 8.3 and higher value of 947, the very high standard deviation of 119.31 is an indication that there is wide variation of parameters within the dry seasons, which can be linked to the high increase of temperature and excessive evaporation resulting from climate change and global warming. The variation of the electrical conductivity in the wet seasons is slower compared to the dry seasons, nonetheless,

significant change is observed between the wet and dry seasons.

Total dissolved solids TDS_{inf} (Figure 4j) is having very high average concentration in the rainy seasons compared to the dry seasons, still within the rainy seasons there is wide range between the lower value (63 mg/l) and the higher value (1530 mg/l) with standard deviation of 264. While in the dry season there is small range (137) between the lower (58 mg/l) and higher (231mg/l) values, having standard deviation of 37. The results clearly demonstrate significant variation between wet and the dry seasons. In the total dissolved solids, the variation is in favor of dry seasons recorded slightly higher average concentration (53.34 mg/l) compared to the (48.19 mg/l) of wet seasons. The lowest (17.90 mg/l) value was recorded in the wet seasons while the highest value (462 mg/l) was observed in the dry seasons. The higher concentration of total dissolved solids in the dry seasons can easily be linked to the irrigation activities taking place along the water course, there is also increased rate of evaporation towards the end of dry season (Figure 4i).

The recorded values of all parameters in both seasons falls below the WHO guidelines, and the raw water was therefore found safe for human consumption and other activities after treatment, however these variations indicates the necessity of the daily water quality laboratory analyses which are highly cumbersome, time consuming and very costly.

Assessment of Seasonal Variation in Treated Water Quality Parameters:

Further analysis carried out on the treated water quality parameters revealed that seasonal variation is similarly established between the treated water quality parameters of the wet and dry seasons. Results of the analyses presented in table 4 shows that the minimum values of all the treated water quality parameters were within the desirable limits of WHO/Nigerian standards (SON) for both the wet and dry seasons except in pH that falls below acceptable value of 6.5 and therefore requires adjustment. The maximum values of all the parameters were also found within acceptable limits but in WT_{eff} (31°C) and pH_{eff} (8.7) where both were found above the desirable values of 25°C and 8.5 respectively during the dry seasons, and the maximum values of Mn_{eff} (0.07mg/l) and Al_{eff} (0.87mg/l) that are also above the maximum desirable values of (0.05mg/l) and (0.2mg/l) but still within the range of maximum acceptable values of (0.4mg/l) and (2.9mg/l) respectively, also in the dry seasons. In the wet seasons, all the treated water quality parameters were within the range of maximum desirable ranges except in the case of WT_{eff} (31°C), $Turb_{eff}$ (7.2 NTU) and Mn_{eff} (0.09mg/l) that were above their limits of (25°C), (5.0 NTU) and (0.05mg/l) respectively, yet Mn_{eff} is within the maximum allowable concentration (MAC) of 2.9mg/l. All the mean average concentration for all parameters are within the desirable range for the dry seasons, whereas only WT_{eff} (27°C) is above the desirable range in the wet seasons. Figures 5 (a and b) show the mean concentration for the treated water quality parameters.

