



## SEASONAL VARIATION IN PHYSICO-CHEMICAL CHARACTERISTICS OF RURAL GROUNDWATER OF BENUE STATE, NIGERIA

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### ABSTRACT

*Groundwater exploitation for rural water supply without proper understanding of its chemistry and changes that may be induced by physical processes and anthropogenic activities may be counter productive. This study examines the effect of season on the physico-chemical concentrations in groundwater in rural areas of Benue State. Water samples were collected from 26 rural community boreholes in the months of October 2005 and February 2006 for both the wet and dry seasons. The analyses was done according to standard methods for water examination and reported based on the WHO prescribed limit for drinking water. The results of analyses show the mean values and CV of the parameters as follows: TP has a mean and CV of 29.15o C and 4.19% for wet season and 32.26 oC; 6.41% for dry season. PH has a mean and CV of 7.55 and 6.21 for wet season as against 8.26 and 4.24% for dry season. The mean and CV of TH is 73.31 and 5.74% for wet season and 65.19 and 94.92% for dry season. EC has a mean and CV of 414.27 and 137.58% for wet season as against 272.13 and 94.53% for dry season. Chloride has a mean and CV of 72.88 and 137.42% for wet season and 29.65 and 60.24% for dry season. The mean and CV of TDS for wet season is 167.73 and 139.26% and 181.78 and 139.06% for dry season. AK has a mean and CV of 117.15 and 78.26% for wet season as against 16.46 and 145.20%. The mean and CV of TBD of 27.09 and 206.05% is for wet season and 16.82 and 209.39% for dry season. Apart from PH and TDS all other parameters show higher concentrations in groundwater during the dry season.*

**Key Words:** Boreholes, Coefficient of variation, Concentrations, Groundwater, Physico-chemical, Season.

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## INTRODUCTION

Globally, problems associated with groundwater exploitation include the following: declining water tables, wells running dry (seasonality) increasing pumping costs, competitive deepening of wells, groundwater subsidence, loss of wetlands and flowing springs and rivers, salt water intrusion, groundwater degradation from natural toxins (fluoride and arsenic, spreading or leaking of anthropogenically used substances from point and non-point sources (Burke and Moench, 2000; FAO, 2003; Richardson et al, 2004). The present and predicted increase in groundwater withdrawals, its unprecedented importance for human consumption globally, and the emerging threats from escalated and unplanned use and degradation especially in the developing countries point the need for intensified efforts to cope with the imbalances. Despite these facts, there is little intervention by governments in developing countries. Sufficient knowledge, awareness and understanding of groundwater resource and their management are missing in these countries, as well as in international communities (Villholth, 2006).

UNESCO (2003) estimates that globally groundwater provides about 50% of current potable water supplies, 40% of the demand of self-supplied industry and 20% of water use in irrigated agriculture. Over much of Africa, groundwater is the most realistic water supply option for meeting dispersed rural demand (Foster et al, 2000). However, increasing demand and withdrawal, significant changes in land use pattern and vast industrial effluent entering the hydrological cycle stresses the quality and quantity of groundwater (Mackey, 1990). The dependence on groundwater will continue to increase in rural and urban area of sub-Saharan Africa (SSA) as climate change and contamination from human activities is fast limiting the available usable surface water resources (Adelana, 2005).

Benue State is predominantly one of the rural states in Nigeria with over 70% of the population living in rural areas. This segment of the population is faced with problems of acute water supply shortages. Traditional water supply sources such as streams, rivers, lakes and pond have come under intense stress due to deforestation activities such as agricultural intensification, land clearance and bush burning, lumbering, uncontrolled livestock grazing by the cattle fulanis and climatic vagaries. Consequently, some of these sources have disappeared completely or are highly polluted. Women and children who are the major drawers of water suffer untold hardships especially in the dry season scavenging for water for household use. Families are exposed to all series of health problems that are water related. In 1986, there was an outbreak of water related disease that claimed several lives in some parts of the state. To tackle this problem a comprehensive programme was needed to be packaged for rural areas of the state. In 1994 and 1995, Benue State Rural Water Supply and Sanitation Agency, UNICEF assisted and WaterAid a British non-governmental DIFD funded water charity organization commenced activities of providing rural areas with boreholes. Although a welcome development, the quality of water from some of the boreholes are however in doubt due to presence of undesirable colour, odour and taste. Water from some of the boreholes have been rejected on account of these problems. According

