Comparative study of groundwater resources in the basement complex and sedimentary terrain of Talata Mafara town and environs, Zamfara State, Northwestern Nigeria

Hamidu H., Abdullahi I. M., Yelwa N. A., Falalu B. H. and Muhammed D.

Department of Geology, Usmanu Danfodiyo University, Sokoto, Nigeria

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ABSTRACT

The Groundwater resources of Talata mafara and its environs have been investigated. The Cretaceous sandy sedimentary aquifer of the Gundumi Formation of fluvio-lacustrine origin and the deeply decomposed crystalline rocks aquifer which are the products of the insitu weathering and decomposition of the crystalline rocks constitute the two aquifers in the area. Comparative studies shows that clean coarser sandy aquifer of the Gundumi formation forms better aquifer with higher yield with average of 4.1 l/s while the weathered / fractured basement aquifer with secondary porosity has a lower average yield of 0.82 l/s with an exceptional higher yield of 6.7 l/s obtained from a deeply decomposed schist. Calculated hydraulic properties for both types of aquifer gives an average transmissivity value of $1.70x\ 10\ m^2/s$ for the Gundumi aquifer while the Crystalline aquifer has an average of $12.80 \times 10\ m^2/s/m$. Specific capacity average for the sedimentary aquifer is $1.40 \times 10\ m^2/m/s$ and the value calculated for the crystalline aquifer is $10.50 \times 10\ m^2/s/m$. The computed properties obtained and the yield recorded shows that in the crystalline area, the deeply weathered rocks mainly the schist and metasediment contain more groundwater than the partially weathered granitic rocks. On the average the area has abundant groundwater resources that can meet the water need for human and animal population, with most of it stored in the sandy formation of the Gundumi and the other in the weathered overburden and fractured aquifers of the basement rocks.

Keywords: Crystalline aquifer, Gundumi formation, Sandy layer, Decomposed schist, Talata Mafara.

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INTRODUCTION

The most important aspect of Geology for groundwater in basement complex terrain is not the lithology but the coarse structure, the fault-lines and the major metamorphic foliation trends, Clark [6]. The yield of boreholes in the crystalline complex varies widely. Du preez and Barber [7] give an average yield of 1.1 l/s for Nigeria. Larger yields of up to 7.5 l/s has been recorded for Mopa town in Nigeria, Clark [6], Chilton and Smith-Carington [5] shows that a yield range of 0.25 – 05 l/s is obtainable where the saturated thickness is more than 10m for the basement overburden aquifer of Malawi, and this is enough for the operation of hand pump. Alagbe [2] calculated the yield of the fractured crystalline aquifer to be 2.7 m^3h^- 1 and that of the overburden aquifer has an average of above 2.0 m^3h^-1. Akaha and Promise [1] recorded a yield range of 2.24 to 17.46 m^2/hr, transmissivity is between $7.39x10^{-6}$ and $3.55x10^{-4}$ with an average specific capacity of $2.10x10^{-4}$ for the aquifer in Azare area of northeastern Nigeria. Omada and Obayomi [12] recorded a yield of 6.70 m^3/hr for boreholes tapping the fractured basement aquifer in the Gwarinpa – Kafe area of Abuja in central Nigeria. Hamidu, H. *et al* [9] Calculated an average transmissivity values for the fractured and regolith aquifer for southern part of Kaduna state to be 4.56×10^{-2} and 4.00×10^{-1} m^2/s, Specific capacity have averages of 3.65×10^{-2} and 4.30×10^{-2} $m^2/s/m$ for the fractured and regolith

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aquifers while an average yield of 0.7 l/s and 1.05 l/s was obtained for the fractured and regolith aquifer respectively.

