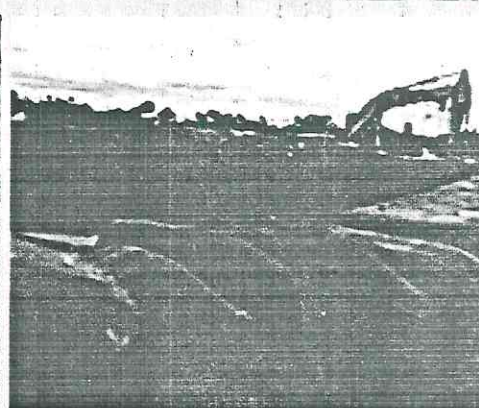
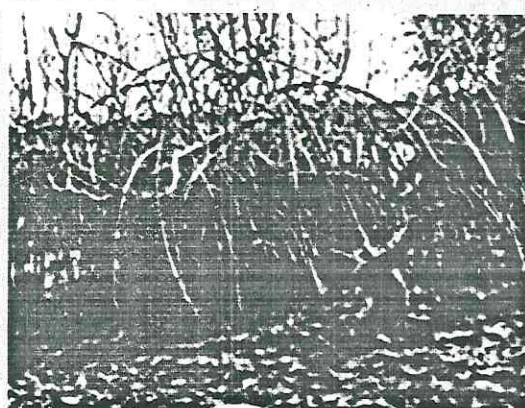
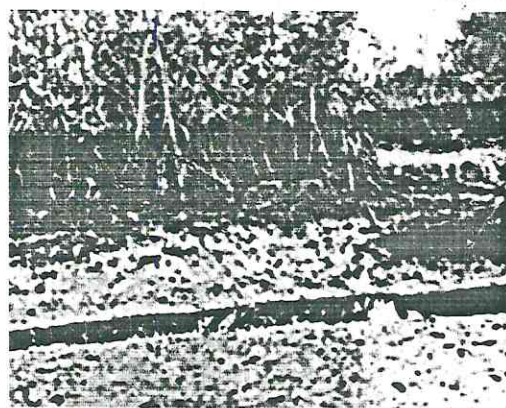
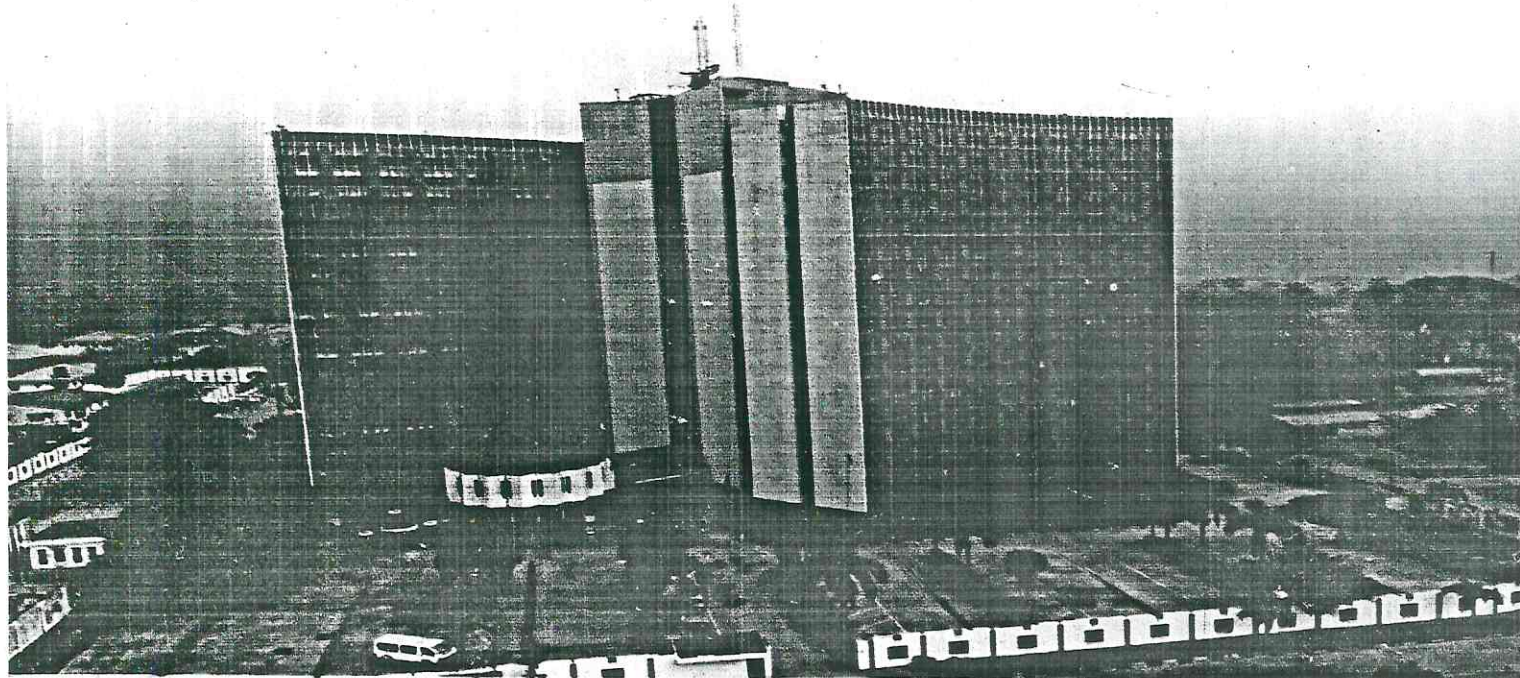