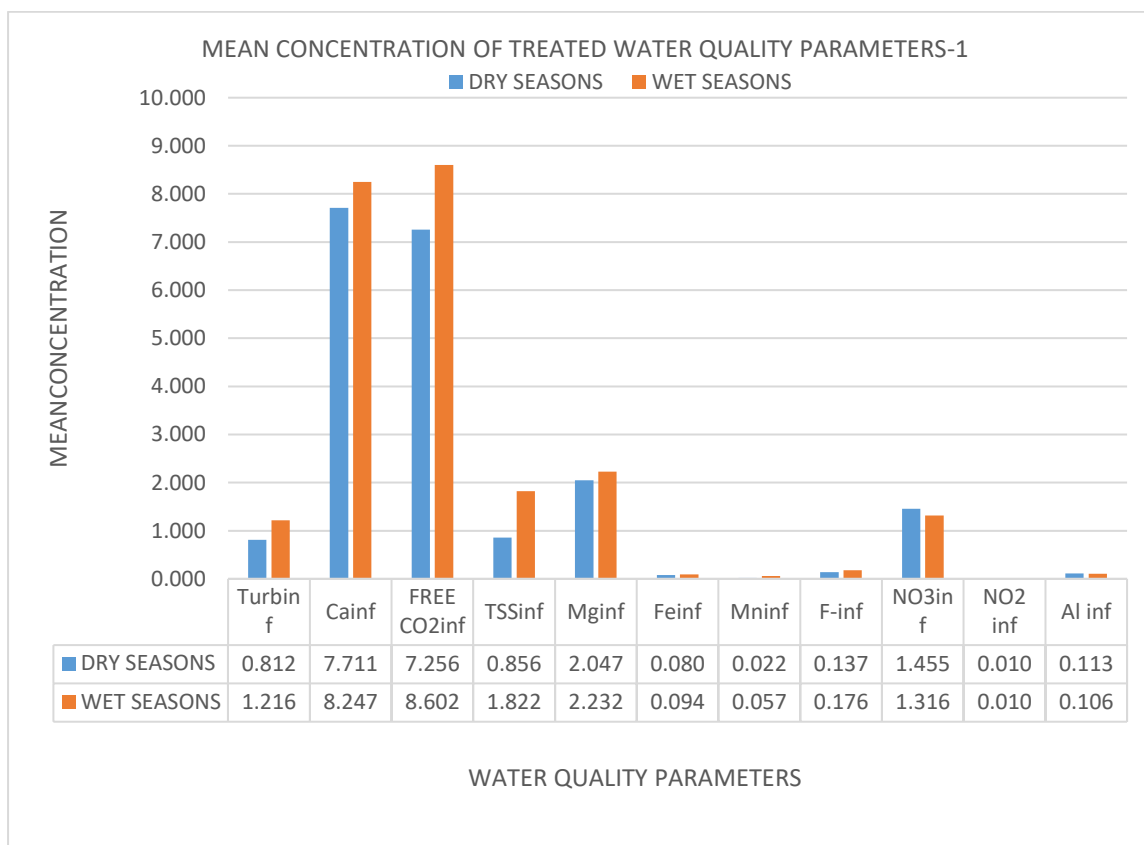


Figure 5a Seasonal variation treated water quality parameters (mean concentration)