Location map of the study area

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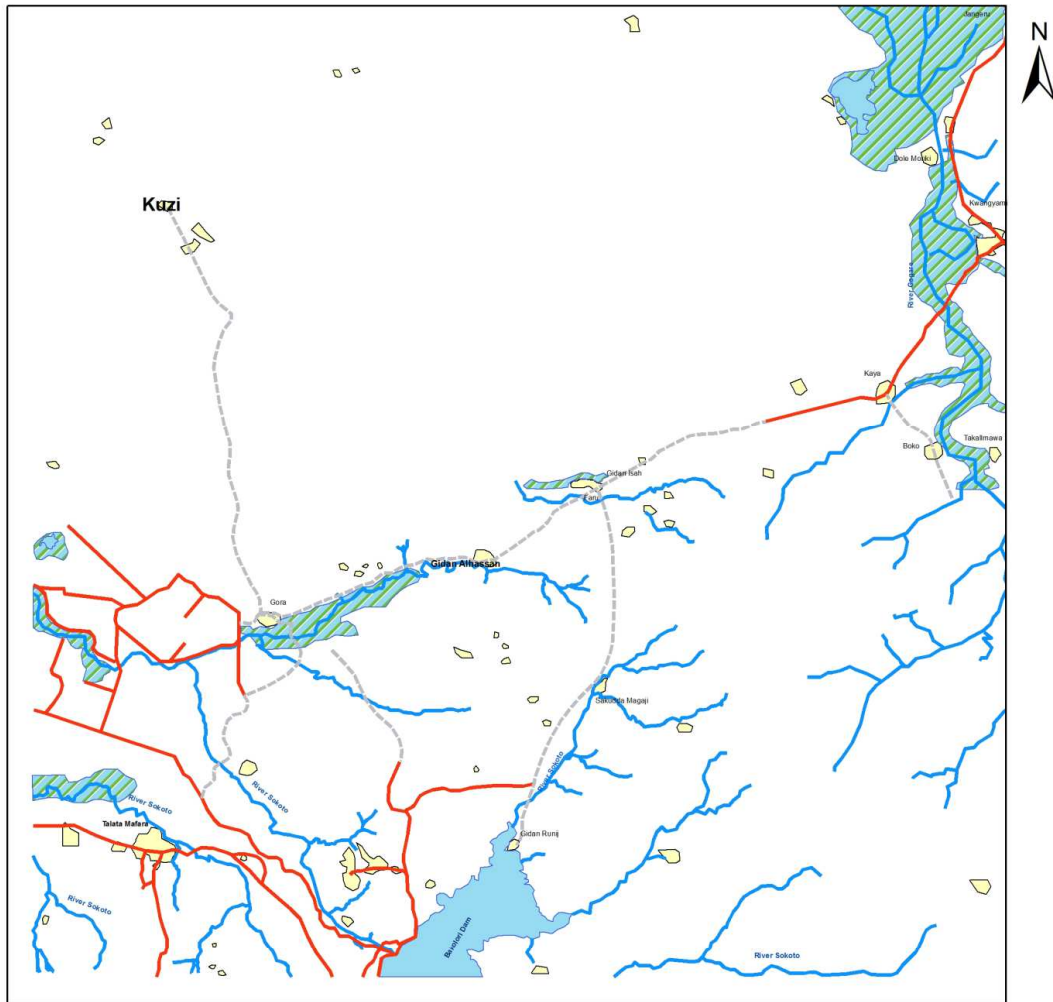
Bala, E.A and Ike, E.C [4] calculated the yield of basement rocks of Gusau Northwestern Nigeria to be between 10.08 – 433.30 m/d, with transmissivity and Specific capacity averages of 5.92m^2/d and 12.33m^3/d/m respectively. For the Gundumi Formation in the Sokoto basin, Anderson and Ogilbee [3] computed a yield of 2,700 gph while a single artesian borehole yield of 6,600 gph was determine for an artesian borehole. They also calculated the transmissivity range of 300 to 5000 gph per ft for the lower portion of the Gundumi formation aquifer while the upper Sandy part of the aquifer has a transmissivity value of 66000 gph per ft. According to Schoeneich *et al* [13] the average thickness of the overburden aquifer on metamorphic rocks is about 30 m while those on the granite and granite related rocks have an average of 10m.

This present study intend to compare the water resources in the sedimentary and crystalline complex that occur in the area of study by computing the hydraulic properties of the aquifers in the two terrain as well as analyzing the lithologic borehole logs of drilled boreholes, so as to determine the water yielding units in all the rock types found the area of study.