to Edmunds and Smedley(1996) the problem of groundwater has been exacerbated during the past decades by widespread installation of rural water supply wells and boreholes which in most cases are developed in places where specific geochemical condition may lead to excessive concentration of toxic or undesirable elements such as arsenic, chromium, iron and manganese. Substantiating this, MacDonald et al(2005) noted that due to the advantages of using groundwater, many rural water supply projects rely on developing groundwater, but do so blindly, with little regard for quality. Boreholes are sited at random or by socio-economic criteria alone, the water supplies are assumed to be safe and sustainable with no water quality testing or understanding of the nature of the resource. The high failure rate from such approach not only has cost implications but also has much wider implication caused by community expectation being raised and not met.

In this study, attempt is made to assess the seasonal variation in the physico-chemical characteristics of groundwater in the study area. Virtually, there is no study of such kind in the area. Because of the latitudinal location of the study area influence of seasons cannot be ignored. There is there the need to understand the nature and the chemistry of groundwater, change that may occur due to physical process and anthropogenic activities. Assessment of water resources will not be complete without the knowledge of quality characteristics as assessed by their physical and biological constituents(Caliandro et al,1995).It is believed that study of this kind will guide rural groundwater developers. The millennium development goal of providing clean and safe drinking water will be a mirage if the issue of quality is not properly taken care of.

### **The Study Area**

Benue State is one of the states located within the middle belt geopolitical zone of Nigeria. Geologically, it falls within the Benue Trough from where the state derive its name. It lies between Lat. 6 32° and 8 07'N and Long. 7 52 and 10 00°E(Fig.1). It has a landmass of about 33,955 Sq Km and population of 4,219,244(NPC,2006).The area has suffered series of setback due to the political development overtime not until 1976 when it became a state of its own with the capital in Makurdi. The state is inhabited indigenously by these tribes:Tiv, Idoma, Igede, Etulo, Jukun and Hausas. They are mostly farmers , fishermen and traders.

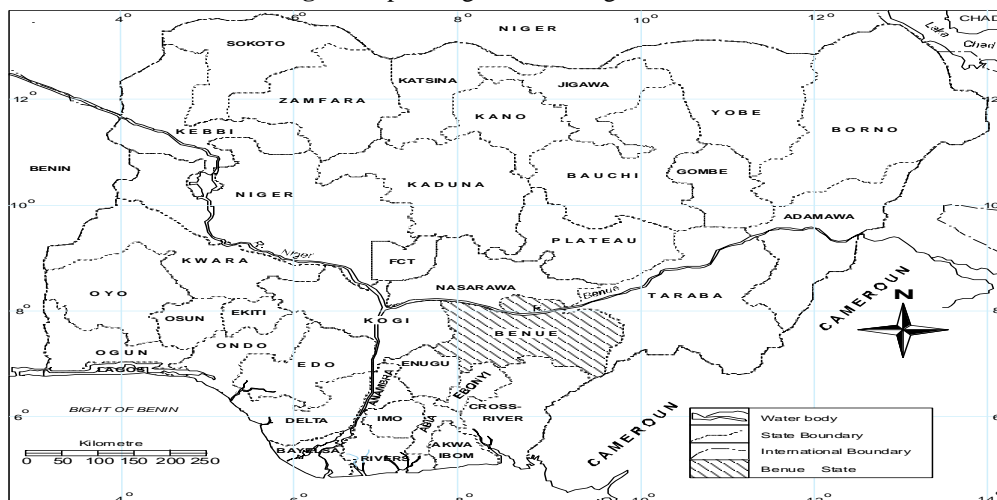
The area is underlain with geological formation mainly sedimentary comprising sandstones, mudstones and limestone (Kogbe et al,1978;Nwachukwu,1972;MacDonald et al 2005).There are isolated pockets of basement complex mainly of porphyritic and magmatics type in some parts of the study area. Major soil types in the study area are:tropical ferrugised, distinguished by a marked differentiation of horizon and abundance of free iron oxide;Lateric soil of highly weathered type dominated by oxide of Fe and Al and contains clay and kaolin;Hydromorphic soil of recent alluvial deposit are found in river flood plain; and lithozol soil of mineral soil with less than 10cm over hard rocks dominated by gravel stone and boulder.

