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Impact of Crush Rock Mining on Soil Enzyme Activities and Nutritional Composition of *Ipomea batata* in Okue-Ishiagu, Ebonyi State, Nigeria

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ABSTRACT

The study assessed the impact of Crush Rock mining on soil enzyme activities and the nutritional composition of Ipomea batata in Okue-Ishiagu, Ebonyi State. Soil samples were collected from mining sites (East, West, North, and South) and a control site. Soil enzyme activities including dehydrogenase, acid phosphatase, alkaline phosphatase, hydrogen peroxidase, and urease were analyzed, along with the nutritional composition of Ipomea batata harvested from the study area. Significant differences ($p < 0.05$) were observed in soil enzyme activities between the control and mining sites. Dehydrogenase, acid phosphatase, alkaline phosphatase, hydrogen peroxidase, and urease activities were significantly reduced in mining site soils compared to the control. Additionally, the nutritional composition of Ipomea batata showed significant alterations in %Moisture content, %Protein, and %Vitamin C in test samples compared to the control, with a decrease in %Ash, %Fat, and %Fibre. These findings highlight the adverse effects of Crush Rock mining activities on soil health and the nutritional quality of an important staple crop in the region.
Keywords: Crush Rock mining, soil enzyme activities, nutritional composition, Ipomea batata, Ebonyi State.

INTRODUCTION

Quarrying is the process of removing rock, sand, gravel or other minerals from the ground in order to use them to produce materials for construction or other uses. So, a quarry is any such working on the surface of the earth where minerals are extracted. Quarry mining activities are identified as a major cause of heavy metal contamination of the ecosystem and are largely responsible for growing amount of pollutants in soil. These mining activities are well known for their deleterious effect on the environment due to the deposition of large volumes of wastes on soil [1]. Mining is distinguished by its different effects, magnitudes and environmental impacts, which can be of two types: the first includes the modification of the landscape, habitat, hydrological regime, changes in topography, among others; and the second involves pollution from the inadequate management of generated waste (e.g. tailings and tails) in the mineral extraction and processing stage, this type of waste usually comes with high concentrations of metals and metalloids [2]. The tailings are generated in the process of concentration of lead minerals, silver, zinc and copper. It usually contains residual metal sulfides such as pyrite, pyrrhotite, galena, sphal erite, chalcopyrite and arsenopyrite, which are sources of potentially toxic elements (PTE) such as arsenic (As), cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), iron (Fe), and so on, which in high concentrations have toxic effects and are considered environmental pollutants capable of altering ecosystems [3]; [4]; furthermore, these elements are not biodegradable, they can bioaccumulate and some of them biomagnify [5]. As a global environmental issue, soil contamination has been increasingly recognized as a problem [6], owing to the importance of soils for agricultural production as well as the maintenance of the health of plants, animals and human beings [7]. Soil does not only provide a place for plants, animals and microbial life, but also a natural reservoir for metals. Its heavy metal concentration is associated

with biogeochemical cycle, parent material, mineralogy, soil age, organic matter, particle size distribution, soil pH, redox concentration, oxidation state and microbial activities [8]; [9]; [10]; [11]. Aside these natural processes, anthropogenic activities, such as agricultural practices, industrial activities, military activities and waste disposal methods tend to increase the concentrations of heavy metals and other trace elements in the soil [12]; [13]. These anthropogenic sources of metal loading interact with the preexisting natural sources of metal that originated from metal-rich parent material [14]. Such conditions resulting to excessive accumulation of heavy metals in the soil are frequently found in areas with metal mining operations like that of Ishiagu [15]. Excessive amount of heavy metals affects soil biological properties and may change its basic physicochemical properties [15]. Enrichment of heavy metals in soil may cause carcinogenic and mutagenic effects, which pose severe threats to the health of animals and humans exposed to the soil environment [16]; [17]. [18], reported that soil heavy metal contamination results in the uptake of metals by plants causing accumulation of these metals in plant tissues, hampered crop quality and phytotoxicity. [19], demonstrated that high level of heavy metals in soil could indicate similar concentration in plants by accumulation at high concentration causing serious risk to human health when consumed. [20] reported that accumulation of heavy metals in crops grown in metal-polluted soil may easily cause damage effect on human health through food chain. Excessive concentration of these metals in food is associated with aetiology of a number of diseases [21]. Some heavy metals like Arsenic (As), Cadmium (Cd) and Lead (Pb) have been reported to have no known bio-importance in human biochemistry and physiology and consumption even at very low concentrations can be toxic [22]. Due to the non-biodegradable and persistent nature, heavy metals are accumulated in vital organs in the human body such as the kidneys, bones and liver and are associated with numerous serious health disorders [23]. Most farmlands in Ishiagu are situated close to the mining sites resulting in increased uptake of heavy metals by crops. This result in not only observable morphological and physiological changes in crops but also, increased risk of human intoxication [24]. The soil in these areas is the principal source of these toxicants [25]. Toxicity symptoms of plants have been observed by experienced farmers in Ishiagu who further predicted that serious deleterious effects of quarry dust on animals, humans, and general impact on the environment may even worsen the plight of the inhabitants in the near future. Thus, it becomes important to understand the sources of heavy metals, the effect of their accumulation in soil, water, plant and on human system for risk assessment. It is against this background that this study was carried out to determine whether the amounts of the heavy metals identified from the soil samples are potentially hazardous to human health and the environment.

