

Research Article

Chemical Water Quality Assessment in Selected Location in Jos, Plateau State, Nigeria

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Abstract: The study examined well water quality (chemical) in Jos metropolis which it collected a total of twenty water samples that were taken for laboratory analysis. The stratified systematic random method was used in the selection of sample area/location. A total of (10) out of the existing (20) wards were systematically selected, while in each of the wards, two wells with one each from higher and lower elevations were randomly selected in which water samples were collected. The samples collected were analysed at UNICEF (WATSAN) Laboratory Bauchi. USEPA method of water analysis was used to test for the chemical parameters. Pearson product moment correlation co-efficient was used to test for the relationship between high and low elevation in the sample elements, as well as mean and standard deviation. The results indicate that pH, E.C, TDS, Pb, As and Cyanide appear within NSDWQMPL, while NO₂, Cl, F, Mn, Mg, Ca, Cu, Zn, CaCO₃ and Cr marginally fall within acceptable standard for drinking water quality maximum permitted limit. Consequently, NO₃, SO₄, Fe and CaCO₃ in some parts of Jos metropolis fall outside acceptable standard of NSDWQMPL. Moreover, pH, E.C, TDS, Pb, NO₂, NO₃, Cl, F, Mn, Cr, As, Cu, Zn, showed that there is no significant relationship within the individual elements in regards to elevation (high and low) in the study area whereas, SO₄, Fe, Mg, Ca, CaCO₃ and CaCO₃ showed that there is significant relationship in elevation (high and low) among the individual sample elements. The study concludes that well water quality through chemical assessment in Jos metropolis is not fit for drinking. It recommends sensitization campaign on the importance of clean water, sanitation, enforcement of existing laws and more research be undertaken to cover for seasonal variation, more elements and sample size.

Keywords: Chemical elements, drinking water standard, water quality

INTRODUCTION

Water that is meant for drinking should be of high quality, while the water for other domestic purposes can be of good quality (Oteze, 1991; Eziashi, 1995; Jidauna *et al.*, 2013). The essential nature of water to man's daily usage vis-à-vis quantity and quality right from time immemorial has been on the increase. World population growth has maintained a consistent pattern of which more pressure is being placed on the limited available resources, with water being dominant.

Globally, 1.1 billion people do not have access to adequate water supply, with 460 million people currently suffering acute water shortage and 2.4 billion lacking adequate sanitary facilities. Water is a potential vehicle for the transmission of organisms of specific disease, four out of every ten children in developing world die from diarrhea before the age of five accounting for over 80% of all human illnesses in developing countries (WHO, 2000). Increasing demand, coupled with limited supply (pipe born water) has forced urban dwellers to resort in the use of well water

for drinking, bathing and other domestic uses. The history of hand-dug well and its importance to man is as old as man itself. Till today the hand-dug wells is still used to satisfy man's water needs all over the world. In Nigeria over 70% of the population use hand-dug wells to satisfy their water needs especially for household drinking purposes (Ashano and Dibal, 2006).

In Sub-Saharan Africa (Jos-Plateau, Nigeria), accessing portable (drinking) water is a major problem. Water is life has been a common phrase that is not peculiar to Nigerian environment (Jos-Plateau), but to the world at large. Geographical distribution of water resources varies both in time and space. Considering that virtually the whole of human civilization vis-à-vis daily activities is dependent on water (Agricultural, Industrial and Domestic), yet scarcity is inevitable and perennial (Ndabula and Jidauna, 2010; Jidauna *et al.*, 2013). According to Faniran (1977) as cited in Ogunnowo (2004) "an assured supply of water both qualitatively and quantitatively for this purpose greatly improves the social and economic activities of the people". Thus, an average man requires 1.5 L of water

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daily for drinking and about 380 L (100 gallons) for daily domestic uses (Ayoade and Oyebande, 1983; Van der Leeden, 1975).