The study area is drained principally by River Benue and its tributary, the river Katsina-Ala. Other rivers include Aya, Guma, Konshisha, Logo, Okpokwu, Obi, and Oyongo. The climate of the area is controlled by two major air masses, namely south west trade wind and north east trade. They are responsible for the wet and dry season in the study area. Rainfall lasts from May to October with annual total between 1,200-2000mm, and dry season from November to April. Dry season is dominated with dry dust laden harmattan wind originating from Sahara desert. Temperature in the study area is particularly high in the months of march and April. This is reflected in high rate of evaporation leading to drying up of some water sources and grasses and trees shading away their leaves.

### Materials and Methods

Data for this study were obtained from both primary and secondary sources. Primary sources were obtained from the field and secondary from official documents and books. Water samples were collected from 26 rural community of boreholes of Benue State, Nigeria in the months of October 2005 for wet season and February 2006 for dry seasons. The analyses of the water samples were carried out according to standards methods for examination of water (APHA-AWWA-WPCF, 1995) and reported in line the WHO (2006) standards for drinking water. Both field based and laboratory methods of analyses were used. Parameters analysed include temperature, PH, total hardness, total dissolved solids, chloride, electrical conductivity, turbidity and alkalinity. Temperature of the water samples were taken in-situ using mercury thermometer. Total hardness, total dissolved solids, chloride and alkalinity were determined using various laboratory titration methods. PH was determined using Gallenkamp PH meter, electrical conductivity using Hach conductivity WPA 400 digital model meter, turbidity using DREL spectrophotometer model 2100. To ensure quality assurance precautionary measures were observed during the collection, transportation, storage and analyses of the water samples. The results of analyses of the physico-chemical parameters for both wet and dry season is shown in Tables 1 and 2.

**Fig-1.** Map of Nigeria Showing Benue State



Source: Longman Atlas, 2003.

**Table-1.** Results of analyses of physico-chemical parameters for wet season

Location	Code	TP	PH	TH	EC	Cl	TDS	ALK	TBD
Ikpayongo	BH1	28	7.63	160	9	35	47	75	1.0
Tsenor	BH2	29	8.24	40	636	55	320	188	2.0
Awajir	BH3	28	8.21	50	668	35	336	200	2.0
Kyoor	BH4	29	8.12	110	419	30	213	125	150
Ega	BH5	27	7.98	200	583	75	290	125	10
Uje	BH6	27	7.65	60	110	40	55	175	90
Obarike-Ito	BH7	28	6.87	110	415	95	206	25	1.1
Ugbodom	BH8	29	7.47	70	160	55	82	125	1.0
Ogi	BH9	31	8.50	30	2230	335	1250	475	1.0
Ulayi	BH10	29	7.40	40	476	55	240	210	2.0
Asaage-Ashe	BH11	30	7.77	130	322	75	162	100	2.0
Udei	BH12	30	7.01	20	58	35	27	38	80
Fiidi	BH13	31	7.30	80	166	40	83	75	2.0
Ake	BH14	30	8.25	230	1139	160	575	200	2.0
Uchi-Mbakor	BH15	30	7.65	80	278	450	140	100	1.0
Annune	BH16	31	7.57	60	117	30	50	8.0	
Ambighir	BH17	29	6.89	60	48	30	24	50	2.0
Tse Kucha	BH18	31	7.05	20	2040	15	104	75	3.0
Garagboughul	BH19	29	7.47	20	67	10	33	50	230
Buruku	BH20	31	7.68	20	114	45	50	1.0	
Sati-Asema	BH21	29	7.47	40	90	25	44	75	4.0
Amaafu	BH22	28	7.56	120	240	10	150	1.0	
Mbaagba	BH23	28	7.68	70	137	40	68	125	6.0
Ushongo	BH24	29	6.88	20	30	35	15	75	80
Ihugh	BH25	28	6.73	20	58	50	29	50	1.2
Mbajor	BH26	29	7.33	20	76	35	38	60	3.0