Aim of the study

This study aims to investigate the effects of Crush Rock mining activities on soil enzyme activities and the nutritional composition of Ipomea batata, commonly known as sweet potato, in the Okue-Ishiagu area of Ebonyi State, Nigeria.

MATERIALS AND METHODS

Study Area

The study area is Ishiagu, a rural lead/ zinc mining community in Ivo Local Government area of Ebonyi State, South-East Nigeria. It is located between latitudes 7°30 and 7°37E and longitude 5°52 and 6°00N. The area is characterized by tall grasses and a few trees. Its inhabitants are mainly farmers.

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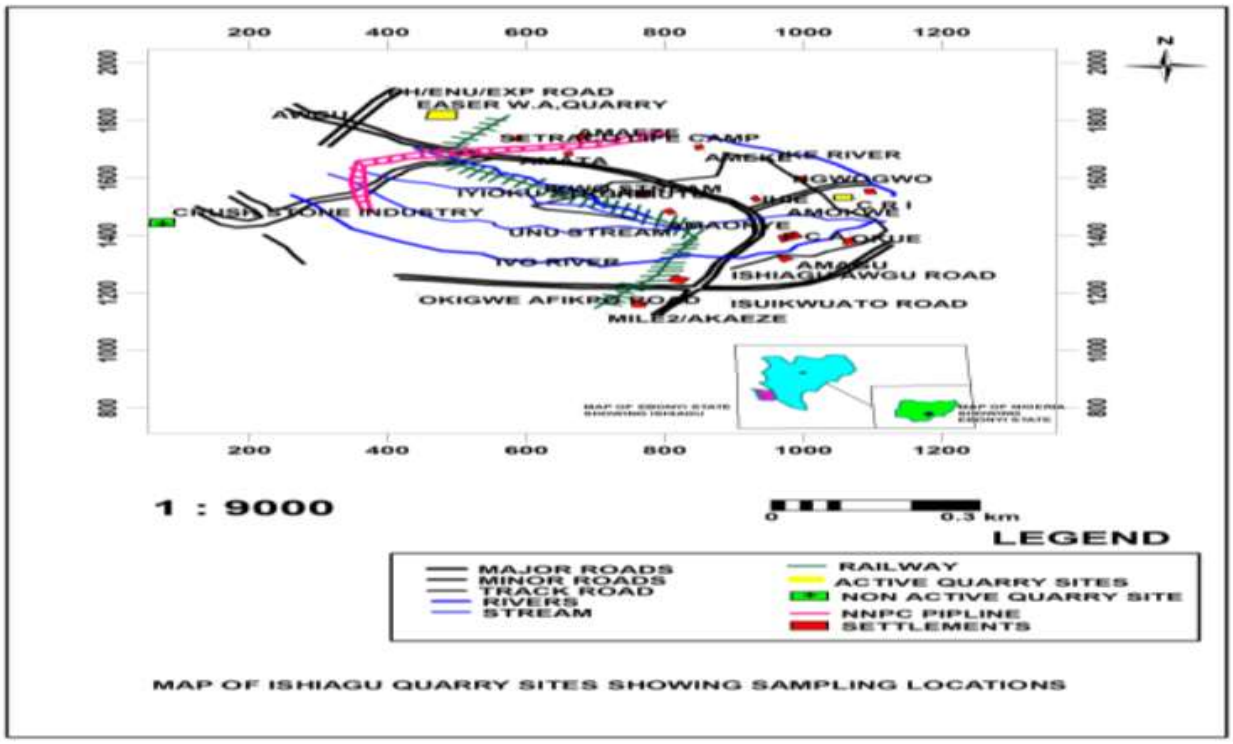

Figure 1.0: Map of Ishiagu Quarry sites showing Crush Rock sampling location.

