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GROUNDWATER QUALITY ASSESSMENT OF ABA URBAN AREA

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Abstract

This work presents groundwater quality assessment of Aba Urban area and its sources of Contaminants within Aba Urban Area. Aba area was divided into nine parts using a 3x3 grid. Water samples were taken from each of these 9 parts of Aba. Five water samples were taken from household boreholes while four samples were taken from boreholes drilled and cased at the remaining four parts in the course of carrying out this research. Site and laboratory tests were conducted to determine the values water parameters in the samples. The parameters analysed in the laboratory include the Phosphate, ammonium, Lead, cadmium, Manganese, Copper, Mercury, Chromium, and magnesium, Electric conductivity (EC), Dissolved oxygen (DO), Total dissolved solid (TDS), Acidity, Turbidity, Alkalinity, oxidation-reduction potential (ORP), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and E-Coli. It was discovered that more than 75% of the water samples are contaminated by E-Coli. Umuagu sample has Manganese value of 0.775mg/l. This more than the limiting value of 0.4mg/l. The values 252, 524 and 472 mg/l of Magnesium in samples from Estate, Abia Polytechnic and Osisio Ngwa respectively are more than the limiting value of 150mg/l. The DO (mg/l) values of 6,4 and 9 from Ariaria Junction and Abia Polytechnic are outside the range limiting of 6.5mg/l – 8.0 mg/l. The values of TDS, ORP and BOD recorded in all the samples are below the limiting values of 600 mg/l, 357 mV and 1mg/l respectively.

1.0 INTRODUCTION

Aba is one of the commercial nerves of South-East Nigeria. It houses many people of different walks of life. It is densely populated with an estimate of 1,189,000 people in 2023 [1]. Ninety five per cent of this population depend on ground water obtained by drilling boreholes at various locations. There is dare need to determine if the ground water at Aba, which is a commercial city, is directly or indirectly affected by the enormous quantity of solid, liquid and gaseous waste products produced therein.

Static water level (SWL) in Aba area is shallow. The work of [2] shows that SWL is as low as 4.57m in Ukwa East. The range of Static water level for some LGA within Aba area are shown on Table 1. According to United States Environmental Protection Agency (EPA) [3], there are three types of private drinking water wells. They are Dug/Bored wells, Driven wells and Drilled wells. The depth of dug wells is within 3 to 9 meters deep whereas that of driven well is within 9 to 15m. Both dug well and driven well can be easily contaminated because their water is drawn from aquifers that are near to the ground

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surface. Drilled well is more than 15m deep and is less likely to get contaminated because it water is drawn from aquifer that is not near the ground surface and the well uses continuous casing.

Some of the parameters to be looked out for include Anions (Phosphate and Ammonia), Cations (Lead, Cadmium, Manganese, Copper, Mercury and Magnesium), Electric conductivity (EC), Dissolve oxygen (DO), Total dissolved solid (TDS), Acidity, Turbidity, Alkalinity, Oxidation-Reduction Potential (ORP), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Escherichia Coli (E-Coli). Some scholars and Bodies like World Health Organization gave limiting (permissible or allowable) values for these parameters in drinking water. These standard values would be used to compare with the values measured in this work to establish if the sample meets the standard for drinking water or not. The standard values are presented on Table 2.

Table 1: Static water level in some LGA within Aba area

Local Government Area	Static water level (m)
Aba North	29.86 to 30.45
Aba South	18.25 to 35.97
IsialaNgwa North	19.0 to 97.5
IsialaNgwa South	23.70 to 50.52
ObiomaNgwa	17.7 to 36.0
Ukwa West	7.8 to 26.52
Ukwa East	4.57-19.20

Source: [2]

1.1 Location and Brief Geology of Study Area

Aba is located on the world map within the following geographical coordinate points - 5° 12' latitude to North and 7° 20' longitude to East; 5° 7' latitude to North and, 7° 27' longitude to East; 5° 2' latitude to North and 7° 20' longitude to East; 5° 7' latitude to North and 7° 17'longitude to East. The elevation is 205m. See Figure 1. According to [4] , Aba falls into tropical climate considered as AM in Köppen-Geiger climate classification [5]. AM stands for the warmest climate with short dry season. It is mostly referred to as a tropical monsoon and trade-wind littoral climate.