The hand-dug wells are in most cases cited in unsanitary locations (close to refuse dumps, pit-latrines or suck-away systems). Some of the wells are even left open and are therefore prone to contamination of various types and degrees. The addition of any undesirable substance (s) to ground or well water either through human activities or natural processes is considered contamination. However, two chief sources of water pollution are point source and non-point source. Water is a potential vehicle for the transmission of organisms of specific disease, accounting for over 80% of all human illnesses in developing countries (WHO, 2002). Among the major water borne disease are cholera, typhoid, bacillary dysentery, infections hepatitis and giardiasis, while the major washed disease (i.e., diseases due to lack of water) are scabies, skin diseases, sepsis ulcers, leprosy, trachoma, dysentery and ascaria (WHO, 2004). The United Nations Millennium Development Goals (MDGs) under one of its targets is the need to reduce by 50% the proportion

of people without sustainable access to safe drinking water and basic sanitation by 2015.

Scarcity which has a perennial dimension in Jos (January to May) often see women and children hauling water over longer distances from questionable surface sources (poor quality) for domestic purposes. Wells, which appear more easily, owned (public/private) is viewed as the most dependable, of which its usage for domestic purposes (drinking) are not put into question. How safe (chemical quality) and fit is the water for drinking? Does relationship exist between slope variations in water quality? and Does climatic trends influences the quality of well water in the study area? These are among issues examined by this study.

STUDY AREA AND METHODOLOGY

Jos metropolis (Plateau State capital) is located on latitudes $10^{\circ}00'$ and $9^{\circ}50'$ and longitudes $9^{\circ}00'$ and $8^{\circ}55'$, with an estimated total land area of about 340 km². It is bounded by Bauchi State to the Northeast, Bassa LGA to the East and Northeast, Bukuru (Jos-

