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*RESEARCH ARTICLE*

# EFFECTS OF STIMULATED PETROLEUM OIL POLLUTION ON THE SOIL CHARACTERISTICS

**Orire, Ekoimi Progress***

***Department of Soil Resources Management, University of Ibadan.***
****Corresponding Author Email: ekoimmighty@gmail.com***



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**ABSTRACT**

This experiment was conducted to investigate the effects of stimulated petroleum oil pollution on the soil characteristics in Ekpoma, Esan West Local Government area. Six sites will be chosen for the investigation: Nigerian National Petroleum Company filling station (NNPC), Rain oil filling, Abeyco filling station and Enlist filling station. At each site, a plot (25m x 25m) will be delineated for soil sample collection. Within each plot six spots will be randomly chosen and soil samples will be augered at two depths (0-15 cm and 15-30 cm), making three samples per site. Samples will be bagged, labelled and taken to the laboratory for analysis. The data generated will be analysed statistically using (ANOVA) to determine significant differences between treatment means (p=0.05) and LSD will be used to separate the means

**KEYWORDS**

Oil pollution, Soil characteristics, Nigerian National Petroleum Company filling station (NNPC), Rain oil filling, Abeyco filling station and Enlist filling station

## 1. INTRODUCTION

Soil is an element that exists naturally that interacts with soil formation factors and has a crucial function in supplying plants with the necessary nutrients needed for the growth, development, and production of crops (Gisilanbe et al., 2017). The Nigerian economy heavily relies on oil production, which serves several purposes such as earning foreign cash and providing energy for the country's economy. In addition to crude oil serving as the primary foundation of the Nigerian economy, industries largely depend on petroleum derivatives. Without these derivatives, industries would be unable to operate and produce at their highest efficiency. Regrettably, the activities involved in exploiting, exploring, processing, storing, and transporting petroleum and its byproducts have caused significant harm to the natural environment, specifically in the Niger Delta region of Nigeria. This has led to the transformation of fertile farmland into barren wasteland due to the detrimental impact of oil spills on agricultural land (Adeleke et al., 2019) Petroleum hydrocarbons may be emitted and overflow at several stages of the oil and gas industry, including exploration, extraction, refining, storage, sales, accidents, oil spills, and faulty operation and equipment maintenance (Wang et al., 2017 in Shi et al., 2013).

Soil is a main recipient of crude oil spills, as well as several other substances and chemicals including herbicides, biocides, and insecticides, which are all hydrocarbon-based products. Soil may be defined in several ways to accommodate diverse vocations and objectives. For the agriculturist, soil serves as a substrate for development, giving plants with anchoring, nutrients (both macro and micro), as well as the required water and air for plant growth, crop production, and successful agriculture (Ibitoye, 2006).

Soil serves as a home for microorganisms and small animals, and it is a dynamic system where intricate interactions occur between its biological, chemical, and physical components. The functioning of soil for various purposes is determined by these components and qualities (Delgado and Gomez, 2016). The agricultural productivity and quality are influenced by the soil type and qualities, which serve as a medium for plant development and regulate water flow and nutrient cycling (Delgado and Gomez, 2016). Soil quality refers to the ability of soil to operate effectively within the limits of an ecosystem. Soil consists of four constituents: sand, silt, clay, and humus (decomposed organic matter).

The aim of this research was to assess the impact of simulated petroleum contamination on soil properties.

## 2. MATERIALS AND METHOD

### 2.1 Study area

The experiment was carried out in Ekpoma, Esan West Local Government Area of Edo State, Southern Nigeria. The site was delineated mapping unit within the Local Government at the southwest portion of the Local Government Area.

### 2.2 Experimental site

SAMPLE 1 to 4 were taken from 4 different filling stations in Ekpoma and 4 controls were taken also.

SAMPLE 1 was taken from NNPC filling station at the depth of 0-15cm and 15-30cm at latitude 6.744241 and longitude 6.086394

SAMPLE 2 was taken from Rain oil filling station at the depth 0-15cm and 15-30cm at latitude 6.741552 and longitude 6.100262.

SAMPLE 3 was taken from Abeyco filling station at 0-15cm and 15-30 cm using a auger at latitude 6.740777 and longitude 6.112371

SAMPLE 4 was taken from Enlist filling station at the depth of 0-15cm and 15-30cm using a soil auger at latitude 6.737736 and longitude 6.120055.