Physical settings / climate
The area of study lies between latitudes 12º30' and 13º00' N and longitudes 6º00' and 6º30' E Zamfara state lies within the dry humid tropics. There is an annual fluctuation in the climate of the area from the North to the South of the State. Lines of Inter tropical Discontinuity (ITD) separate the dry continental air masses in the north from moist monsoon air masses in the south. The south westerly moist air mass brings wet season in the area from early may to late September with an average of 140 rainy days. Relative humidity is about 90% in the morning to about 60% in the afternoon. A mean annual rainfall of 849mm has been recorded for the area. By early October to late October a dry air brought from the Sahara by the northeasterly wind gives condition of dry season which lasts till April with a monthly minimum, maximum and average temperatures of 19-21^{0}C, 33-35^0 C and 26-28^{0}C respectively.

The vegetation cover is the Sudan Savannah type mostly made up of grass, shrubs and scattered trees, Ghazanfar [8] refers to this type of vegetation as Sudanian woodland. Two important rivers drain the area, at the Southwestern parts of the area, river Sokoto flow in to the Bakalori Dam while at the northeastern part of the study area, the river Gagere flows from the north and southward, this river is the tributary of the river Rima. The Gagere is characterized with dendritic drainage pattern, it is seasonal and ephemeral Figure 1.

Geology
The rock types expose to the surface in the area are made of two main groups, the sedimentary rock of the Cretaceous – Tertiary Sokoto basin and the rocks of the crystalline shield of northern Nigeria. Gundumi formation occupied the NW, NE and part of SW in the area of study, this formation account for 21% of the sedimentary rocks in Zamfara state. It consist of clay mostly with interbedded sand and gravel lenses, the age of the Gundumi is upper Cretaceous Kogbe [10] The second group of rocks in the area which falls under the crystalline rock is divided into the Older Granite series; this is represented in the area with granite gneiss, Biotite granite gneiss, Granodiorite and Quartz diorite while the metasediment series consists of phyllite, shale, meta siltstone, metaconglomerate and ferruginous quartzite. The pre–Cambrian series which consists of rocks that include, metagabbro, hornblende, schist, pegmatite, granite, aplite with meta – gabbro and hornblende schist. Figure 2

MATERIALS AND METHODS

Lithological borehole logs and pumping test data (Figure 2) were studied, analysed and interpreted in the course of this research. Eight of the logs were chosen from the sedimentary Gundumi formation and twenty three from the crystalline complex making a total of thirty one boreholes logs drilled by Wardrob Engineering consulting company for SARDA [14] The data which include borehole yield, aquifer thickness, drawdown, static water levels were utilized to determine the hydraulic properties. Using the Logan's [11] equation, Transmissivity was calculated from

T = a x (Q/s)