The average annual temperature in Aba is 26° C with peak and lowest temperatures of 33° C and 22° C respectively. Precipitations of up to 200mm are recorded for the months of April to October every year. December, January and February are the driest months with average precipitation of 57mm. The months with more than 6 hours of day light include December, January, February, March, April and May. Other months have average of 5 hours of sunlight a day [4].

Aba is one of the commercial hub cities in the South Eastern Nigeria. Lots of commercial and industrial activities go on in Aba on daily basis. According to [6], the waste generation in Aba is estimated at 236,703 tons/month. The typical municipal solid waste management technique used by ASEPA (Abia State Environmental Protection Agency) include: storage by the producers, collection by ASEPA, transportation and disposal at dumpsites and Incineration [7].

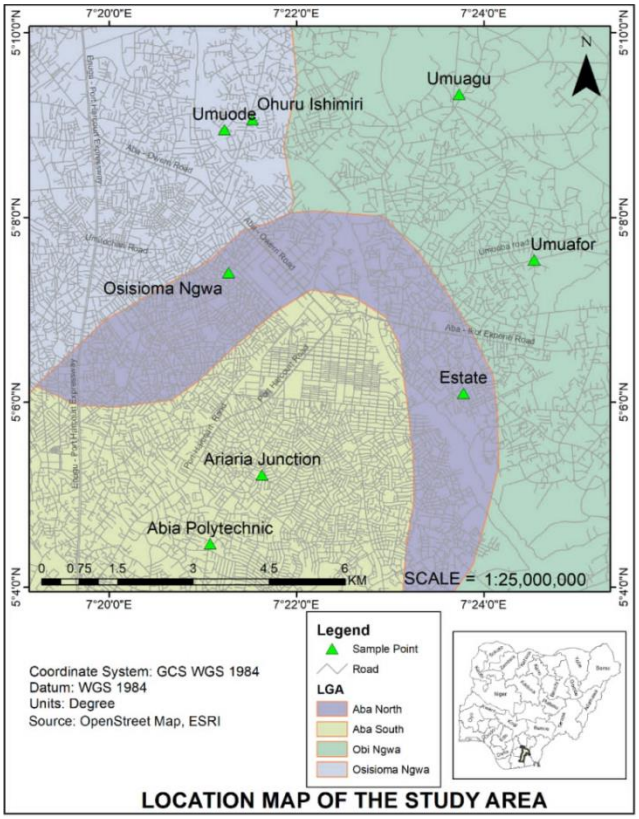

Figure 1: Map of Aba city, Nigeria
Legend: ΔThis indicates area where water sample was collected

The nearest cities around Aba include Owerri (North-west), Umuahia (North-East), Akwa-Ibom (South-East) and Port Harcourt (South-West). The nearest airports to Aba are Sam Mbakwe Airport (QOW), which is 39.40km away, Port Harcourt International Airport (PHC), which is 47.40km away and Margaret Ekpo International Airport (CBQ), which is 110.05km.

The plan area of Aba is roughly 72 km^2. The average population density of Aba is 36,111.11/km2. Aba has no municipal water supply. Residents of Aba rely on direct rain water, river (stream) water and groundwater (shallow well or deep well). However, they all rely on deep well (aquifer well) for drinking water. Benin formation composed of shale and

sandstone underlies Aba. This formation is composed of shale/sand sediments sandwiched among clay beds ([8],[9]]).