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CONTROL 1 was taken 100m away from sample 1 at 0-15cm at latitude 6.737072 and longitude 6.127483

CONTROL 2 was taken 100m away from sample 2 at 15-30cm. Control 2 at latitude 6.737072 and longitude 6.127483

CONTROL 3 was taken 100 meters away from sample 3 at 0-15cm at latitude 6.740749 and longitude 6.126084.

CONTROL 4 was taken 100m away from sample 4 at 15-30cm using a soil auger at latitude 6.740749 and longitude 6.126084.

Elevation: The site has elevation of 100m above sea level (Google Altimeter 2021)

Vegetation: Humid tropical for all the sites

Topography: the site is dominated by the Esan plateau, which rises to 350m above sea level, and descends to numerous dry vallies, and small stream of about 150m above sea level (Eghaghara and Denye 2016).

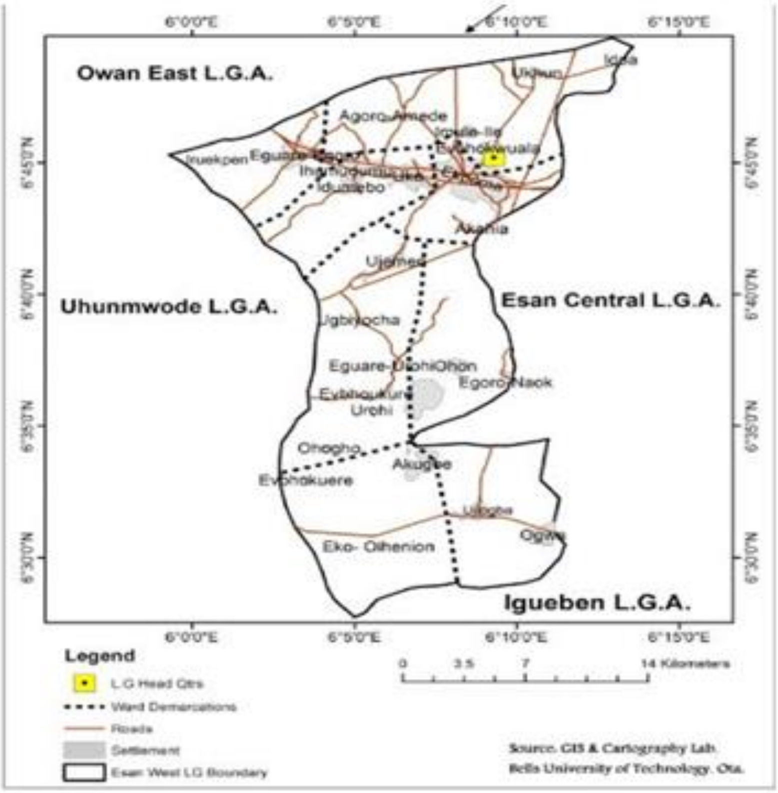


**Figure 1:** Location: Esan west the study area

### 2.3 Climate of the area

The climate of the area is known to be humid. Dry seasons last for about three to four months. Average temperature is 28ºC. rainfall figure range was 1600-2200mm per annum (Department of Geography, Ambrose Alli University, 2015).

Landform: The landform is undulating, and within the general land of Esan plateau which rises to about 420m above the sea level, the soils are said to belong to red acid sand soil of Benin. Its characterized by moderately acid soil (pH 6.8) (Eghaghara and Denye 2016)

Drainage: The area is well drained, with deep soils, greater than 190cm.

Biological Activities: The soil in the area is characterized with termites mound, earthworm and ant casts.

Slope: The slope percentage of the site between 2-6%.

Land use: The area is the characteristics rural setting with the majority of the inhabitants engage in small holder subsistence agriculture. There is no evidence of urbanization such industries.

### 2.4 Field work

Samples were collected from four (4) different filling stations with the use of a soil auger at depths of 0 to 15cm and 15cm to 30cm. Two samples were collected from contaminated soils at each site and control sample was also taken from each site far from the contaminated soils. A total of eight samples were collected and four controls making a grand total of twelve samples. The samples collected were sieved using a 2 mm sieve, bagged and properly labelled for routing laboratory analysis. The bagged samples were then taking to a soil laboratory for routing analysis.