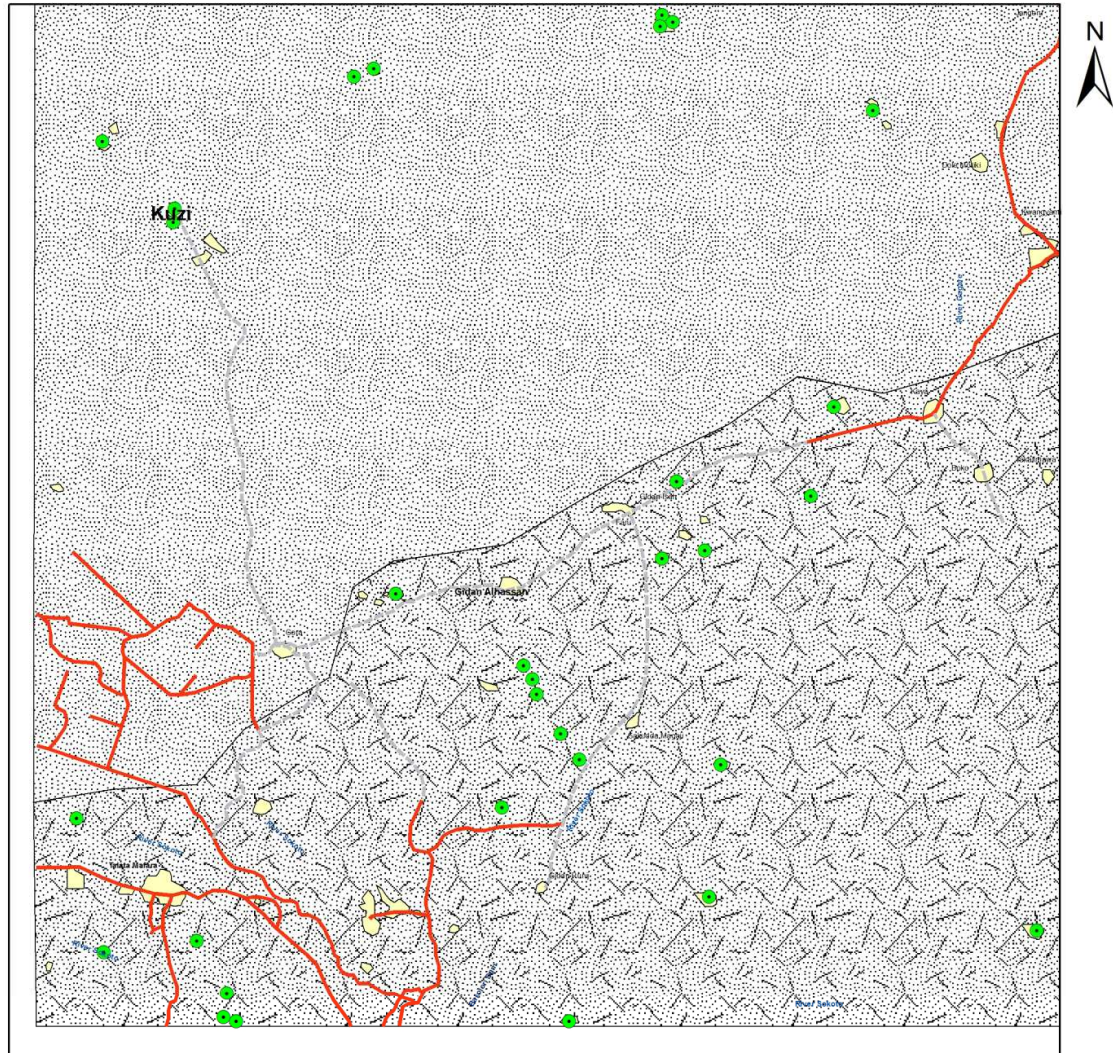Where T = Transmissivity of Aquifer m^2/d or (m^2/s)
a = dimensional constant = 1.22
Q = Yield of well (l/s)
s = drawdown in the pumping well (m)

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Geological map of the study area

Legend

- ● Borehole Location
- ----- Minor Road
- —— Major Road
- ☐ Settlement
- ▦ Gundumi Fm
- ▧ Basement

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RESULTS AND DISCUSSION

 Summary of the results obtained are presented in tables 1 and 2.

Transmissivity
The Transmissivity of the Gundumi formation in the area ranges from 1.00×10^{-1} to 4.03×10 m^2/s with an average value of 1.70×10 m^2/s, the Transmissivity calculated for the aquifers in the basement terrain within the study area is between 7.14×10^{-3} m^2/s and 272.50×10 m^2/s with a calculated mean value of about 12.80×10 m^2/s.

Specific capacity
An average Specific capacity value of 1.40×10 $m^2/s/m$ was recorded for the Gundumi formation that outcrops in the study area with a range of between 9.00×10^{-2} $m^2/s/m$ and 3.30×10 $m^2/s/m$. The basement aquifer calculated specific capacity values range between 5.85×10^{-3} $m^2/s/m$ and 223.33×10 $m^2/s/m$ with a mean value of 10.50×10 $m^2/s/m$.

Yield
The yield recorded for the boreholes that tap the Gundumi formation have a range of between 0.58 to over 6.7 l/s with an average of 4.1 l/s while the yield of the crystalline boreholes is from 0.13 l/s to 6.7 l/s with a mean value of 0.81 l/s.