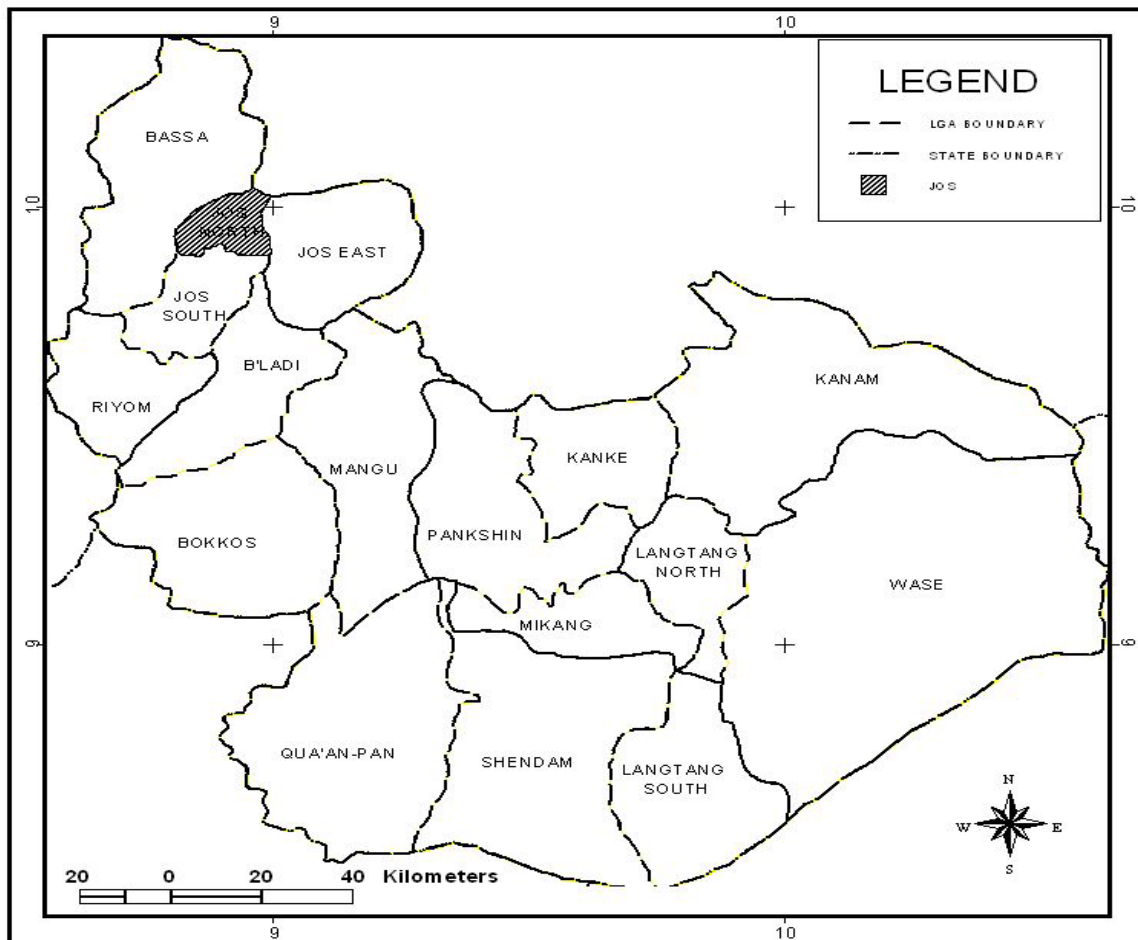


Fig. 1: Plateau state showing the study area

Table 1: Name, location and elevation of sample wells

Sample	Ward	Name of place	Altitude	Elevation	Latitude	Longitude
S1	Angwan Rogo/Rimi	Unijos Bauchi Road Mosque	High	1185 m	N09 9504°	E08 89220°
S2	Angwan Rogo/Rimi	Layin Mal Ya'u Rogo	Low	1152 m	N09 94681	E08 88220°
S3	Kabong	Honda Villa Garge by Gordon Hotel	High	1184 m	N09 94604°	E08 86646°
S4	Kabong	Algadama junction	Low	1166 m	N09 93907°	E08 86746°
S5	Jenta Apata	Apata Mosque	High	1186 m	N09 93281°	E08 82710°
S6	Jenta Apata	Beside Biggoe Park	Low	1164 m	N09 93184°	E08 87899
S7	Gangare	Plateau Specialist Hospital Premises	High	1274 m	N09 89514°	E08 88491°
S8	Gangare	Railway Qrts Gangare	Low	1167 m	N09 91741°	E08 89636°
S9	Jos Jarawa	Beside NDLEA Rikkos	High	1227 m	N09 91507°	E08 90640°
S10	Jos Jarawa	Tudun Osse	Low	1143 m	N09 91875°	E08 89864°
S11	Sarkin Arab	Cntral Mosque Jos	High	1190 m	N09 92913°	E08 88840°
S12	Sakin Arab	Halliru Street	Low	1169 m	N09 93445°	E08 88637°
S13	Abba Na Shehu	Layin Zana	High	1181 m	N09 93633°	E08 89158°
S14	Abba Na Shehu	Dan Maraya	Low	1140 m	N09 95523°	E08 87984°
S15	Tudun Wada	Federal Secretariat	High	1239 m	N09 90563°	E08 82544
S16	Tudun Wada	INEC Office	Low	1153 m	N09 90866°	E08 83012°
S17	Amamzah	Old Legislative Qrts Etobaba	High	1198 m	N09 93657°	E08 84391°
S18	Amamzah	Maza PHC Clinic	Low	1028 m	N09 96264°	E08 56029°
S19	Naraguta 'B'	Dogon Dutse	High	1192 m	N09 94021°	E08 89172°
S20	Naraguta 'B'	Gongo Russia	Low	1152 m	N09 93623°	E08 89025°

Authors' field work May, 2010

South) to the South and Jos-East LGA to the East (Fig. 1). Jos North LGA is divided into 20 political wards inhabited by various ethnic nationalities (both foreign and local), with an estimated human population of about 437, 217 (NPC, 2006).

The climate is affected by altitude and changing position of Inter-Tropical Convergence Zones (ITCZ) or Inter-Tropical Discontinuity or Inter-Tropical Front (ITF). Rainfall is high (1,305 mm) and characterize with two distinct season (wet and dry), with temperature range of 32°C to 18°C, respectively (Eziashi, 2007). Its geology is largely made-up of younger granite complex. It has attracted a lot of surveys since Falconer (1924) recognized it as a source of caseterite. Schoeneich (1991), observed that the Jos Plateau consist of an undulating dissected surface highest in the south and slopping Northwards with an area of about 9,400 km². The highest peak is at Shere hills which rise to 1,777 m while the gently undulating surface lies between 915 m amsl and 1,300 m amsl. The two aquifers in existence are fractured crystalline aquifer and the soft over-burden aquifer (Schoeneich, 1991).