Table 2: Standard (Limiting) values of parameters

Parameter	Unit	Guideline Value	Guideline Reference
pH	-	6.5-8.5	[10]
Electrical conductivity	µ/cm	2500	[13]
Turbidity	NTU	1	[10], [13]
Dissolved Oxygen	mg/l	6.5 to 8.0 (80%-120%)	[14], [15]
Oxidation Reduction Potential ORP	mV	357 to -25	[16]
Total dissolved solid (TDS)	mg/l	600 (1500)	[12] ([14])
Phosphates	mg/l	0.015	[17]
Ammonia	mg/l	1.5	[12]
E-Coli	MPN/100ml	0	[11], [14]
Lead	mg/l	0.01	[11], [14]
Cadmium	mg/l	0.03 (0.05)	[11] ([14])
Manganese	mg/l	0.4 (0.1)	[11] ([14])
Copper	mg/l	1	[11], [14]
Mercury	mg/l	0.006	[11]
Chromium	mg/l	1	[11]
BOD after 5 days	mg/l	1	[18]

2.0 METHODOLOGY

Aba area was divided into 9 parts using a 3x3 grid. A water sample was taken from each of these 9 parts of Aba. Five water samples were taken from household bore holes while four samples were taken from boreholes drilled and cased at the remaining four parts in the course of carrying out this research. The coordinate locations (lat., long.) of the nine boreholes are 1-Estate (Latitude 5.101°N and Longitude 7.39°E), 2-Umuagu (Latitude 5.15°N and Longitude 7.39E°), 3-Alaoji (Latitude 5.18°N and Longitude 7.55°E), 4-Ariaria Junction (Latitude 5.08°N and Longitude 7.36°E), 5-Umuafor (Latitude 5.12°N and Longitude 7.40°E), 6-Abia Polytechnic (Latitude 5.07°N and Longitude 7.35°E), 7-Osisioma Ngwa (Latitude 5.12°N and Longitude 7.35°E), 8-Ohuru Ishimiri (Longitude 5.15°N and Longitude 7.35°E) and 9-Umuode (Latitude 5.14°N and Longitude 7.35°E).

These coordinates were obtained using handheld GPS receiver. The four boreholes drilled in the course of this research were flushed two times a day (4 hours each time) for four consecutive days to ensure that any impurity introduced into the wells was removed before collection of samples. The water samples were collected directly from the boreholes using 27 rinsed sterilized plastic containers. Three samples were collected from each location. The temperature and pH of the water collected from the boreholes were measured and recorded, before taking the samples to Laboratory. One per cent (1%) of Trioxonitrate (V) acid (HNO_3) was used to acidify the samples for main cations analysis in order to stabilize trace metals with pH~2. At the same time, Boric acid H_3BO_3 was used to acidify the samples for nitrate analysis. All the samples were put in an ice container and stored below the temperature of 4° C while being conveyed to the Laboratory. The parameters analysed in the laboratory include the Anions (phosphate and ammonia), Cations (lead, cadmium, manganese, copper, mercury, chromium and magnesium), Electric conductivity (EC), Dissolve oxygen (DO), Total dissolved solid (TDS), Turbidity, pH, oxidation-reduction potential (ORP), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and E-Coli.

Nephelometric turbidimeter was used to measure Turbidity of the water samples. It expresses turbidity in NTU (Nephelometric Turbidity unit). However, one Turbidity unit is equivalent to 1 mg/L of silica in suspension [19]. Electrical conductivity was measured using an electrical conductivity meter (EC meter) that has a probe which consists of two metal electrodes spaced 1 cm apart. (the unit of measurement is microsiemens per centimeter (µS/cm)) [19]. Winkler titration method was used to measure dissolved oxygen in water samples. It is measured in mg/l [19]. Total dissolved solids (TDS) was measured using a TDS Meter. It is measured in mg/l [19]. The pH of the water samples was measured using a pH meter. pH is used to measure the acidity or alkalinity of water. It is a dimensionless quantity measure on a scale of 1 to 14 [19]. Oxidation-Reduction Potentials of the water samples was measured using ORP meter. It is measured in millivolts (mV). Higher values of ORP indicates higher presence of oxygen [19]. Biochemical oxygen demand (BOD) was measured using Winkler titration method. BOD is the difference in dissolved oxygen measured at the beginning and that measured after 5 days period at a temperature of 20°C in the dark. It is measured in mg/l [19]. Chemical oxygen demand (COD) was measure using the COD colorimeter. Strong oxidizing agent (potassium dichromate), tetraoxosulphate (vi) acid and heat were employed in the test. It is measured in mg/l [19].