Drawdown
The drawdown after pumping for twelve hours in the sedimentary formation ranges between 1.6 and 27.35 m, while in the basement area the recorded drawdown ranges from 0.03 to 27.35 m

From the computed value of aquifer characteristics and yield recorded for the two types of aquifers in the area of study, it is clear that the groundwater resources of the sedimentary parts of the area being investigated is more when compared with that from the crystalline basement tables 1 and 2 above. The reasons for this variation are discussed below;

Higher yield recorded in the Sedimentary Gundumi Formation is due to the presence of clean sandy permeable aquifer material which constitutes the water bearing layers, this has the ability to store and transmit large quantity of water due to its higher permeability.

For the crystalline aquifer with lower permeability the depth of weathering is an important indices which determine the quantity of water that can be stored or transmitted by the aquifer, yield also depend on the number, size and extent of the water bearing fractures that are intersected by the boreholes.

From the results obtained for the study in table (2) higher yield are recorded for the boreholes that tap the deeply weathered or decomposed schist or sandy unit while low yield were obtained from the boreholes that draw their water from the poorly decomposed granite, granodiorite or metasedimentary rocks. However, an exceptionally higher yield was recorded from the borehole located at Gidan bugaje. Three factors are responsible for the high yields of 6.7 l/s, in this borehole these are, a lower drawdown value of 0.03 m, presence of highly decomposed water bearing schists unit and a thick aquifer unit of 7 m.

Only four boreholes recorded a yield of less than 0.25 l/s from the crystalline aquifers which constitute 17.4%, these boreholes cannot give the minimum yield required for hand pump operation. It can also be seen that the average hydraulic properties determined for the crystalline aquifer is higher than those recorded for the sedimentary aquifers, this is due to the number of boreholes used for the analysis of the crystalline terrain (23) as compared to the data used on the sedimentary formation (8).

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TABLE 1: Summary of aquifer properties from the sedimentary formation in the study area

| BREHOLE No. | Community | Co-ordinates | | S.W.L | Yield | Drawdown | Screen | Pumping | Transmissivity | Specific Capacity | Water yielding unit |
		Latitude	Longitude	37.8	Q(l/s)	(m)	length (m)	rate(l/s)	T (M2/S)	(m2/s/m)	
1	Subudu	6°.304´	12°992´	37.8	6.7	5.07	2.5	1.08	1.61x10	1.32x10	Sand (Gundumi)
2	Subudu	6°.303´	12°987´	36.61	5.7	27.35	3.5	1.08	2.54x10-1	2.01x10-1	Coarse sand+clay(Gundumi)
3	Subudu	6°.309´	12°989´	36.57	1.4	15.57	2.5	0.5	1.10x10-1	9.00x10-2	Coarse sand(Gundumi)
4	Zazzaka	6°.407´	12°946´	20.67	3.6	1.56	4.0	0.43	3.00x10	2.31x10	Coarse sand (Gundumi)
5	Ruddunu kanwuri	6°.161´	12°966´	37.7	6.7	2.03	2.5	1.16	4.03x10	3.30x10	Gravel (Gundumi)
6	Ruddunu kanwuri	6°.154´	12°963´	35.83	6.7	2.48	2.5	1.16	3.30x10	2.70x10	Coarse sand(Gundumi)
7	Gidan mai buru	6°.02´	12°602´	5.51	0.58	4.5	5.0	0.4	1.60x10-1	1.30x10-1	Coarse sand+clay(Gundumi)
8	Babban tunga	6°.175´	12°711´	20.49	1.3	1.6	14	0.3	1.00x10-1	8.13x10-1	Coase sand+clay(Gundumi

TABLE:2 Summary of aquifer properties for the Crystalline Complex in the area of study