To adequately cover or ensure spread, a stratified systematic randomly method was used. The study area was made already divided into twenty electoral wards. Ten out of the 20 wards was systematically selected with an interval of one electoral ward between each of the selected wards.

In each of the ten selected wards, two wells with one each from higher and lower elevations were randomly selected in which water sample was collected. This brings the number of samples collected from higher and lower elevations to 20 samples. The selected wards are: Angwan Rogo/Rimi, Kabong, Jenta Apata, Gangare, Jos Jarwa, Sarkin Araba, Abba Na Shehu, Tudun Wada, Amanzah and Naraguta (Table 1). A total of twenty water samples were taken from hand dug wells in the rainy season (May, 2010) for laboratory

analysis. Hand-dug wells were sampled with a clean plastic bucket tied to a plastic rope. This was lowered down and the water was collected. The water was then poured into a new one liter plastic bottle, sealed with the cap, free from air bubble and labeled with sample code numbers: S1, S2,...Sn. The bottles were rinsed with ionized water before the collection of the samples. The sample was then kept in a field cooler with ice packs before taken to the laboratory. This was to avoid a rise in temperature which may cause either growth or death of Bacteria and thus affect the result. The twenty water samples collected were analysed at UNICEF assisted water and environmental sanitation project (WATSAN), Laboratory Bauchi. USEPA method of water analysis was used to test for the physical and chemical parameters. The following instruments were used for the test: TDS/Conductivity Meter (HACH) model 446000.00, Titremetry-Digital Titrator (HACH) model 16-99-01, Spectrophotometer (HACH) model DR/2000, Palintest parameter and the HANA pH meter, model IH 98129. Pearson product moment correlation coefficient was used in testing for the relationship between samples taken on high and low elevation in individual mineral elements (α 0.05) (Appendix 1). The World Health Organization (WHO, 2000) standard for domestic water quality and the Standard Organization of Nigeria (SON, 2007) which is the National Standard for Drinking Water Quality Maximum Permitted Limit (NSDWQMPL) were used in comparing the results of the different chemical elements used for water quality assessment.

PRESENTATION AND DISCUSSION OF RESULTS

The results of the different chemical parameters considered and analysed from the water samples collected within Jos metropolis of Plateau State is presented in Table 2 and consequently discussed under different subsection.

Table 2: Chemical parameters analysed for water quality (Well water) in Jos metropolis

S/N	Parameter	UNIT	WHO	SON	Minimum	Max	Average	Range	STDV
1	pH	-	6.5-8.5	6.5-8.5	5.3	6.8	6.0	1.5	0.5
2	E. Conductivity	μcm	1,500	1,000	69	1000	351.50	931	122.83
3	TDS	mg/L	500	500	34	500	193.50	466	70.45
4	Nitrate ion (NO_3)	mg/L	50	50	7.48	118	40.00	110.52	37.83
5	Nitrite ion (NO_2)	mg/L	0.02	0.2	0.01	0.06	0.40	1.05	0.31
6	Sulphate ion (SO_4)	mg/L	200	100	5	330	111.33	325	74.24
7	Chloride ion (CL)	mg/L	400	250	40	250	110.29	210	44.38
8	Fluoride ion (F^-)	mg/L	1.5	1.5	0	1.5	0.63	1.5	0.33
9	Manganese ion (Mn^{12})	mg/L	0.1	0.2	0	0.2	0.03	0.2	0.02
10	Magnesium (mg)	mg/L	50	20	0.4	20	6.49	19.6	3.19
11	Calcium (Ca)	mg/L	75	75	6.4	75	32.58	68.6	16.96
12	Copper ion (Cu^{2+})	mg/L	1	1	0.03	1	0.31	0.97	0.21
13	Zinc ion (Zn)	mg/L	5	3	0	3	0.50	3	0.18
14	Total iron (Fe^{+2})	mg/L	0.3	0.3	0	0.78	0.29	0.78	0.26
15	Hardness (as CaCO_3)	mg/L	200	150	20	262	114.96	242	76.57
16	Alkalinity (as CaCO_3)	mg/L	120	100	6	100	33.08	94	11.28
17	Lead ion (Pb)	mg/L	0.05	0.01	0	0.010	0.00	0.01	0.00
18	Chromium (Cr^{+6})	mg/L	0.01	0.05	0	0.05	0.01	0.05	0.01
19	Arsenic (DS)	mg/L	0.05	0.01	0	0.01	0.00	0.001	0.00
20	Cyanide (Cr^-)	mg/L	0.01	0.01	0	0.01	0.00	0.01	0.00