3.0 RESULTS AND DISCUSSIONS

The values of the parameters measured at site and in the laboratory are summarized on Table 3. From Table 3 the pH value (a logarithmic measure of the concentration of hydrogen (H+)), which indicates the degree of acidity of the water samples collected ranges from 4.35 (Osisioma) to 8.50 (Alaoji). Apart from Umuagu (pH = 8.05), Alaoji (pH = 8.50) and Ariara (pH = 6.59) the pH values for other places are more acidic than the neutral (pH = 7).The acceptable pH for drinking water is between 6.5 and 8.5 [10]. It could be seen that water at Osisioma is the most acidic and the

one from Umuagu is most alkaline. The electrical conductivity of the water samples ranges from 15 μS/cm (Alaoji) to 311 μ/cm (Umuagu). Another high value of 133 μ/cm is recorded at Umuafor. The high value of electrical conductivity implies high dissolved salt in the water and the low values imply that the dissolved salts minimal. However, they are all low compared to the standard value of 250 µS/cm set by [10], which is 2500 μ/cm. This indicates that the water samples are not aggressive.

The temperature of the wells as measured at site ranges from 28.6°C (Abia Poly and Umuode) to 28.9°C (Umuagu and Alaoji). They all indicate that the water samples are all at ambient temperature, which is expected.

The turbidity (a measure of the muddiness of water due to suspended clay or silt, effluents or microbes in water) is lowest at Umuafor and Ariaria Junction (0 NTU each). The highest turbidity of 4 NTU was obtained at the Estate. The sample from Umuafor and Ariara Junction are the clearest indicating that the wells are in pure sandy-gravel aquifer. WHO [10]recommended the allowable turbidity of 1NTU. Beyond this value the disinfection of water will be ineffective.

The dissolve oxygen (DO) values range from 6.0 mg/L (Osisioma Ngwa and Ohuru Ishimiri) to 9.0 mg/L (Abia Poly). Dissolved oxygen less than 4.0mg/l is not good for aquatic life and dissolved oxygen more than 5.0mg/l is not good for steel and iron conduit [15]. When the dissolved oxygen is more than 5.0mg/l, it leads to fast corrosion of iron. In this case iron and iron alloys shall not be recommended as pipes for the water. For drinking water, dissolved oxygen should be in the range of6.5mg/l – 8.0 mg/l (equivalent of 80% - 110%). The water is contaminated and not good for drinking if DO falls below 6.5 mg/l [15].

High oxidation-reduction potential (ORP) in water is an indication of high dissolved oxygen in water and vice versa. The limiting range of ORP in water according to [16] is from -25 mV to 357mV. The measured values of ORP from all the water samples fall within this range. No values was below -25 mV and none was above 357 mV. They are positive and less than 357 mV. This indicates that the water is good for consumption.

Total dissolved solids (TDS) value of 600 mg/l is considered good for drinking water [9]]. Water becomes unpalatable for drinking when TDS is more than 1000 mg/l. The measured values of the TDS for all the soil samples are below 600mg/l. Thus, all the water samples are palatable and good for drinking. Water samples from Estate (29 mg/l)) and Alaoji (66 mg/l) are the most palatable of all the water samples as they contain less TDS.

According to Lehigh Environmental Initiative [20], Phosphates value less than 1.0 mg/L is considered excellent especially for aquatic and plant life. However, Kotoski[17]gave the limit of phosphate for water supply as 0.015 mg / L. Only the water samples from Estate (0.05 mg/L), Umuafor (0.04 mg/l), Osisioma (0.05 mg/l), Ohuru Ishimiri (0.01 mg/l) met this requirement for drinking water. The maximum allowable value of ammonia in drinking water is given by [12] as 1.5 mg/l. All the water samples collected met this requirement. Estate (0.17 mg/l), Alaoji (0.10 mg/l), Ohuru Ishimiri (0.10 mg/l) are the most suitable for drinking. According to [18] the allowable limit of Biochemical Oxygen Demand (BOD5) is 1 mg/l. The water sample obtained from Umuagu fell short of this criterion. Other water samples met the requirement.