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ENVIRONMENTAL RISK OF CEMENT PRODUCTION IN OBAJANA, NORTH-CENTRAL NIGERIA

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Abstract

Persistent pollutants from industrial discharges produce toxic metals that can become injurious to human health in an industrial area and therefore there is necessary for environmental monitoring in such area. This study was carried out with the aim of determining the environmental risk of cement production in Obajana, North-central Nigeria. The study area lies within longitude 6° 24'E to 6° 27'E and latitude 7° 54'N to 7° 56'N. A random sampling method was used in field exercise. Twenty (20) groundwater, soil and plant samples were taken and analysed for heavy metals (Cu, Mn, Fe, Zn, Cr, Pb, Ni) using atomic absorption spectrophotometry. Heavy metals in groundwater such Pb, Mn, Zn, Ni, Cr, Cu and Fe showed (0.09mg/l; 0.02mg/l; 0.01mg/l; 0.01mg/l; 0.13mg/l; 0.02mg/l and 0.09mg/l) concentrations respectively. Environmental Pollution Indices were used to ascertain the extent and source of pollution in groundwater, soil and plant in the area. Metal Pollution Index (MPI) showed that the groundwater is very lightly polluted, lightly polluted, moderately polluted but highly polluted with respect to lead that is emitted from the power plant in the factory while the contamination factor (CF) and index of geo-accumulation (Igeo) showed that the soil and plant in the area are unpolluted. Continuous monitoring of groundwater, soil and plant in the area is recommended.

Keywords: Cement, Heavy-metals, Obajana, Pollution-indices, Risk

Introduction

One of the recommendations to the glitches that affects economic growth particularly in the developing countries is the availability and increase in industrialization (Afolabi, *et al.*, 2012; Ojekunle *et al.*, 2020). The impact of industrialization on socio-economic development cannot be over-emphasized (Aribigbola, *et al.*, 2012). In developing countries, it will continue to provide technological development and employment. Interestingly, about a fifth of global income is generated from manufacturing industry and nearly half of household consumption relies on goods from industrial processes (Ibbih and Gaiya, 2013).

The intention behind the encouragement of industrialization according to (Ofori-Cudjo, 2009; Endashaw, 2010; Boakye, 2010), lies in the development of a diversified economy that could propel the achievement of stable and sustainable societies. However, economic growth through the establishment of industries has some disadvantages such as creating anthropogenic actions such as discharges of industrial wastes which generates heavy metals that are harmful to the environmental

ecosystem (Sirajudeen *et al.*, 2014; Bhutiani *et al.*, 2017).