**Table-2.** Results of analyses of physico-chemical parameters for dry season

Location	Code	TP	PH	TH	EC	Cl	TDS	ALK	TBD
Ikpayongo	BH1	31	7.64	20	30	15	15	5	4.43
Tsenor	BH2	32	8.08	60	300	20	150	10	70
Awajir	BH3	40	8.87	60	635	18	320	30	50.18
Kyoor	BH4	32	8.58	70	380	25	190	15	150
Ega	BH5	34	8.55	90	450	20	220	20	90
Uje	BH6	30	8.32	90	207	35	104	10	2.59
Obarike-Ito	BH7	34	8.71	120	350	25	170	125	2.50
Ugbodom	BH8	32	8.49	310	1101	23	557	125	6.27

Ogi	BH9	30	8.16	30	130	20	1109	5	8.0
Ulayi	BH10	30	8.49	70	230	25	125	125	5.72
Asaage-Ashe	BH11	32	8.70	120	370	25	185	15	0.79
Udei	BH12	31	7.60	50	49	15	25	75	3.68
Fiidi	BH13	34	8.39	80	210	15	108	10	5.80
Ake	BH14	35	8.68	20	850	85	425	30	2.30
Uchi-Mbakor	BH15	32	8.35	110	316	35	160	15	3.77
Annune	BH16	31	7.78	10	56	22	28	5	2.50
Ambighir	BH17	32	7.65	20	86	50	45	12.5	2.55
Tse Kucha	BH18	34	8.49	90	240	15	115	5	3.50
Garagboughul	BH19	32	7.94	10	50	20	30	2.5	1.09
Buruku	BH20	32	8.02	20	135	55	65	7	1.09
Sati-Asema	BH21	32	8.49	15	200	12	65	40	4.79
Amaafu	BH22	32	8.28	110	310	30	160	10	0.55
Mbaagba	BH23	30	8.39	40	210	23	105	5	2.11
Ushongo	BH24	32	7.86	40	65	23	30	5	6.40
Ihugh	BH25	32	8.23	20	10	60	30	6	1.40
Mbajor	BH26	31	8.11	20	100	60	49	7.5	4.12

TP-temperature TH-total hardness, EC-electrical conductivity, Cl-chloride, TDS-total dissolved solids, ALk-alkalinity, TBD-turbidity

**Table-3.** Descriptive characteristics of physico-chemical parameters of groundwater quality for wet and dry seasons in the the study area.