### 2.5 Collection of samples

Soil samples were collected from generic horizon of the four (4) different filling station with the aid of a soil auger and bagged separately, labeled and taken to the laboratory for routine analysis.

### 2.6 Laboratory analysis

The soil samples, which had been dried by exposure to air at a room temperature, were pulverized and filtered using a 2 mm sieve. The particle size distribution was analyzed using the hydrometer technique, as described by Gee and Bauder in 1986. Sodium hexametaphosphate was used as the dispersion agent. The pH of the soil-water mixture (1:1) was determined using an electrometric glass electrode pH meter (IITA, 1982). The wet-oxidation technique (Walkley and Black, 1934) was used to determine soil organic carbon. The nitric/perchloric acid digestion process, as described by Odu et al. (1986), was used to digest one gram of each of the sieved soil samples. The levels of heavy metals, namely Pb, Cr, and Cd, were measured using an atomic absorption spectrophotometer (UnicamSolaar32 model) in accordance with the recommended protocols outlined in APHA (2008). The contents of total petroleum hydrocarbons (TPH) in the obtained soil samples were measured using the methods outlined by (Hussain et al., 2019).

## 3. Results And Discussion

The descriptive statistics of the particle size distribution (Table 1) show that petroleum polluted soils were characterized by relatively high sand content ranging from 70.8 – 83.2 %, and an average mean (74.92 ± 6.80 sd); silt 2.2 - 17 % (8.48 ± 4.37%) and clay 8.2 – 22.4 % (16.93±). The textural designations of soils from the study sites were mostly sandy loam. Soil samples from locations were of varying texture; sandy clay loam, and loamy sand,

| **Table 1:** Particle size distribution | | | | |
|---|---|---|---|---|
| **Site** | **%Sand** | **%Silt** | **%Clay** | **Textural Class** |
| Ctrl1 0-15cm | 75.6 | 6.2 | 18.2 | Sandy clay loam |
| Crtl1 15-30cm | 77.2 | 2.8 | 20 | Sandy clay loam |
| Crtl2 0-15cm | 80.6 | 7.4 | 13 | Loamy sand |
| Crtl2 15-30cm | 83.6 | 2.2 | 14.2 | Loamy sand |
| SP1 0-15cm | 71.6 | 6.4 | 22 | Sandy clay loam |
| SP1 15-30cm | 80 | 6.8 | 13.2 | Sandy clay loam |
| SP2 0-15cm | 77 | 12 | 11 | Loamy sand |
| SP2 15-30cm | 75.6 | 4.4 | 20 | Sandy clay loam |
| SP3 0-15cm | 65.2 | 13.8 | 21 | Sandy clay loam |
| SP3 15-30cm | 60.6 | 17 | 22.4 | Sandy clay loam |
| SP4 0-15cm | 81.2 | 13.6 | 8.2 | Loamy sand |
| SP4 15-30cm | 70.8 | 9.2 | 20 | Sandy clay loam |
| **Mean** | 74.92 | 8.48 | 16.93 | |
| **SD** | 6.80 | 4.37 | | |