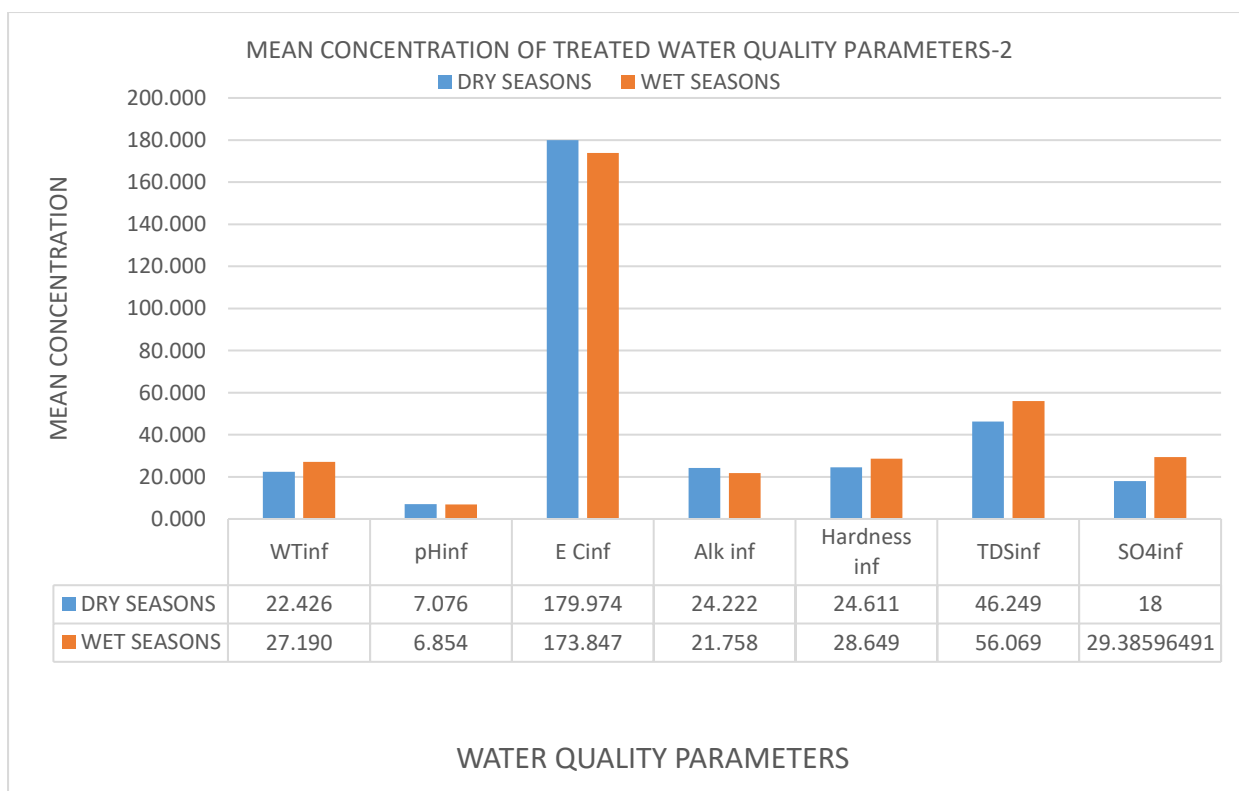


Figure 5b Seasonal variation treated water quality parameters (mean concentration)

Seasonal correlation of water quality parameters:

Statistical dependence analyses technique was carried out using statistical correlation matrix to measure the strength of the relationship between the WQPs to evaluate the interdependency between WQPs. Tables 5a and 5b shows the range of the seasonal correlation between the physico-chemical water quality parameters in both dry and wet seasons, Table 5a shows the seasonal correlation matrix between the parameters in the dry seasons and Table 5b shows the seasonal correlational matrix between the parameters in the wet seasons.

The correlation coefficient is used to translate the nature of relationship between the changing water quality parameters. The values for the correlation coefficients ranges between ± 1 to 0, positive correlation coefficient indicates direct relationship between the parameters while negative correlation indicates inverse relationship. The degree of correlation is often considered perfect correlation if the values are ± 1 , where values are between ± 0.5 to ± 1 the relationship between the parameters is considered

strong, the higher the value the stronger the is relationship. The relationship is considered moderate at values between ± 0.3 to ± 0.49 , and weak at values below ± 0.29 while 0 value indicates no correlation.

The tables (5a and 5b) show that water temperature WT_{inf} has a very strong inverse correlation with water pH_{inf} (-0.7) during the wet seasons, and also good correlation with manganese ions Mn_{inf} (0.560) during the dry seasons, while having from weak to poor correlation with all other parameters in both wet and dry seasons. The raw water turbidity $Turb_{inf}$ is also having very strong correlation with total suspended solids TSS_{inf} in both wet and dry seasons (0.856) and (0.926) respectively, and also good relationship with manganese ions Mn_{inf} (0.598) and (0.568) in both wet and dry seasons respectively, the relationship of Turbidity with chlorine ion Cl_{inf} is also good (0.610) in wet seasons, its relationship with other parameters was rather between weak to poor in all the seasons. There is also a good relationship of raw water pH (pH_{inf}) with raw water

Table 5a: Correlative Statistics Analysis of Seasonal Water Quality Parameters (Dry Seasons)