Standard limit value of E-Coli in drinking water, according [11] and [14] is 0 MPN/100 ml. From the samples tested, only the samples obtained from Alaoji (0 MPN/100 ml), Ariara Junction (0 MPN/100 ml) met this requirement. The rest of the samples fell short of this criterion. It is advisable to treat water from these boreholes with Chlorine before drinking them.

Standard value of lead contamination in drinking water is 0.01 mg/l. This is according to both [11] and [14]. The water samples from all the boreholes tested have lead contamination less than 0.001 mg/l. This implies that all the samples met the criterion of lead contamination. Hence, drinking of water from these boreholes will not lead to lead poisoning.

The standard value of Cadmium in drinking water, according to both [11] and [14] are 0.003 mg/l and 0.005 mg/l respectively. However, the value of cadmium measure from all the water samples are less than 0.001 mg/l. The water samples cannot lead to Cadmium poisoning. According to [11] and [14], the standard values for Manganese in drinking water are 0.4 mg/l and 0.1 mg/l respectively. All the water samples tested with the exception of Umuagu (0.775 mg/l) have Manganese contamination less than 0.034. This means that water from Umuagu can lead to Manganese poisoning whereas the rest cannot lead to poisoning. These contaminations may be due to the

generated solid and liquid waste within the Aba environs.

Limiting value of copper in drinking water is 2 mg/l according to [11] and 1 mg/l according to [14]. However, the values of copper found in the water samples are all less than 0.001 mg/l. thus, the water obtained from the boreholes whose samples were tested cannot lead to copper poisoning.

The standard value of Mercury in drinking water, according to both [11] is 0.006 mg/l. However, the values of Mercury measure from all the water samples are less than 0.001 mg/l. The water samples may likely lead to Mercury poisoning if taking continuously for a very long time. Thus, there is need to treat them before consumption. Limiting value of Chromium in drinking water according to [11] is 1 mg/l and according to [14] is 0.05 mg/l. The water samples from all the boreholes tested are less than 0.001 mg/l. Thus, water from the boreholes cannot lead to Chromium poisoning. Threshold value of Magnesium allowed in drinking water according to [14]is 150mg/l. any value more than this may not be tolerable. With the exception of Estate (252 mg/l), Abia Poly (524 mg/l) and Osisioma Ngwa (427 mg/l) whose Magnesium values are more than 150 mg/l, the rest of the water samples have value that are less than the threshold value of 150 mg/l.

Analysis of variance (ANOVA) test for a statistically significant difference between the means of nineteen parameters in nine different locations was carried as shown on Table 4. The Null hypothesis is "there is no significant statistical difference between the means of the nineteen parameters measured in nine different location at 95% confidence level". The alternative hypothesis is "there is significant statistical difference between the means of the nineteen parameters measured in nine different location at 95% confidence level".

Table 3: Summary values of parameters in the water samples from the boreholes in Aba area

	Samples from various locations – 1, 2, 3, 4, 5, 6, 7, 8 and 9								
	1-Estate	**2-Umuagu**	**3-Alaoji**	**4-Ariaria Junction**	**5-Umuafor**	**6-Abia Polytechnic**	**7-Osisioma Ngwa**	**8-Ohuru Ishimiri**	**9-Umuode**
PH Value	4.72	8.05	8.5	6.59	6.25	4.5	4.35	5.46	6.25
Cond. (μS/cm)	52	311	15	28	133	87	40	90	20
Temp. (°C)	28.8	28.9	28.9	28.7	28.8	28.6	28.9	28.7	28.6
Turbidity (NTU)	4	3	2	0	0	1	5	1	1
DO (mg/l)	7.5	7.2	7.3	6.4	8.6	9	6	6	7.2
ORP (mV)	212	252	195	181	197	211	223	181	220
TDS (mg/l)	29	171	66	73	128	101	300	350	161
PO_4^{3-} (mg/l)	0.05	0.25	0.36	0.17	0.04	0.28	0.05	0.01	0.28
NH_4^+ (mg/l)	0.17	0.43	0.1	0.35	0.68	0.75	0.24	0.1	0.35
BOD_5 (mg/l)	0.12	1.17	1	0.42	0.46	0.17	0.25	0.13	0.25
COD (mg/l)	0.18	1.75	1.5	2	1.19	0.81	0.38	0.19	1.19
E-Coli (MPN/100ml)x10^2	0.7	0.8	0	0	1.3	0.2	1.6	0.8	0.2
Pb (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cd (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn (mg/l)	0.033	0.775	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hg (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mg (mg/l)	252	44	62	65	39	524	427	51	68