The soil samples were analyzed for soil reaction, electrical conductivity, organic carbon, heavy metals, and total petroleum hydrocarbons (TPH). The findings for these parameters at depths of 0-15 and 15-30 are shown in Table 2. The petroleum hydrocarbon concentrations in the oil-polluted soils ranged from 206.10 to 7447.03 mg/kg, whereas in the control group, they ranged from 76.76 to 107.26 mg/kg. The control yielded the lowest value, while Abeyco produced the greatest value. The findings also indicated that the levels of TPH content were greatest at a depth of 0-15 cm and dropped as the soil depth increased to 15-30 cm. Hydrocarbons may enter the body by inhalation of air, ingestion of food, exposure to polluted water, or direct contact. When hydrocarbons are breathed or ingested, they rapidly enter the circulation as vapor or mist. The various chemicals present in different percentages of petroleum hydrocarbons have distinct effects on the human body. Certain petroleum hydrocarbon chemicals, namely smaller molecules like benzene, touene, and xylene (which are included in gasoline), have the potential to impact the human central nervous system. Research has shown that the chemical benzene, which is found in petroleum, may induce the development of leukemia, a kind of cancer, in human beings. The International Agency for Research on Cancer (IARC) has classified benzene as a human carcinogen (ATSDR, 1999). Petroleum hydrocarbons have a detrimental impact on soil fertility, causing the soil to become infertile and inhibiting the development and productivity of plants for extended durations (Onwurah, 1999). This discovery facilitated the identification of the underlying causes for the presence of discolored and lifeless vegetation in soil contaminated by oil spills, as seen at all gas stations over the course of this study. The soil pH values exhibited modest fluctuations, with a range of 6.7 to 8.3 for soils impacted by oil and 6.0 to 6.9 for soils not affected by oil. The soil pH varied from mildly acidic to moderately alkaline, and the elevated pH levels cannot be completely attributable to the oil spill since the unaffected soil also exhibited similar acidity. The soil acidity in the Nigerian regions is characteristic. Oil-affected soils have a lower pH (more acidic) compared to soils that have not been damaged by oil. In contrast to the previous comparison, the pH values in the study sites were determined to be greater than those of some hydrocarbon-contaminated soils in Nigeria.

The pH level in Eluama, Abia State was measured to be 4.5 according to a study conducted by Ezeigbo et al. in 2013. In Bomuin, located in Ogoni land of Gokana Local Government Area in Rivers State, the pH level was found to be 6.5 as reported by (Stanley et al., 2017). The pH values of the soil samples closely resembled those of some uncontaminated areas in the Momoge wetland in China, as reported by (Wang et al., 2013). Prior research has shown that elevated levels of total petroleum hydrocarbons might lead to a decrease in soil pH (Leahy and Colwell, 1990; Zongqiang et al., 2008; Kisic et al., 2009). It has been observed that soil oil pollution causes an increase in soil pH (Jia et al., 2009). Additionally, the study found that the quantities of hydrocarbons in the soils had no significant effect on soil pH. Soil acidity implies that the increase in metal content via cation exchange will be limited, whereas the main cause of metal enrichment will be the adsorption onto soil organic matter. The organic carbon levels varied between 0.98 and 14.40 in soils not impacted by oil, and between 1.3 and 11.43 in oil-contaminated soils. The data exhibited greater magnitudes in soils impacted by oil compared to soils unaffected by oil in all of the gas stations. The elevated levels of organic carbon in the soils from the filling stations may be linked to the presence of petroleum hydrocarbons in the petroleum products, as documented in previous studies (Abosede, 2013). The increase in soil carbon content in the polluted areas is expected to have a negative impact on the degradation rate by microorganisms.

The electrical conductivity values ranged from 106 to 300 m/s in soils polluted with oil, and from 40 to 77.0 m/s in soils not contaminated with oil. The values in the oil-contaminated soils were greater than those in the adjacent uncontaminated soils. The findings indicate that oil spills enhance the redox characteristics of the soil, as compared to uncontaminated soils. The rise in electrical conductivity after an oil spill suggests a significant buildup of heavy metal ions, including nickel, copper, and lead, at elevated quantities. High conductivity is an indirect indicator of the concentration of ions. Increased amounts of nickel, copper, and lead in soils may result in plants absorbing these elements to a significant extent, potentially causing them to accumulate in both plants and animals. This can lead to harmful responses throughout the food chain. The levels of Cadmium were below the detection limit (ND) in most of the locations, except for NNPC 2 and SP4, where they were measured at 0.03 mg/kg and 0.09 mg/kg, respectively. The concentration of Cadmium in the studied region is consistent with earlier data and was found to be within the acceptable limits of 0.3 mg/kg (WHO, 1984).

The measured amounts of Mercury (Hg) are 0.00 mg/kg in both the control and oil-polluted soils at all locations. The mercury level in these soils is much below the allowed limit defined by FAO 1996, which is 1.00 mg/kg. Therefore, the lack of mercury in these soils does not pose any harm to plants or people. Direct contact with elevated levels of mercury in the soil may lead to harm to the kidneys and cardiovascular system, as well as the encouragement of necroplastic transformation (Alysson and Fabio, 2014). The low concentration of Hg is due to the volatilization of Hg into organo-mercury forms (Environmental Health and Safety Manual, 2000).