Wet season						Dry season				
Parameters	Min	Max	Mean	SD	CV	Min	Max	Mean	SD	CV
TEMP	27	31	29.15	01.22	4.19	30	40	32.26	2.07	6.41
P <sup>H</sup>	6.73	8.50	7.55	0.47	6.21	7.60	8.87	08.26	0.36	4.24
TH	20	230	73.31	57.43	5.74	10	310	65.19	61.87	94.92
EC	30	2230	414.27	569.95	137.58	10.00	110	272.13	257.25	94.53
CL	10	450	72.88	100	137.42	12.00	85.00	29.65	17.86	60.24
TDS	10	1109	167.73	233.58	139.26	15	1109	181.78	252.79	139.06
AK	25	475	117.15	91.68	78.26	2.50	125.00	16.46	23.90	145.20
TBD	1.0	230	27.09	55.82	206.05	0.55	150	16.82	35.22	209.39

SD – Standard Deviation

CV –Coefficient of Variation

**Table-4.** Quality Criteria for Drinking Water

Quality Characteristics	WHO Guide value	
Temperature	30-40	oC
PH	7-9.2	
Total hardness	100-500 mg/l	
Electrical conductivity	750-2,500	unhos/cm
Chloride	200-600 mg/l	
Total dissolved solids	500-1,500	mg/l
Alkalinity	100-500 mg/l	
Turbidity	5-25	FTU

**Source:** WHO (2006) Drinking water guideline

### Results and Discussion

From Tables 1 and 2 the results of the physico-chemical analyses of water samples are shown, and Table 3 is the WHO prescribed guideline used in the description of groundwater quality characteristics in the study area.

The results of analyses show temperature of all the water samples are within the WHO prescribed limit for drinking water. Temperature of water samples analysed have a mean and coefficient of variation of 29.15oC and 4.19% for wet season as against a mean and coefficient of variation of 32.26oC and 6.41% for the dry season. This shows that temperature of groundwater is lower in the wet season than in the dry season (Fig.2). This is not unconnected with the ambient environment of the boreholes. Temperature in water quality test is used as a good measure of contamination as it has marked effect on bacteria and chemical reaction rates in water (Mink, 1964; Dixey, 1972; Hutton, 1983).

The measurement of PH is one of the most frequently used tests in water chemistry (Hem, 1985). The results of analyses of water samples show PH of groundwater is all within the WHO allowable limit of 7-9.2 for drinking water for both wet and dry season. The groundwater quality in the study area of alkaline type. The PH of groundwater in the study area has a mean and coefficient of 7.55 and 6.21% for wet season as against a mean and coefficient of 8.87 and 4.24% for the dry season. This suggest PH in groundwater is lower in the wet season than in the dry season (Fig.3). This is implied because during wet season rainfall combines with carbon dioxide can influence the water toward acidity.

Total hardness in water samples as shown by the analyses have concentrations all within the WHO guide range for drinking water both for wet and dry seasons. Total hardness in water samples have a mean and coefficient of variation of 73.3mg/l and 5.74% for wet season as against a mean of 65.19mg/l and coefficient of 94.92% for the dry season. From the mean concentration of total hardness, concentrations in water is higher in wet season than in the dry season (Fig.4). This is

obvious because of the solvent action of rainwater coming in contact with soil and rocks is capable of dissolving calcium and magnesium that promote water hardness. Although, water hardness has no harmful effect on human health except that it can react with ordinary soap to form scum, plume solvent, scale formation in boilers and in hot water systems.

Electrical conductivity is viewed as a valuable indicator of the amount of dissolved materials in water (Olajire and Imeokparia, 2001). Potable water should not have high electrical conductivity (Hutton, 1983). The analyses show electrical conductivity in water samples are within the WHO guide range of 750-2,500  $\mu\text{mhos/cm}$ . However, BH9, BH18 and BH14 are noted to have very high values of electrical conductivity of 2230  $\mu\text{mhos/cm}$ , 2040  $\mu\text{mhos/cm}$ , and 1139  $\mu\text{mhos/cm}$  for the wet season, with only BH8 with high conductivity of 1101  $\mu\text{mhos/cm}$  for the dry season. The electrical conductivity in groundwater in the study area have a mean and coefficient of variation of 414.27  $\mu\text{mhos/cm}$  and 137.58% for wet season as against the mean of 272.13  $\mu\text{mhos/cm}$  and 94.92% for the dry season. Electrical conductivity in groundwater are noted to be higher in the wet season than the dry season (Fig.5). The cause of high electrical conductivity in some of the boreholes may be traced to the local environment of the waterpoints in terms of geology, soil and land use activities. These boreholes are located within Eze-Aku and Awgu geological formations mainly of sandstones and shales.