Industrial wastes produce toxic metals which percolates to the soils, groundwater aquifer systems and contaminate them (Mohankumar *et al.*, 2016; Bhutiani *et al.*, 2017). Negative effects of these heavy metal to the environment and ecosystem include reduction in growths of plants and animals, and could also result in the development of cancer in human being (Malassa *et al.*, 2014; Bhutiani *et al.*, 2017). These heavy metals are persistent pollutants in any industrial area with possibilities of contaminating water, soil and plant which therefore necessitate this study. Impact of industrialization on the environment have been investigated and reported by some researchers (Omanayin, 2017; Blessing and Akobundu, 2020; Ojekunle *et al.*, 2020). However, no previous study has been reported on the impact of industrialization in Obajana area.

Obajana Cement Plc (OCP) was incorporated by the Kogi State Government in 1992. It was however acquired by Dangote Industries Limited in 2002 and commenced the construction of the first cement production plant

in 2004. The company's name was changed from Obajana Cement Plc to Dangote Cement Plc in July 2010. Dangote Industries Ltd (DIL) owns 99.14% of the issued shares of the

company. The cement plant was a green field cement plant initiated in 2003 and commissioned in 2007 with an annual capacity of 5 million tones (Vetiva, 2010).

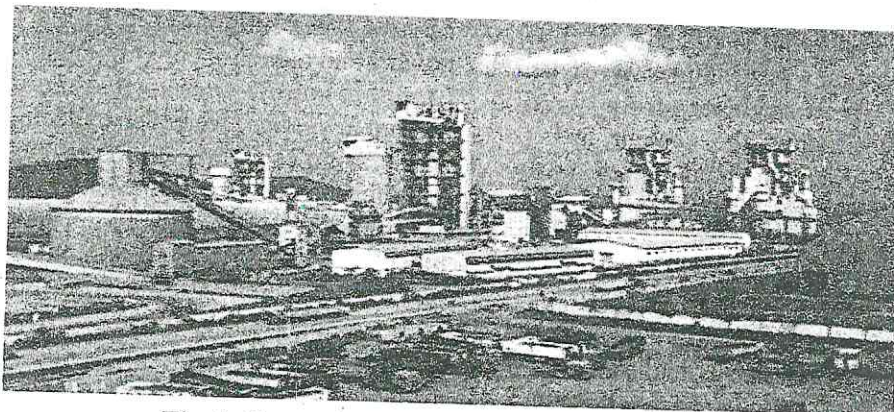


Fig. 1. Front-view of cement factory in Obajana, North-central Nigeria (Fieldwork, 2021).

Emission of cement dust from cement factories has increased alarmingly with the proliferation of cement plants. This in turn has contributed to environmental deterioration. This study aimed at assessing the environment risk of cement production in Obajana, North-central Nigeria.

Location and Geology of Study Area

Obajana is a small but very important community in north-central Nigeria. It is part of Lokoja local government area and is home to the famous Dangote cement factory, rated as the largest in Africa.

Obajana can be assessed both by road and by air transport as it has two functional roads and a landing stip. The area lies within longitude 6° 24'E to 6° 27'E and latitude 7° 54'N to 7° 56'N of the Greenwich meridian. It has an undulating surface which gently slopes downward and southwest-northeast trend. The study area is

underlain by basement complex rocks, predominantly composed of folded gneisses and metasediments (Figure 2). Obajana district is underlain by granite gneiss, quartzite, quartz-mica schist, phyllites, silicate facies iron formation, marble and biotite granites. The biotite granite gneiss constitutes the largest portion of the crystalline rocks of the area, displaying fairly hilly topographic features. It was as a result of the high concentration of marble which is the raw material for manufacturing cement that gave room for the establishment of Obajana cement factory. The study area has an estimated marble deposit of about 450,000,000 tones with a depth of between 30 and 60 metres OCP (2005). An overburden of 2m and 8m thickness of soil overlies the marble. The area is characterized by two types of landforms, domed shaped residual hills and river valleys (Afeni *et al.*, 2008).