<i>Parameters</i>	<i>WTinf</i>	<i>Turbinf</i>	<i>pHinf</i>	<i>E Cinf</i>	<i>Alk inf</i>	<i>Hardness inf</i>	<i>Cainf</i>	<i>FREE CO2inf</i>	<i>TDSinf</i>	
WTinf	1.00									
Turbinf	0.10	1.00								
pHinf	0.13	-0.17	1.00							
E Cinf	-0.02	0.26	-0.16	1.00						
Alk inf	0.14	-0.04	0.54	-0.15	1.00					
Hardness inf	0.11	0.43	-0.21	0.13	-0.13	1.00				
Cainf	0.01	0.12	-0.28	0.28	-0.02	0.02	1.00			
FREE CO2inf	0.39	-0.16	0.42	-0.35	0.27	0.08	-0.21	1.00		
TDSinf	-0.08	0.38	-0.10	0.86	-0.12	0.10	0.22	-0.39	1.00	
TSSinf	0.10	0.86	-0.03	0.21	0.11	0.39	0.20	-0.09	0.30	
Mginf	0.34	-0.18	0.41	-0.06	0.53	-0.09	-0.20	0.03	-0.31	
SO4inf	0.19	0.44	0.12	0.18	-0.34	0.53	-0.25	0.37	0.16	
Feinf	0.14	0.02	-0.33	0.47	0.03	0.11	0.15	-0.05	0.34	
Mninf	0.56	0.57	0.55	-0.10	0.25	0.28	-0.22	0.51	-0.13	
F-inf	0.14	0.43	-0.33	0.64	-0.15	0.25	0.46	0.25	0.58	
NO3inf	0.27	-0.31	-0.06	-0.06	0.14	0.07	-0.18	-0.19	-0.15	
NO2 inf	0.03	0.13	0.15	-0.01	-0.24	0.00	0.04	-0.19	-0.05	
Cl-inf	0.44	0.21	0.32	0.25	0.02	0.08	-0.14	0.26	0.10	
Al inf	0.17	0.25	0.17	-0.01	0.23	0.10	-0.11	-0.02	0.16	
<i>Parameters</i>	<i>TSSinf</i>	<i>Mginf</i>	<i>SO4inf</i>	<i>Feinf</i>	<i>Mninf</i>	<i>F-inf</i>	<i>NO3inf</i>	<i>NO2 inf</i>	<i>Cl-inf</i>	<i>Al inf</i>
WTinf										
Turbinf										
pHinf										
E Cinf										
Alk inf										
Hardness inf										
Cainf										
FREE CO2inf										
TDSinf										
TSSinf	1.00									
Mginf	0.31	1.00								
SO4inf	0.25	0.00	1.00							
Feinf	-0.07	0.14	0.13	1.00						
Mninf	0.54	0.33	0.45	-0.14	1.00					
F-inf	0.12	-0.23	0.19	0.50	0.02	1.00				
NO3inf	-0.17	0.23	-0.07	0.24	-0.08	-0.18	1.00			
NO2 inf	0.03	-0.17	0.07	-0.21	0.05	-0.12	0.07	1.00		
Cl-inf	0.32	0.17	0.31	0.24	0.22	0.23	0.17	-0.26	1.00	
Al inf	0.16	0.18	0.04	0.08	0.43	-0.05	-0.12	0.11	0.11	1.00

Table 5b: Correlative Statistics Analysis of Seasonal Water Quality Parameters (Wet Seasons)

Parameters	WT_{inf}	$Turb_{inf}$	pH_{inf}	EC_{inf}	Alk_{inf}	$Hardness_{inf}$	Ca_{inf}	$FREE\ CO_2_{inf}$	TDS_{inf}	
WT_{inf}	1.00									
$Turb_{inf}$	-0.23	1.00								
pH_{inf}	-0.70	0.10	1.00							
EC_{inf}	0.12	-0.23	0.06	1.00						
Alk_{inf}	-0.14	-0.02	0.55	0.10	1.00					
$Hardness_{inf}$	0.00	0.39	-0.02	0.10	-0.14	1.00				
Ca_{inf}	-0.04	0.12	-0.01	0.14	0.02	0.22	1.00			
$FREE\ CO_2_{inf}$	0.15	0.06	-0.11	0.10	0.07	0.10	0.16	1.00		
TDS_{inf}	0.02	-0.13	-0.07	0.53	-0.03	0.25	0.14	-0.06	1.00	
TSS_{inf}	-0.22	0.93	0.04	-0.28	-0.11	0.38	0.09	-0.05	-0.13	
Mg_{inf}	0.02	0.03	0.30	0.02	-0.03	0.44	0.10	-0.02	0.12	
SO_4_{inf}	-0.06	0.00	0.08	0.27	-0.09	0.49	0.52	0.18	0.16	
Fe_{inf}	-0.15	0.49	-0.02	-0.16	0.14	0.37	0.07	0.23	-0.15	
Mn_{inf}	-0.31	0.60	0.28	-0.23	0.01	0.05	0.08	0.33	-0.37	
F^{-}_{inf}	0.10	-0.08	-0.22	0.15	0.23	0.14	0.04	0.31	0.07	
NO_3_{inf}	0.28	-0.04	-0.38	0.06	-0.18	-0.03	-0.05	-0.22	-0.03	
NO_2_{inf}	-0.15	-0.03	0.49	-0.12	-0.13	-0.01	-0.03	-0.37	-0.10	
Cl^{-}_{inf}	-0.09	0.61	-0.12	-0.15	-0.07	0.15	0.18	0.28	-0.19	
Al_{inf}	-0.24	0.03	0.59	-0.03	-0.01	0.06	0.04	-0.29	0.15	
Parameters	TSS_{inf}	Mg_{inf}	SO_4_{inf}	Fe_{inf}	Mn_{inf}	F^{-}_{inf}	NO_3_{inf}	NO_2_{inf}	Cl^{-}_{inf}	Al_{inf}
WT_{inf}										
$Turb_{inf}$										
pH_{inf}										
EC_{inf}										
Alk_{inf}										
$Hardness_{inf}$										
Ca_{inf}										
$FREE\ CO_2_{inf}$										
TDS_{inf}										
TSS_{inf}	1.00									
Mg_{inf}	0.01	1.00								
SO_4_{inf}	-0.03	0.06	1.00							
Fe_{inf}	0.35	0.00	0.08	1.00						
Mn_{inf}	0.55	0.04	-0.12	0.34	1.00					
F^{-}_{inf}	-0.11	0.00	0.02	0.04	0.06	1.00				
NO_3_{inf}	-0.13	-0.24	-0.11	-0.10	-0.19	0.02	1.00			
NO_2_{inf}	0.07	0.11	-0.07	-0.05	0.05	-0.14	-0.07	1.00		
Cl^{-}_{inf}	0.60	-0.27	0.04	0.40	0.50	0.08	-0.04	-0.12	1.00	
Al_{inf}	0.02	0.39	-0.08	0.02	0.05	-0.35	-0.20	0.49	-0.12	1.00