The results of analyses show that chloride concentrations in water samples for wet and dry season are all within the WHO prescribed limit of 200-600  $\text{mg/l}$  for drinking water. Chloride concentration in boreholes have a mean and coefficient of variation of 72.88  $\text{mg/l}$  and 137.42% for wet season, and 29.65  $\text{mg/l}$  and 60.24% for the dry season (Fig.6). Chloride concentrations in groundwater are lower in the dry season as compared to that of the wet season. However, boreholes with appreciable concentrations are BH15 and BH9 (450  $\text{mg/l}$ , 335  $\text{mg/l}$ ). This may be attributed to the local environment of the boreholes. The effect of chloride on taste may be critical to water use. Some water containing up to 250  $\text{mg/l}$  of chloride may have detectable salty taste if the predominant cation is sodium (Hutton, 1983; Ademoroti, 1996).

Total dissolved solids test provides a quantitative measure of the amount of dissolved ions. It is used as indicator test to determine the general quality of water (DeZuane, 1977). Studies however have not shown any health effect associated with ingestion of water with high concentrations of total dissolved solids. Water samples analysed have a mean and coefficient of variation of 167.73  $\text{mg/l}$  and 139.26% for wet season, and 181.78  $\text{mg/l}$  and 139.06% for the dry season. The concentration of total dissolved solids in groundwater are noted to be higher in dry season than in wet season (Fig.7). This is consistent with the findings of Howell et al (1996) and Efe et al (2005).

The results of analyses of water samples show alkalinity in groundwater in the study area are within the WHO allowable limit for drinking water for the wet and dry season. Water samples have alkalinity mean and coefficient of variation of 117.15  $\text{mg/l}$  and 78.25% for wet season as against



16.46mg/l and 145.2% for dry season. Alkalinity level in groundwater is higher in the wet season than in the dry season(Fig.8).

The concentration of turbidity in water samples analysed show BH19(230FTU) BH4(150FTU) BH6(90FTU) and BHs 12 and 13(80FTU) to have elevated values above the WHO guide limit for wet season,BH4(150FTU),BH5(90FTU)BH2(70FTU) BH3(50.18FTU) for the dry season.Turbidity in water sample have a mean and coefficient of 27.09FTU and 206.05% for the wet season as against a mean and coefficient of 16.82FTU and 209.39% for the dry season. Turbidity concentrations in groundwater are noted to be higher in the higher in the wet season than in the dry season(Fig.9).The cause of turbidity in boreholes may be traced to dissolved clay and mud materials into the groundwater. Frequency of drawn down from borehole can contribute to turbidity in water.

**CONCLUSION**

The study has shown that change in season can have influence on the concentrations of physico-chemical properties of groundwater. Parameters such as temperature,PH and total dissolved solids are noted to have lower concentrations in the wet season. While concentrations total hardness, electrical conductivity, chloride, alkalinity and turbidity are noted to be higher in the dry season. The concentration of these parameters in the boreholes is reflected in the coefficient of variation.

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**Fig-2.** Seasonal variation in temperature of groundwater in the study area