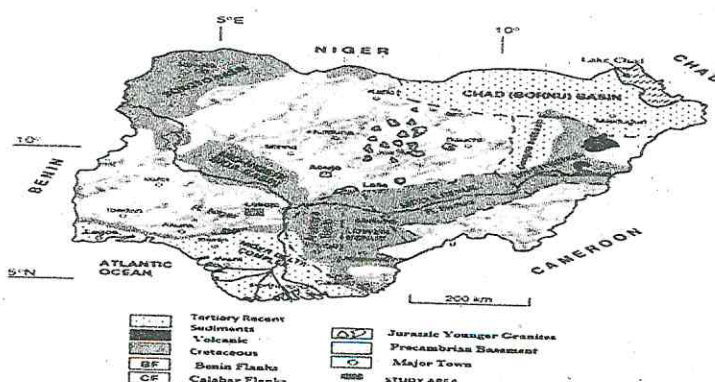


Fig. 2. Geological map of Nigeria showing study area (After Obaje and Abba, 1996)

Methods

A random sampling technique was used for the field exercise. The factory was made the central point while profile lines of about 1km long were identified and defined to the east, west north and south of the factory respectively. Groundwater samples were taken along the defined profiles from small settlements surrounding the cement factory (Figure 3), soil and plant samples were taken along the defined profiles from farmland surrounding the cement factory.

A total of twenty (20) groundwater, soil and plant samples were collected. Water samples were taken using polyethylene bottles of one litre capacity for heavy metals analysis (Figure 2). The water from boreholes were allowed to flow for about 2 minutes before it is sampled (collected), and containers were thoroughly washed and rinsed with the water to be collected into them. Samples for the determination of metals were stabilized with a

drop of dilute hydrochloric acid on collection. Soil samples were collected at depths ranging from 3 – 5 cm using a stainless steel soil auger. Plants growing in the soil such as young cassava leaves (*Manihotesculenta*) used as vegetable and cassava tubers normally processed to cassava powder and flakes for cooking, sugarcane leaves (*Saccharumofficinarum*), mango leaves (*Mangiferaindica*) were also collected. Soil and plant samples were collected in separate polythene bags for the present study. All the samples were preserved by refrigeration and Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) Model-Optima 200 by Perkin Elmer was employed to determine the metals. The analyses were carried out in accordance with the American Public Health Association standards and Nigeria Standard for Drinking Water Quality (NSDWQ 2017) at the Central Research Laboratory, University of Ilorin, Ilorin, Nigeria.

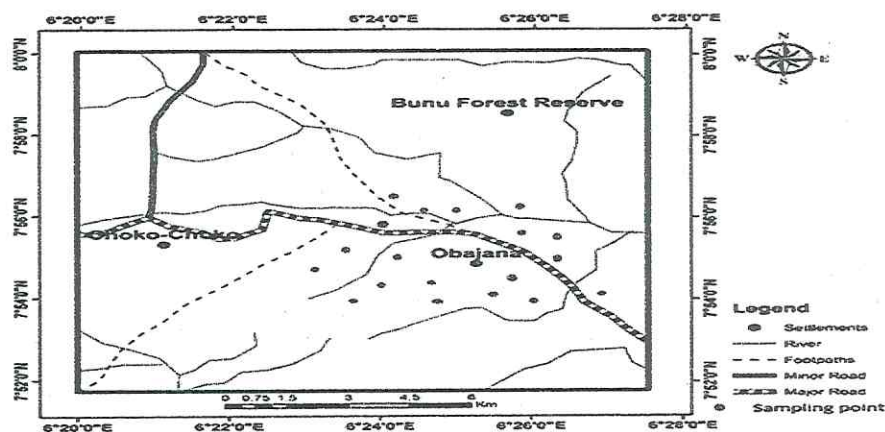


Fig. 3. Location map of study area showing sampling points

The statistical summary of the results for the analysed heavy metals in groundwater of the study area is presented in Table 1 below

Table 1: Statistical Summary of the Groundwater Analysis in Study Area.

Parameters (mg/l)	Minimum (mg/l)	Maximum (mg/l)	Mean (mg/l)	NSDWQ (2017)
Lead (Pb)	0.01	0.10	0.09	0.01
Iron (Fe)	0.03	0.21	0.09	0.30
Manganese (Mn)	0.01	0.07	0.02	0.20
Zinc (Zn)	0.01	0.02	0.01	3.00
Nickel (Ni)	0.01	0.02	0.01	0.02
Chromium (Cr)	0.01	0.02	0.01	0.05
Copper (Cu)	0.01	0.06	0.02	1.00

From the table 1 above, the concentrations of all analysed heavy metals in the groundwater samples are lower than the recommended levels except lead (Pb). The high concentration of lead (Pb) above the recommended level by NSDWQ may be attributed to the cement production in the region with an emphasis to the devastating effects of emission of lead from the power plant as coal account for one of the major source of energy (about 35%) after natural gas (57%) used in firing the plants in the factory. It is carcinogenic and affects several organs of the human body, including the nervous system, the blood system, the kidney, the cardiovascular system and the reproductive system. The adverse effects of lead on the nervous system of children include reducing intelligence and behavioral abnormalities. Exposure to high level may cause anemia, weakness, and kidney and brain damage.