Authors field work, WHO (2000) and SON (2007)

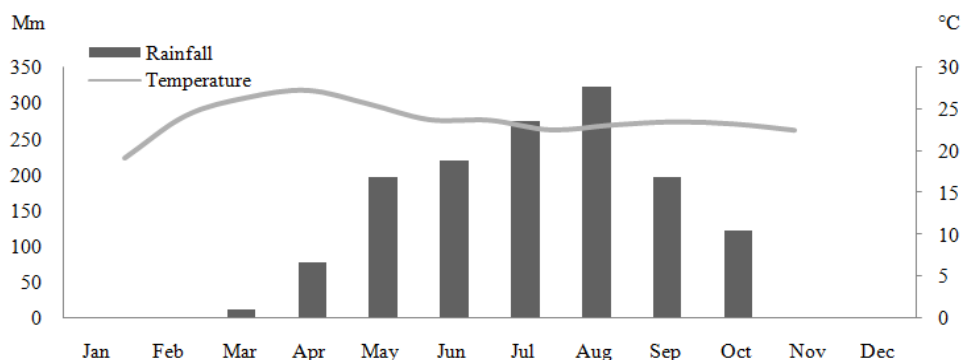


Fig. 2: Monthly average rainfall and temperature trends in jos (1999-2008)

Total Dissolved Solids (TDS) and electrical conductivity of water samples: TDS is the measure of total amount of all materials that are dissolved in water. These materials, both natural and anthropogenic are mainly inorganic solids with minor amount of organic materials. Both TDS and E-Conductivity values ranges from 34 to 274 mg/L and 69 to 477 mg/L, respectively which are below the 500 and 1000 mg/L for NSDWQMPL in that order. The average reading lies within the acceptable standard, with a lower standard deviation values (Table 2). There is no significant relationship between samples taken on high and low elevation with regards to E. Conductivity.

Nitrite and nitrate concentration in water samples: Nitrite is more toxic than nitrate. Nitrite finds its way into water bodies through contamination with chemical fertilizer, organic waste and surface water. Nitrite ion can combine with hemoglobin (red blood cells pigment) to form methaemoglobin complex, which makes impossible the transportation of oxygen to the various parts of the body. This causes methaemoglobinemia or cyanosis in infants under 3 months (blue-baby syndrome) and stomach cancer.

Nitrate is essential for growth, thus high concentration of nitrate indicates potentials or excessive

weed or algae growth which impaired water quality. 70 and 80% of Nitrite and Nitrate level in water samples, respectively falls within NSDWQMPL, with average values in the study area being within acceptable water quality standard. Both elements show a lower standard deviation value (Table 2) and that there is no significant relationship between (nitrite and nitrate elements) the samples taken from high and low elevation in the study area. The average rainfall trend between 1999-2008 showed a higher trend (324 mm) which is around August (Fig. 2) often aid in the leaching processes that in turn influence the elements content ratio (nitrate) in water. The leaching of nitrate into the water table depends on factors such as geology, soil type, crop utilization rate of nitrogen, microbial conversion rate of nitrate and fertilizer application pattern. Thus, it can be deduced that relatively high nitrate values may be due leaching from sewages, pit latrines and refuse dump located close to wells.

Sulphate and Iron concentration in water samples: Sulphate when combined with magnesium, gives a bitter taste to water (Laxative effect). High concentration of sulphate above the recommended limit in drinking water is known to cause catharsis, dehydration and gastro-intestinal irritation. Sulphate

values recorded in some places exceeded that of NSDWQMPL. However, average values in the study area falls within acceptable standard, with a slightly lower standard deviation. Thus, there is a significant relationship between (Sulphate) samples taken on high and low elevation in the study area.