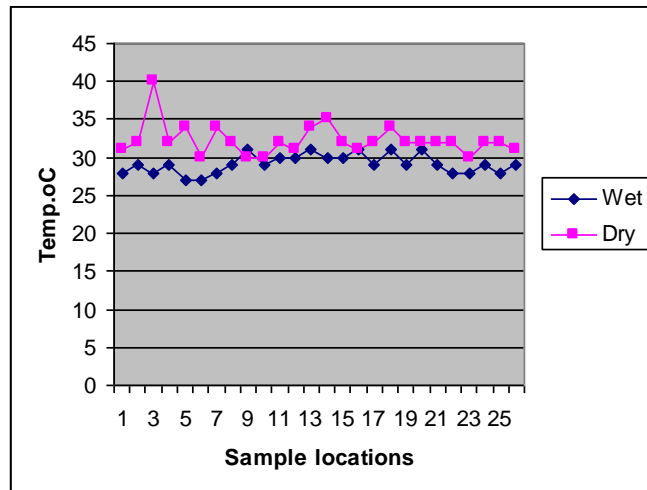


Fig-3. Seasonal variation in PH of groundwater in the study area

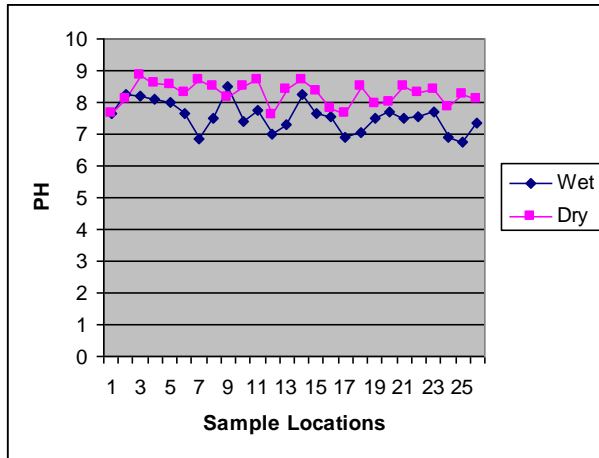


Fig-4. Seasonal variation in total hardness of groundwater in the study area

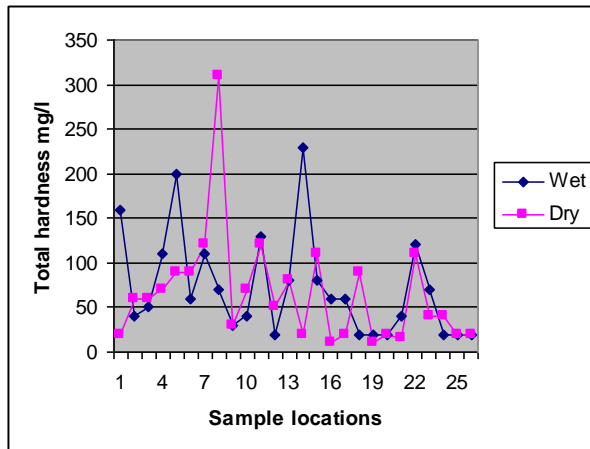


Fig-5. Seasonal variation in electrical conductivity of groundwater in the study area