Metal Pollution Index for Groundwater

The groundwater pollution index in study area

was determined using metal pollution index (MPI) method which used to indicate the impact of metallic parameters on the overall quality of the water (Udoh and Amadi, 2020). MPI values also indicates the relative impact of individual elements on the quality of water in the study area. The higher the concentration of a metal when compared to its maximum permissible level, the poorer the quality of the water (Taylor and McLennan, 1995).

The MPI formula is expressed as follows:

$$MPI = \sum_{i=1}^n \left(\frac{C_i}{MAC_i} \right)$$

Equation 1

Where C_i is the mean concentration

MAC_i is the maximum allowable concentration

There are generally five (5) groups of MPI namely as:

$MPI < 0.01$ = Very lightly polluted

$0.01 - 1.0$ = Lightly polluted

$1.0 - 5.0$ = Moderately polluted

$5.0 - 10.0$ = Highly polluted

> 10.0 = Very highly polluted

The calculated MPI values for the groundwater in the study area is presented in Table 2.

Table 2: Calculated Metal Pollution Index for Groundwater in the Study Area.

Parameters	C_i	MAC_i	MPI Value	Rating
Lead (Pb)	0.09	0.01	9.00	Highly polluted
Iron (Fe)	0.09	0.30	0.30	Lightly polluted
Manganese (Mn)	0.02	0.20	0.12	Lightly polluted
Zinc (Zn)	0.01	3.00	0.00	Very lightly polluted
Nickel (Ni)	0.01	0.02	0.50	Lightly polluted
Chromium (Cr)	0.13	0.05	2.60	Moderately polluted
Copper (Cu)	0.02	1.00	0.02	Lightly polluted

The computed metal pollution index for the study area as presented in Table 2 above showed that the groundwater in the study area are categorised into very lightly polluted, lightly polluted and moderately polluted except the lead (Pb) that is highly polluted. The high concentration of lead (Pb) in the groundwater samples of the study area may be

attributed to the cement production in the region with an emphasis to the devastating effects of emission of lead from the power plant as coal account for one of the major source of energy (about 35%) after natural gas (57%) used in firing the plant in the factory.

Heavy metals in soils and plants

The statistical summary of the results for the analysed heavy metals in soil and plant of the study area is presented in Table 3.

Table 3. Statistical Summary of Soil and Plant Samples in study Area Compared with Average Crustal Abundance / Background Value by Wedepohl (1995) and Taylor and McLennan (1995)

Heavy Metals (ppm)	Soil mean (ppm)	Plant mean (ppm)	Wedepohl (1995)	Taylor and McLennan (1995)	Pollution Status
Lead (Pb)	0.08	0.07	17.00	20.00	Very low
Manganese (Mn)	0.27	0.07	527.00	600.00	Very low
Zinc (Zn)	0.12	0.05	52.00	71.00	Very low
Nickel (Ni)	0.02	0.04	18.60	20.00	Very low
Copper (Cu)	0.03	0.02	14.30	25.00	Very low

The concentrations of heavy metals in both soil and plant samples in the study area (Table 3) are very low when compared to the permissible limits of the average crustal abundance and background values and showed that both soils and plants in the study area are not polluted.

Contamination Factor (CF) in Soil and Plant of the Study Area

Contamination factor is used in determining the degree of contamination of soil, sediment or plant relative to the average crustal abundance of the respective metal or to measured

background values from geologically similar material or area (Amadi et. al., 2013; Tijani et. al., 2004). Contamination factor is expressed as:

$$\text{Equation 2 } CF = C_m / B_m$$

Where C_m is the mean concentration of metal m in soil and plant, while B_m is the background value of metal m , either taken from the literature (average crustal abundance) or directly determined from a geologically similar material. The results of the CF for the soil and plant in the study area is described in Table 4.