alkalinity and aluminum ions in both wet (Alk_{inf}) (0.550) and (Al_{inf}) (0.593), and dry seasons (Alk_{inf}) (0.542) and (Al_{inf}) (0.554) respectively, while the relationship between raw water pH and all other parameters also ranged between weak to poor correlation. Raw water electrical conductivity EC_{inf} is also having very strong correlation with total dissolved solids (TDS_{inf}) during dry seasons (0.858) and good relationship (0.525) at wet seasons, the relationship of TDS_{inf} with the rest of parameters was between weak and poor. Good correlation was also recorded between Alk_{inf} and Mg_{inf} (0.524), $Hardness_{inf}$ and $SO4_{inf}$ (0.533), Free $CO2_{inf}$ and Mn_{inf} (0.508), TDS_{inf} and F^{-}_{inf} (0.583), TSS_{inf} and Mn_{inf} (0.539) in the dry seasons, and between Ca_{inf} and $SO4_{inf}$ (0.519), TSS_{inf} and Mn_{inf} (0.547) and Cl^{-} (0.595), Mn_{inf} and Cl^{-}_{inf} (0.501) in the wet seasons, all other relations between the parameters were either weak or poor.

CONCLUSION AND RECOMMENDATION

The analysis of physico-chemical (raw) water quality parameters (WQPs) between wet and dry seasons over the span of four hydrologic cycles on 19 WQPs at the intake of Tamburawa WTP shows wide variation of 4 WQP parameters both with-in and in between the wet and the dry seasons (including $Turb_{inf}$, TSS_{inf} , TDS_{inf} , and EC_{inf}), while little or no variation was recorded both with-in and between the wet and dry season on 10 WQPs (including pH_{inf} , Ca_{inf} , Free $CO2_{inf}$, Mg_{inf} , $SO4_{inf}$, Fe_{inf} , Mn_{inf} , $NO3_{inf}$, $NO2_{inf}$ and Al_{inf}), the remaining five WQPs(WT_{inf} ,

Alk_{inf} , $Hardness_{inf}$, F^{-}_{inf} and Cl^{-}_{inf}) moderately varies in wet and dry seasons. These variations due to daily and seasonal changes of climate systems necessitates the needs for numerous water sampling, laboratory tests, and analyses. There exists also a strong correlation between 6 WQPs (including WT_{inf} , pH_{inf} , $Turb_{inf}$, TSS_{inf} , TDS_{inf} , and EC_{inf}) both in the wet and dry seasons, all other parameters were observed to be in good correlation with at least one parameter in the wet or dry seasons, with only exception of $NO3_{inf}$, and $NO2_{inf}$ that are of poor correlation with all the parameters both in wet and dry seasons, these correlations indices indicates parameters that requires regular and close assessment to ensure proper monitoring and evaluation in water quality management, policies, planning strategies, and risks management and assessments. All the 19 WQPs falls within WHO/SON standard after treatment, which proved very high efficiency of Tamburawa WTP and hence the good quality in drinking water production.

Assessment of more water quality indices, such as the heavy metal, radioactive materials, bacterial contaminations etc. is recommended, more so, in depth analysis of the results obtained is highly recommended, more splits of the hydrological seasons of the study area to accommodate further the effects of climate variability such as the cold dry seasons, hot dry seasons, warm wet seasons and cool wet season may as well be check for more accurate results is also recommended.

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