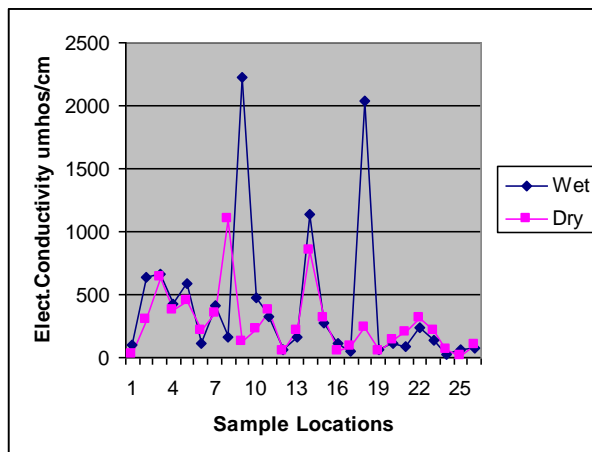


Fig-6. Seasonal variation in chloride of groundwater in the study area

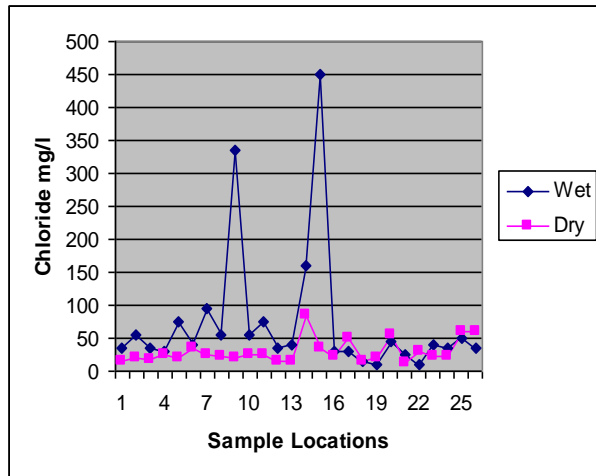


Fig-7. Seasonal variation in total dissolved solids in groundwater in the study area

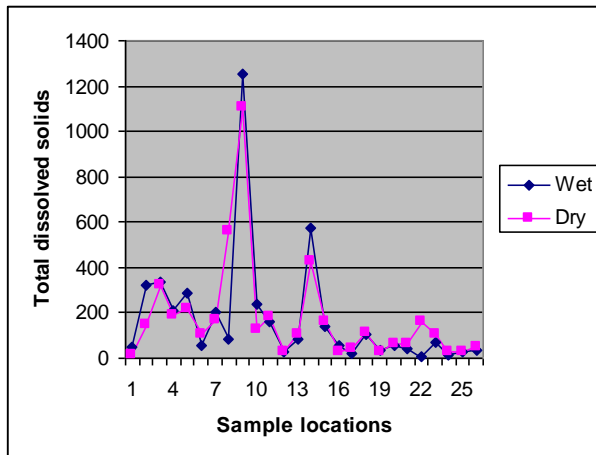
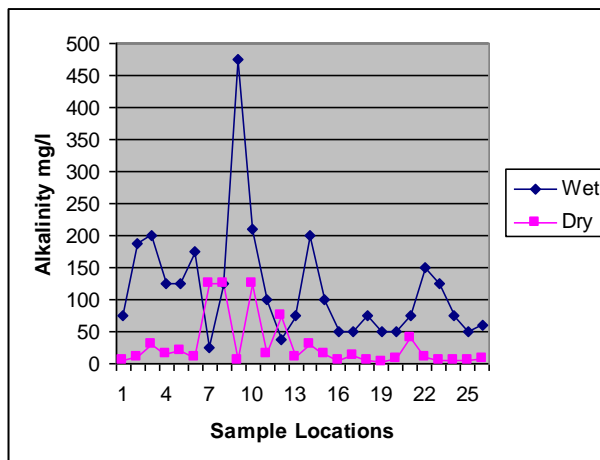
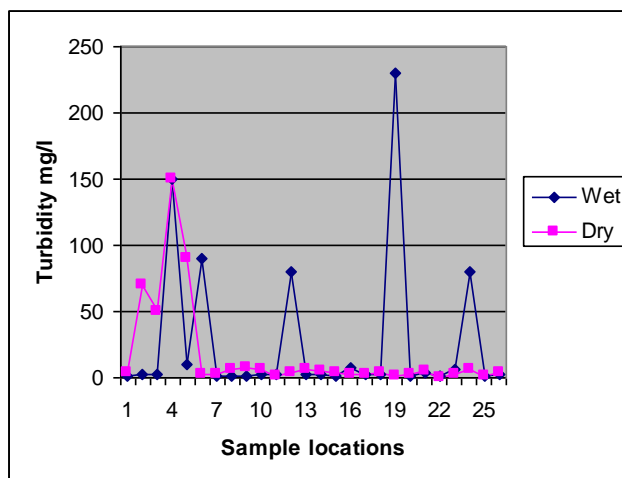


Fig-8. Seasonal variation in alkalinity of groundwater in the study area



**Fig-9.** Seasonal variation in turbidity of groundwater in the study area

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