Table 4: Computed Contamination Factor for Soil and Plant in study Area

Heavy Metals	CF value Soil	CF value Plant	Contamination Status
Lead (Pb)	0.003	0.004	Low contamination
Manganese (Mn)	0.0004	0.0001	Low contamination
Zinc (Zn)	0.003	0.0009	Low contamination
Nickel (Ni)	0.001	0.002	Low contamination
Copper (Cu)	0.002	0.001	Low contamination



$CF < 1$ = Low Contamination; $1 \leq CF < 3$ = Moderate Contamination; $3 \leq CF < 6$ = Considerable

Contamination; $CF \geq 6$ = Very High Contamination. The results as presented in Table 4 above showed that the soil and plant samples in the vicinity of the cement factory in the area are low contaminated with respect to heavy metals tested (Lead, Manganese, Zinc, Nickel and Copper).

Index of Geo-Accumulation (*I_{geo}*) for Soil and Plant in Study Area

Index of geo-accumulation (*I_{geo}*) simply described the concentration inclination of metals in both soil, plant, sediment and rock as proposed by Muller (1979). It is generally used to determine the degree of heavy metals contamination in terrestrial and aquatic

environment. The index of geo-accumulation is expressed as follow:

$$I_{geo} = \ln (C_m / 1.5 * B_m)$$

Where *C_m* is the mean concentration of metal *m*, and *B_m* is the background value of metal *m*, either taken from the literature (average crustal abundance) or directly determined from a geologically similar material while 1.5 is a factor for possible variation in the background concentration due to lithologic differences.

Table 5: Computed Index of Geo-Accumulation for Soil and Plant in Study Area

Heavy Metals	<i>I_{geo}</i> Soil	<i>I_{geo}</i> Plant	<i>I_{geo}</i> Rating
Lead (Pb)	-8.11	-8.52	Unpolluted
Manganese (Mn)	-10.41	-11.62	Unpolluted
Zinc (Zn)	-8.52	-12.02	Unpolluted
Nickel (Ni)	-9.57	-9.21	Unpolluted
Copper (Cu)	-9.21	-9.32	Unpolluted

< 1 = Unpolluted; $1.0 - 1.99$ = Very Polluted; $2.0 - 2.99$ = Lightly Polluted; $3.0 - 3.99$ = Moderately Polluted; $4.0 - 5.0$ = Highly Polluted; > 5.0 = Very Highly Polluted.

The *I_{geo}* results showed that the soil and plant in the area are unpolluted with respect to Lead, Manganese, Zinc, Nickel and Copper as presented in (Table 5) above. The consistency and similarity in both calculated contamination factor (CF) and index of geo-accumulation (*I_{geo}*) for the soil and plant in the area showed that the environmental pollution indices are useful and effectiveness in assessing the general quality of soil and plant.

Conclusion

This study has showed the present quality status of groundwater, soil and plant in cement production area of Obajana. The groundwater, soil and plant samples were analysed for heavy metals concentrations and compared with Nigerian Standard Drinking Water Quality (NSDWQ) and Average Crustal Abundance / Background Values which showed that the concentrations of all analysed heavy metals in the groundwater samples are lower than the

recommended levels except lead (Pb). The high concentration of lead (Pb) above the recommended level may be attributed to the cement production in the region with an emphasis to the devastating effects of emission of lead from the power plant using in the factory. The concentrations of heavy metals in both soil and plant samples in the study area are very low when compared to the permissible level of the average crustal abundance and background values and this showed that both soil and plant in the study area are not polluted with respect to the heavy metals tested. Results were validated with environmental pollution indices which include metal pollution index (MPI) for groundwater, contamination factor (CF) and index of geo-accumulation for both soil and plant samples. The metal pollution index showed that the groundwater in the area is very lightly polluted, lightly polluted and moderately polluted but highly polluted with respect to lead which is



correspond to the earlier discussion. The contamination factor showed that the soil and plant samples in the vicinity of the cement factory in study area are low contaminated while index of geo-accumulation proved that soil and plant samples tested in the area are presently unpolluted. This study therefore, recommended continuous monitoring of groundwater, soil and plant in the area. Also, the cement production in the study area should be environmentally conscious and friendly.

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