Excessively high amount of Iron is known to interfere with normal fluid regulation in humans and also causes stains in laundry and fixtures. Iron concentration in some places fall above NSDWQMPL while the average taken in the study area marginally lies within the accepted standard for drinking water quality (WHO and SON) and with a standard deviation of 0.26. Hence, there is negative, but significant relationship between samples of Iron taken on high and low elevation in the study area. Thus, a 65 and 55% of Sulphate and Iron, respectively falls within acceptable standard (NSDWQMPL).

Chloride and zinc concentrations in water samples:

Domestic waste contains considerable quantities of chloride due to the presence of urine (Miroslaw, 1999). Chloride is used to express the senility of water. High chloride concentration particularly in water that contains magnesium and calcium increases the corrosive nature of the water. It renders the water salty which makes it unsuitable for household use and commercial food production. It also corrodes metallic equipment and adversely affects certain fruit crops when water is used for irrigation (Miroslaw, 1999). Zinc has gastro-intestinal effect on human at a higher concentration and cause liver damage (WHO, 2000). Chloride and Zinc concentration range from 40 to 250 mg/L. and 0.00 to 0.50 mg/L, respectively all below the 250 mg/L and 3 mg/L NSDWQMPL. Both elements show no relationship with regards to elevations in samples taken, with both elements having a mean value with acceptable standard for domestic water quality.

Manganese and magnesium concentration in water samples:

Magnesium is useful to the nervous balance of the body, but high concentration of magnesium combined with sulphate has a laxative effect which can manifest by giving water a bitter taste. It also predisposes human body to the formation of kidney or bladder stones and irritation of Urinary passages (Sax, 1974). High concentration of Manganese causes neurological disorder (SON, 2007). Magnesium and Manganese contents ranges between 0.4 to 20, 0.0 to 0.02 mg/L, respectively. About 100% and only 10% of samples has manganese and magnesium content, respectively within NSDWQMPL. While manganese showed no significant relationship, magnesium indicated a significant relationship with regards to the elevation in the samples taken in the study area.

Arsenic and chromium concentration in water samples: Chromium, when present in desirable amount (0.05 mg/L) in human body is known to remedy impaired carbohydrate metabolism by increasing the

effectiveness in insulin (Jidauna *et al.*, 2011). However, high concentration of chromium causes malignant growth in respiratory tract, painless perforation of the nasal septum, dermatitis and cancer of the lungs (Forstner and Wittaman, 1983). High concentration of Arsenic also causes cancer (SON, 2007). Thus, 60% of the samples have average chromium content 0.01 mg/L within NSDWQMPL and all the values of Arsenic are within NSDWQMPL. Both elements showed no relationship with regards to elevation in the samples taken in the study area.

Lead and cyanide concentration in water samples:

Leads are highly toxic. High concentration of lead in human body can cause brain damage and even death (Sax, 1974). High concentration of lead also causes cancer, interfere with vitamin D metabolism and affect mental development in infants and toxic to the central and peripheral nervous systems. Cyanide in high amount is very toxic to the thyroids and the nervous system (SON, 2007). Both lead and Cyanide contents are within 0.01 mg/L NSDWQMPL, with no significant relationship in regard to elevation (high and low) on the samples taken in the individual elements.

Copper and fluoride concentration in water samples:

High copper concentration in drinking water above the 1 mg/L NSDWQMPL may cause gastrointestinal disorder, while high amount fluoride above 1.5 mg/L causes fluorosis, skeletal tissue (bones and teeth) morbidity (SON, 2007). However, fluoride is beneficial to human health. When ingested at tolerable levels, fluoride plays a very important role in the formation of teeth (WHO, 2000). Too low fluoride intake below 0.5 mg/L could also give rise to dental caries. Both copper and fluoride contents are within NSDWQMPL, with both showing no significant relationship in elevation (high and low) in the samples taken in the study area for the respective elements analysed.