The copper concentrations in the oil-polluted soils ranged from 5.02 to 29.03 mg/kg, whereas in the control group, the amounts ranged from 2.95 to 14.01 mg/kg. The concentration of copper above the control level, with the lowest value obtained from the control sample and the highest value from NNPC. However, all readings remained within the World Health Organization's standard of 150.0 mg/kg.

The lead concentrations varied from 0.65 to 39.60 mg/kg in the areas contaminated with oil, whereas in the control samples, the lead concentrations ranged from non-detectable to 0.70 mg/kg. The control had the lowest value, while NNPC had the greatest value. The zinc content in the oil-polluted soils varied from 26.18 to 113.70 mg/kg, whereas in the control locations it ranged from 5.07 to 7.28 mg/kg. NNPC had the greatest value, while control had the lowest. The levels of Lead and Zinc exhibited increments compared to the control values, but typically remained below their respective acceptable thresholds of 40.0 and 500.0 mg/kg.

The concentration of Aluminum ranges from 0.20 to 0.30 mg/kg in the oil-polluted soils and from 0.10 to 0.30 mg/kg in the control soils.

In the control soils, the content of Iron varied from 12823.96 to 14847.95 mg/kg, whereas in the oil contaminated soils, it ranged from 11906.66 to 25007.48 mg/kg. The iron (Fe) concentration was found to be low in the control soil, but increased in the oil-polluted soils. The highest Fe values were seen in the NNPC soil. The recorded readings exceeded the acceptable limit set by the World Health Organization, which is 40.7 mg/kg.

The Sulfur content in the oil-contaminated soils varied between 38.32 and 56.43 mg/kg, whereas in the uncontaminated soils it ranged from 5.65 to 14.85 mg/kg. The sulfur (S) level was low in the control group and showed rising values in the oil-polluted soils. The highest S values were found in the NNPC group. Sulfur is a ubiquitous element in the environment and has a vital role in the growth and development of plants (Marschner, 2011). Excessive quantities of sulfur have a detrimental impact on plants, causing harm to their root systems and foliage, diminishing the thickness of crowns, distorting trees, and impeding development (Tomlinson, 1983). A high sulfur concentration in the soil causes the displacement of alkaline Ca2+ and Mg2+ cations from the sorption complex, leading to soil acidification and enhanced mobility of trace elements (Menz and Seip, 2004). Increased sulfur deposition in ecosystems results in a decrease in microbial activity, which in turn disrupts biogeochemical cycles and mineral nutrition (Menz and Seip, 2004). The chromium concentrations varied from 3.82 to 56.68 mg/kg in the areas contaminated with oil, whereas the control samples had chromium concentrations ranging from 0.98 to 1.93 mg/kg. The control had the lowest value, whereas Sp4 had the greatest value. The measured quantities above the acceptable threshold of 1.30 mg/kg set by (WHO, 1996). However, they were still below the limits established by USEPA and NESREA, which are 50 mg/kg and 100 mg/kg, respectively.

The concentration of nickel in the oil-polluted soils varied from 7.71 to 34.40 mg/kg, whereas in the control sites it ranged from 0.92 to 16.20 mg/kg. The sp3 group yielded the greatest result, whereas the control group got the lowest value. The levels of Ni exhibited an upward trend compared to the control values, but typically remained below, within, and above the recommended limit of 35 mg/kg set by (WHO, 1996).

The soil's fertility and nutritional condition are significantly influenced by the concentration of heavy metals present. Zinc (Zn), copper (Cu), iron (Fe), and strontium (Sr) are vital for the proper development of plants and living beings. Nevertheless, elevated levels of these metals may be detrimental to health. Non-essential metals, such as Pb and Cr, may be tolerated by the environment in small amounts but become toxic at greater quantities (Alloway and Ayres, 1997; Nriagu, 1992). Soil acts as an intermediary between the environment and life, functioning as a dynamic and permeable medium that links the atmosphere to the Earth's crust (Lybrand, 2023). Agricultural operations are facilitated by the support it provides, since plants get their nutrients from the soil. Furthermore, plants have the ability to collect excessive amounts of certain elements in their growth environment, even if they do not need such components. The presence of excessive hazardous substances in soil may have harmful consequences for people due to the process of bioaccumulation and their transfer via the food chain, resulting in the development of diseases or malfunction in organs (Bansal, 2019; Okereafor et al., 2020). The elevated quantities reported in soil samples are most likely attributed to many factors, such as geological weathering, artisanal mining and processing operations, leaching of metals from waste and landfills, and the presence of heavy metals in animal and human excretions.