Table 4: Analysis of variance for mean of nineteen parameter in nine locations

	Sum of squares, SS	**Degree of freedom, df**	$\boldsymbol{Mean\ Square = \frac{SS}{df}}$	$\boldsymbol{F = \frac{MSB}{MSW}}$
Between Group, B	727599.9	19 – 1 = 18	MSB = 40422.22	13.81
Within Group, W	444880.8	9*19 – 19 = 152	MSW = 2926.847	

The sum of squares between parameters (SSB) and the sum of squares within parameters (SSW) are respectively given as Equations 1 and 2:

$$SSB = \sum n_k (\bar{Y}_k - \bar{Y})^2 \quad (1)$$

$$SSW = \sum (Y_i - \bar{Y}_k)^2 \quad (2)$$

Where; k is the number of parameters, n_k is the number of locations for a parameter, $\bar{Y}_k$ is the average value of the parameters in the nine locations, $\bar{Y}$ is the overall average of all the parameters in the nine locations and Y_i is the value of the parameter in each location.

The degree of freedom between parameters (dfb) and degree of freedom within parameters (dfw) are respectively given as Equations 3 and 4:

$$dfb = K - 1 \quad (3)$$

$$dfw = N - k \quad (4)$$

Where; N is the product of number of parameters and number of locations given as Equation 5:

$$N = k \times n_k = k.n_k \quad (5)$$

Substituting Equation 5 into Equation 4 gives the equation for degree of freedom within parameters:

$$dfw = k.n_k - k = k.(n_k - 1) \quad (6)$$

The F taken from statistic table at confidence level of 95%, dfb of 18 and dfw of 152 is 1.6697. Since the calculated F (that is 13.81) is greater than the F from the statistical table (that is 1.6696) then the Null hypothesis is rejected. Hence, there is significant statistical difference between the means of the nineteen parameters measured in nine different locations at 95% confidence level.

4.0 CONCLUSIONS

From the results obtained in this work it is obvious that the majority (up to 75%) of the water samples obtained within Aba area cannot be taken without treatment. The contain E-Coli. Thus, treating them with chlorine before drinking is ideal. This is because Chlorine is capable of eliminating the E-Coli from water. Drinking water obtained from Aba area, which is not treated with chlorine is not encouraged. Boiling the water can also be recommended since the E-Coli may not survive at a temperature above 70°C. Treating the water within Aba area with chlorine is recommended. Apart from eliminating E-Coli and improving the Oxidation Reduction Potential of the water, it is capable of precipitating Magnesium, which is dominant in majority of the water samples) out of the water. The chlorine can also precipitate Manganese out of water. Recall that value Manganese in the water sample from Umuagu (0.775 mg/l) is more than the standard value of 0.1 mg/l.

Since the values of E-Coli obtained from the ground water at Aba area are more than zero it will be concluded that faecal contamination is rampant. This is an indication that most people may be using pit latrine instead of septic tank toilet system in Aba. It is the pit latrine that is capable of transporting faecal contaminant into the ground water this is true because the distance from the base of the latrine and the ground water in Aba is small. The ground water level in Aba is shallow. The work of [2] shows that static water level in some area is as low as 4.57m. Some pit latrine can be as deep 5 to 6m. With this, it is obvious that in any area within Aba where they practice the use of pit latrine, the water from the boreholes there will be affected by faecal contaminants like E-Coli. So government should make legislation to ban and discourage the use of pit latrine within Aba area to avoid outbreak of water borne disease.

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