Hardness and Alkalinity of water samples:

Hardness or softness of water varies from one place to another and mostly reflects the nature of the geology of the area with which the water has been in contact. The major principal cat ions causing hardness are Ca^{2+} , Mg^{2+} , Fe^{2+} , Sr^{2+} and Mn^{2+} . Hard water is important, because it supplies the minerals Ca and Mg, which are nutrients for plant growth and also essential minerals for humans. Soft water is associated with heart disease. The hardness ranges between 20 to 262 mg/L. Some areas were above the 150 mg/L recommended for total hardness by NSDWQMPL. The alkalinity of water refers to its ability to neutralized acids. Alkalinity values of the water samples range from 6 to 100 mg/L which is within the recommended limit by SON. Both elements showed a significant relationship in elevation (high and low) in samples taken in the study area with regards to the individual elements analysed.

Calcium and pH concentration in water samples: Calcium concentration in water samples analysed ranges between 6.4 to 75 mg/L, which is within the acceptable standard for drinking water quality (NSDWQMPL), with a significant relationship in

elevation (high and low) for the elements analysed in the study area.

The pH of water has a profound effect on the mobility of most of the elements (Davis and Dewest, 1969). Iron diminishes rapidly as pH of water increases

Appendix 1: Pearson product moment correlation co-efficient for the samples taken on high and low elevation in the study area

Serial No.	pH		E.C		Nit ion		Nit		Sulphate	
	(H)	(L)	(H)	(L)	(H)	(L)	(H)	(L)	(H)	(L)
1	6.8	6.5	69	477	13.2	104	0.01	0.614	10	108
2	5.4	5.4	125	165	13.2	17.6	0.234	0.95	5	23
3	6.2	6.8	412	349	15.4	13.2	0.29	0.74	88	148
4	5.9	6.5	232	256	118	39.6	0.52	1.06	65	55
5	5.6	6.5	213	426	26.4	7.48	0.19	0.07	60	160
6	6.1	6.4	338	467	11.9	13.6	0.1	0.05	165	330
7	6.2	6	345	425	8.36	18	0.09	0.13	75	170
8	6.3	6.6	234	187	7.92	15	0.45	0.61	57	92
9	5.3	6.6	205	152	109	91.6	0.51	0.21	55	82
10	6.4	6.2	179	180	11.4	19.2	0.35	0.02	40	124
Total	6.02	6.35	235	308	33.5	33.93	0.274	0.445	62	129
Mean		6.185		271.8		33.703		0.3599		95.6
Relationship		0.283		0.268		0.4468		0.2955		0.86
Serial No.	Lead		Chloride		Fluoride		Manganese			
	(H)	(L)	(H)	(L)	(H)	(L)	(H)	(L)	(H)	(L)
1	0	0	40	217	0.5	0.8	0.005	0.001		
2	0.0002	0.0001	60	52	0.65	0.25	0.01	0.03		
3	0	0	65	62	0.35	0.3	0.06	0		
4	0	0	122	108	0.35	0.8	0.02	0.01		
5	0.0002	0	62	122	0.5	1.2	0	0		
6	0	0	108	160	0.5	1.4	0.01	0.002		
7	0	0	75	141	0	0.1	0	0		
8	0	0.0002	59	114	0.3	0.41	0.01	0		
9	0	0.0003	61	104	0.62	0.45	0.06	0.002		
10	0	0	54	111	0.52	0.61	0.002	0		
Total	0.00004	0.00006	70.6	119	0.43	0.632	0.0177	0.005		
Mean		0.00005		94.85		0.5305		0.0111		
Relationship		-0.04903		-0.06		0.3569		-0.077		
Serial No.	Chromium		Arsenic		Total Iron		T/Hardness		Alkalinity	
	(H)	(L)	(H)	(L)	(H)	(L)	(H)	(L)	(H)	(L)
1	0.002	0.003	0	0	0.78	0.08	20	130	16	32
2	0	0	0	0	0.38	0.24	24	40	6	8
3	0.01	0.02	0	0	0.42	0.06	262	248	28	40
4	0	0.01	0	0	0.02	0.4	82	96	12	28
5	0.02	0	0	0	0.08	0.04	78	56	38	48
6	0.01	0.002	0	0	0.6	0.06	226	192	20	26
7	0.01	0.02	0	0	0	0.1	110	122	18	16
8	0.002	0.003	0	0	0.02	0.6	25	33	15	35
9	0	0.001	0	0	0.04	0.37	76	55	27	30
10	0.04	0.003	0	0	0.73	0.07	48	162	17	34
Total	0.01	0.01	0	0	0.31	0.202	95.1	113.4	19.7	29.7
Mean		0.008		0		0.2545		104.25		24.7
Relationship		-0.035		0		-0.578		0.7857		0.759
Serial No.	Magnesium		Calcium		Copper		Zinc			
	(H)	(L)	(H)	(L)	(H)	(L)	(H)	(L)	(H)	(L)
1	0.98	6.35	6.4	41.7	0.2	0.13	0.42	0.23		
2	2.93	2.44	19.2	16.7	0.18	0.2	0.12	0.22		
3	2.04	2.9	18.5	19.3	0.3	0.55	0.41	0.01		
4	5.86	4.64	39	30.8	0.03	0.1	0.03	0.02		
5	3.7	2.84	25	16.3	0.13	0.23	0.04	0.07		
6	10.99	9.28	72.5	61.6	0.13	0.1	0.08	0.02		
7	5.3	6.1	35	39	0.03	0.1	0	0		
8	3.39	3.21	9.2	9.04	0.19	0.9	0.05	0.11		
9	11.9	7.93	32.5	26.2	0.25	0.2	0.51	0.03		
10	2.5	0.4	21	18	0.07	0.52	0.05	0.54		
Total	4.959	4.609	27.83	27.9	0.15	0.303	0.171	0.125		
Mean		4.784		27.85		0.227		0.148		
Relationship		0.748302		0.722		0.3481		-0.115		