Soil Sampling, Collection and Preparation

A total of ten (10) soil samples collected from depths 0-5cm and 5-10cm at each quadrant, for both the nearby farmland of about 30m distance from the quarrying site and control location, were used for this study. The sites were visually divided into four quadrants and from each quadrant, soil samples were collected at different points and homogenized to represent a sample for each quadrant. The control samples were chosen at a point about 500m away from the quarry site to ensure that samples from the control site does not have a different texture from the quarry site and free from quarrying activities. These soil samples were collected using a plastic auger and before collection, sample tools were properly washed with distilled water and dried. All soil samples were stored in sealed clean dry polythene bags, properly labeled, preserved in a cooler and transported to the laboratory for analysis. This was to avoid denaturation of enzymes present in the soil samples. Samples for enzyme assay were stored in a refrigerator at temperature 4°C when not in use. However, samples for other analysis other than enzyme assay were air dried and ground using a porcelain mortar and pestle. The ground soils were sieved using a 2mm sieve so as to obtain samples with fraction less than 2mm.

Tuber Crop Sample Collection and preparation

Fresh samples of sweet potatoes (*Ipomea batatas*) root tubers were harvested at the same nearby farmland of about 30m distance from Crush rock mining site Okue, in Ishiagu, Ebonyi State- Nigeria, and submitted to the department of Plant Science and Biotechnology, Abia State University Uturu for proper identification. The control tuber crops were harvested from an unimpacted area about 500m away from the study area and devoid of mining activities. The usual household practices were followed in preparing the samples except for the use distilled or deionized water to remove soil particles and impurities. These samples were stored in sealed clean grease–free polythene bags and transported to the laboratory for analysis. Samples not used immediately were stored in a refrigerator at about 4°C. The tuber crops were carefully washed to remove soil particles prior to storage and analysis.

METHODS AND STATISTICAL ANALYSIS

Soil samples were collected from Crush Rock mining sites (East, West, North, and South) and a control site in Okue-Ishiagu, Ebonyi State. Soil enzyme activities including dehydrogenase, acid phosphatase, alkaline phosphatase, hydrogen peroxidase, and urease were determined using standard assay methods. Additionally, Ipomea batata samples were harvested from the study area, and their nutritional composition was analyzed. Statistical analysis was conducted to determine significant differences between control and test samples.

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RESULTS

Table 1 Nutritional composition of *Ipomea batata* harvested from the study area.

	%Mc	%Ash	%Fibre	%Protein	%Fat	%CHO	Vit. A	Vit. E	Vit. C	Vit. B1	Vit. B2
						(ug/g)			mg/100g		
C	60.040±0.08^{a}	1.600±0.17^{a}	1.970±0.01^{a}	4.310±0.32^{a}	1.260±0.03^{a}	30.820±0.41^{a}	4.525±0.12^{a}	0.237±0.11^{a}	15.575±0.06^{a}	0.325±0.22^{a}	0.020±0.07^{a}
E	60.460±2.04^{b}	0.925±0.32^{b}	1.025±0.24^{b}	5.475±0.02^{b}	1.135±0.01^{b}	30.980±0.30^{a}	4.825±0.08^{a}	0.256±0.04^{a}	15.925±0.03^{bc}	0.341±0.05^{a}	0.023±0.11^{a}
W	60.540±1.67^{c}	0.920±0.18^{b}	1.060±0.28^{b}	5.545±0.02^{b}	1.170±0.02^{b}	30.765±0.21^{a}	4.865±0.02^{a}	0.259±0.01^{a}	16.015±0.04^{bc}	0.342±0.09^{a}	0.026±0.19^{a}
N	60.510±0.89^{c}	0.955±0.61^{c}	1.065±0.08^{b}	5.545±0.01^{b}	1.175±0.16^{b}	30.745±745^{a}	5.005±0.03^{a}	0.260±0.18^{a}	15.870±0.12^{bc}	0.343±0.04^{a}	0.028±0.07^{a}
S	60.510±1.31^{c}	0.940±0.13^{bc}	1.080±0.01^{b}	5.580±0.05^{b}	1.155±0.09^{b}	30.745±0.08^{a}	4.765±0.06^{a}	0.256±0.26^{a}	15.795±0.04^{b}	0.344±0.13^{a}	0.024±0.02^{a}

Legend: C= Control, E= East, W= West, N= North, S= South, Mc= Moisture content, CHO= Carbohydrate Vit.= Vitamin. Values are represented as means of five (4) replicate determination ± standard deviation, (n=4). Values in the same column bearing different superscripts are significantly different ($p<0.05$).