**Table 2:** The chemical properties of some fueling stations around Ekpoma

| | | dS/m | ⟶ | | | | Mg/kg | ⟵ | | | | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | **pH** | **EC** | **TPH** | **Fe** | **S** | **Cd** | **Cr** | **Cu** | **Pb** | **Ni** | **Hg** | **Al** | **Org. C** |
| **Ctrl1 0-15cm** | 6.9 | 60 | 107.26 | 4345.65 | 14.85 | ND | 1.01 | 2.95 | ND | 1.11 | ND | 0.20 | 1.28 |
| **Crtl1 15-30cm** | 6.7 | 106 | 94.68 | 2317.18 | 8.94 | ND | 0.98 | 3.04 | ND | 0.92 | ND | 0.30 | 0.98 |
| **Crtl2 0-15cm** | 6.60 | 25 | 76.76 | 12,823.96 | 16.76 | ND | 51.93 | 14.01 | 0.01 | 16.20 | ND | 0.41 | 04.01 |
| **Crtl2 15-30cm** | 6.79 | 33 | 84.90 | 14,847.95 | 5.65 | ND | 41.58 | 9.22 | 0.00 | 13.76 | ND | 0.20 | 14.40 |
| **SP1 0-15cm** | 6.87 | 228 | 3250.05 | 25,007.48 | 71.68 | ND | 55.06 | 29.03 | 102.141 | 31.32 | ND | 0.22 | 11.13 |
| **SP1 15-30cm** | 6.67 | 123 | 2011.05 | 13,404.78 | 41.05 | ND | 56.68 | 11.77 | 74.528 | 33.15 | ND | 0.06 | 11.43 |
| **SP2 0-15cm** | 6.95 | 125 | 2566.80 | 11,906.66 | 52.33 | ND | 47.87 | 13.91 | 0.39 | 34.40 | ND | 0.50 | 2.79 |
| **SP2 15-30cm** | 6.82 | 143 | 3060.10 | 17,923.16 | 77.84 | ND | 30.58 | 15.14 | 0.29 | 8.39 | ND | 0.90 | 3.77 |
| **SP3 0-15cm** | 8.2 | 182 | 3544.76 | 36001.07 | 56.43 | 0.09 | 5.76 | 8.43 | 0.5 | 12.5 | ND | 0.10 | 1.98 |
| **SP3 15-30cm** | 8.1 | 205 | 2132.99 | 21001.32 | 38.32 | ND | 3.82 | 5.19 | 0.34 | 8.73 | ND | 0.20 | 1.3 |
| **SP4 0-15cm** | 8.3 | 300 | 7447.03 | 19981.22 | 55.65 | 0.03 | 6.84 | 10.46 | 0.65 | 15.75 | ND | 0.15 | 2 |
| **SP4 15-30cm** | 8 | 282 | 4300.98 | 10001.76 | 40.00 | ND | 4.15 | 5.02 | 0.34 | 7.71 | ND | 0.30 | 1.75 |

## 4. Conclusion

Based on the detail experimental investigations, the conclusions derived are as follows:

i. Results of physical and chemical analysis at the polluted soil samples from the filling station show large differences compared to the results from an unpolluted soil profile as a result of crude oil pollution in the most of the stations.

ii. ii. The Concentration of most of the heavy metals in the soil obtained from the study areas are below USEPA and NESREA standard.

iii. The data gathered suggest that the level of hydrocarbons recorded for soil matrices are more significantly from industrial and domestic wastes discharge, storm waters, urban runoff and other anthropogenic sources other than oil spillage.

## Recommendation

The pollution level is generally adjudged to be minimal; nevertheless there is need for frequent evaluation and strict enforcement of the environmental laws relating to sitting of cottage industries like Filling stations and waste disposal in the study areas.

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