Table value = 0.564 α 0.05

above 6.0. The pH ranges between 5.3-6.8 mg/L which is within NSDWQMPL and thereby showed that no significant relationship exist in elevations for the sample elements. It is however observed that over the last few years, Jos Metropolis seems to have witnessed increased number of oxidized roofs over a much shorter period of time as compared to other periods. This is believed as a result of acid rain effect (Fig. 2) brought about by high average temperature and rain regime, there by resulting in the dissolution of the acid gasses from the atmosphere by rain and the subsequent infiltration of this acidified water to recharge groundwater is believed to be largely responsible for the lowering of groundwater pH.

CONCLUSION AND RECOMMENDATIONS

The results of the different samples analysed indicates that pH, E.C, TDS Pb, As and Cyanide appears within NSDWQMPL, while NO₂, Cl, F, Mn, Mg, Ca, Cu, Zn, CaCO₃ and Cr marginally falls within acceptable standard for drinking water quality maximum permitted limit. Consequently, NO₃, SO₄, Fe and CaCO₃ in some parts of Jos metropolis fall outside acceptable standard of NSDWQMPL. Moreover, pH, E.C, TDS, Pb, NO₂, NO₃, Cl, F, Mn, Cr, As, Cu, Zn, showed that there is no significant relationship within the individual elements in regards to elevation (high and low) in the study area whereas, SO₄, Fe, Mg, Ca, CaCO₃ and CaCO₃ showed that there is significant relationship in elevation (high and low) among the individual sample elements. The study concludes that well water qualities in Jos metropolis are not fit for drinking. Therefore, well water in the study area should be treated before drinking. This study recommends aggressive public awareness on the dangers of drinking contaminated water especially as it relates to the negative health effects; The public should also be educated on the negative relationship between unclean environment and water quality; The laws on groundwater quality protection provided by NEREA should be enforced and protection zones within the study area also created; Routine sanitary inspections on private drinking water system should be conducted to assist residents with information on state their drinking water; There is the need for the establishment of water safety plan for the study area which should including wells and strictly ensure compliance. In addition, some chemical parameters such as Mercury, Nickel, Aluminum and Barium were not investigated. It is therefore recommended that subsequent studies should cover the entire Metropolis, sampling of more wells, both seasons (rainy and dry) be considered and consideration of more chemical parameters.

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