| Borehole No. | Community | Co-ordinates | | S.W.L | Yield | Drawdown | Screen | Pumping rate | Transmissivity | Specific Capacity | Water yielding layer |
		Latitude	Longitude	(m)	(l/s)	(m)	length(m)	(l/s)	(m2/s)	(m2/s/m)	
1	Bulu/Jeka	6°.388´	12°.802´	28.94	0.5	5.07	13	0.26	1.20x10-1	1.00x10-2	Coarse sandy clay
2	Tungar ardo	6°.337´	12°.758´	20.23	0.16	27.35	7	0.17	7.14x10-3	5.85x10-3	Poorly decomposed granite
3	Gidan Isa shiyar tudu	6°.311´	12°.765´	14.7	0.13	15.57	0.6	1.02x-2	8.35x10-3	8.35x10-3	Poorly decomposed granite
4	Sabon sara	6°.262´	12°.063´	10.62	0.13	15.56	7	0.13	1.02x-2	8.35x10-3	Moderate to poorly decomposed granite
5	Kababe	6°.637´	12°.563´	12.37	0.35	5.77	7	0.23	7.40x10-2	6.07x10-2	Moderately decomposed granite
6	Kandare gidan ruji	6°.333´	12°.628´	21.3	0.33	2.27	7	0.3	1.80x10-1	1.45x10--1	Decomposed granite
7	Gidanbiri	6°.259´	12°.503´	30.43	0.38	6.77	15	0.17	7.00x10-2	5.61x10-2	Decomposed granite
8	Kyara	6°.325´	12°.732´	19.09	0.28	11	13	0.2	3.11x10-2	2.55x10-2	Decomposed granodiarite
9	Burmi	6°.304´	12°.728´	18.76	0.4	6.82	13	0.25	7.20x10-2	6.00x10-2	Partialydecomposed granite
10	Sakkida kan wuri	6°.486´	12°.547´	19.14	1.7	1.87	7	0.4	1.12x10	9.10x10-1	Decomposed gneisses
11	Kuzi shiyar tudu	6°.066´	12°.892´	19.89	0.23	8.94	7	0.22	3.14x10-2	2.60x-2	Sandy clay and decomposed granite
12	Kuzi shiyar tudu	6°.067´	12°.898´	17.85	1.6	1.52	7	0.4	3.00x10	2.43x1`0	Decomposed granodiorite
13	Gere	6°.032´	12°.966´	20.3	0.22	7.93	7	0.18	3.40x10-2	2.80x10-2	Partiallydecompsed schist
14	Dunduma	6°.078´	12°.542´	10.46	0.25	7.3	9	0.18	4.20x10-2	3.43x10-2	Decomposed Schist
15	Dada	6°.255´	12°.643´	3.88	5	0.51	4	0.5	12.00x10	9.80x10	Coarse sand
16	Inwala	6°.093´	12°.517´	17.24	1.83	1.46	7	0.36	1.53x10	1.25x10	Partiallydecompsed schist
17	Gidan bugaje	6°.091´	12°.505´	23.12	6.7	0.03	7	0.33	272.50x10	223.33x10	Deeply decomposed schist
18	Sakida/tasha	6°.241´	12°.669´	5.48	0.13	11.91	7	0.13	1.33x10-2	1.10x10-2	Partiallydecompsed granite
19	Kalgo gidan ruji	6°.226´	12°.607´	21.05	0.33	7.69	7	0.25	5.24x10-2	4.30x10-2	Partiallydecomposed granite
20	Gidan bugaje	6°.388´	12°.503´	23.41	1	1.16	6	0.33	1.05x10	8.62x10-1	Decomposed Schist
21	Sakkida tasha	6°.388´	12°.676´	16.41	1.42	2.21	7	1.03	8.00x10-1	6.43x10-1	Decomposed Schist
22	Imasa	6°.388´	12°.662´	19.8	0.7	5.02	6	0.32	1.70x10-1	1.4ox10-1	Decomposed granite
23	Gidan Ardu	6°.388´	12°.537´	22.98	1	2.86	13	0.3	4.30x10-1	3.50x10-1	Department schist

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CONCLUSION

The area consists of two types of rocks, the Crystalline Basement and the Sedimentary, each of which constitutes an aquifer; the higher yielding aquifers are those from the sedimentary area with coarse sandy aquifer material while the low yielding aquifers constitute the partially decomposed crystalline aquifer like the granite, metasediment and schist. Relative higher yield were also obtained in the basement for boreholes that tap the fractured and deeply weathered basement rocks like schist and metasediment. However, the area is generally endowed with huge groundwater resources, if correct and appropriate Geophysical investigation method is conducted especially in the crystalline areas, good drilling site with high groundwater potentials can be discovered and exploited, provided the drilling is properly conducted under the full supervision of a professional and the recommended depth attained.

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