Table 1 shows the nutritional compositions of *Ipomea batata*. %Mc, %protein and %vitamin C increased significantly ($p<0.05$) at the test samples when compared to the control with a significant ($p<0.05$) decrease recorded for %ash, %fat and %fibre contents. While %CHO, Vit. A, Vit. E, Vit. B1 and Vit. B2 had no significant difference ($p>0.05$) when compared to the control.

Table 2 Dehydrogenase assay on soil from Crush Rock mining site, Okue-Ishiagu Ebonyi state (mg/Tpf/g).

Soil	Soil depth (cm)	
Samples	0-5	5-10
C	13.025±0.05^{a}	10.310±0.07^{a}
E	4.635±0.03^{b}	2.205±0.12^{b}
W	5.280±0.02^{c}	3.160±0.01^{c}
.N	4.965±0.17^{b}	2.215±0.09^{b}
S	5.255±0.03^{c}	3.07±0.04^{c}

Legend: C= Control, E= East, W= West, N= North, S= South. Values are represented as means of four (4) replicate determination ± standard deviation, (n=4). Values in the same column bearing different superscripts are significantly different.

Table 2 shows dehydrogenase soil enzyme activity. There were significant difference in the test samples for both depths 0-5cm and 5-10cm respectively when compared to the control.

Table 3 Acid phosphatase assay on soil from Crush Rock mining site, Okue-Ishiagu Ebonyi state (mg/g/h).

Soil	Soil depth (cm)	
Samples	0-5	5-10
C	7.075±0.02^{a}	5.610±0.16^{a}
E	3.285±0.05^{b}	1.825±0.05^{b}
W	3.055±0.08^{b}	2.755±0.18^{b}
N	2.560±0.07^{b}	1.300±0.07^{b}
S	3.105±0.03^{b}	1.620±0.12^{b}

Legend: C= Control, E= East, W= West, N= North, S= South. Values are represented as means of four (4) replicate determination ± standard deviation, (n=4). Values in the same column bearing different superscripts are significantly different ($p<0.05$).Table 3 shows acid Phosphatase activity on the soil. The result showed a significant decrease ($p<0.05$) on the test samples for both depths 0-5cm and 5-10cm respectively when compared to the control.

Table 4 Alkaline phosphatase assay on soil from Crush Rock mining site, Okue-Ishiagu Ebonyi state (mg/g/h).

Soil	Soil depth (cm)	
Samples	0-5	5-10
C	4.980±0.13^{a}	2.180±0.15^{a}
E	3.395±0.17^{b}	1.595±0.12^{b}
W	3.295±0.08^{b}	1.890±0.09^{ab}
N	3.460±0.04^{b}	1.490±0.29^{b}
S	3.510±0.08^{b}	1.610±0.16^{b}

Legend: C= Control, E= East, W= West, N= North, S= South. Values are represented as means of four (4) replicate determination ± standard deviation, (n=4). Values in the same column bearing different superscripts are significantly different ($p<0.05$).

Table 4 shows alkaline phosphatase enzyme activity on the soil. A significant decrease ($p<0.05$) was also recorded on the test samples for depths 0-5cm and 5-10cm respectively, when compared to the control sample.

Table 5 Hydrogen peroxidase assay on soil from Crush Rock mining site, Okue-Ishiagu Ebonyi state (ml 0.1ml/$KMnO_4$/g).

Soil	Soil depth (cm)	
Samples	0-5	5-10
C	2.100±0.54[a]	1.810±0.18[a]
E	0.435±0.32[b]	0.245±0.11[b]
W	0.600±0.24[b]	0.320±0.06[b]
N	0.425±0.13[b]	0.165±0.02[b]
S	0.555±0.31[b]	0.275±0.07[b]

Legend: C= Control, E= East, W= West, N= North, S= South. Values are represented as means of four (4) replicate determination ± standard deviation, (n=4). Values in the same column bearing different superscripts are significantly different (p<0.05).

Table 5 shows hydrogen peroxidase activity on the soil. The test samples show a significant decrease ($p< 0.05$) for all depths 0-5cm and 5-10cm respectively when compared to the control.

Table 6 Urease assay on soil from Crush Rock mining site, Okue-Ishiagu Ebonyi state (mg NH_3–Ng/dry soil).

Soil	Soil depth (cm)	
Samples	0-5	5-10
C	40.850±0.55[a]	26.550±0.17[a]
E	10.260±0.31[b]	2.560±0.02[b]
W	9.610±0.64[c]	2.360±0.06[b]
N	9.390±0.87[c]	2.395±0.03[b]
S	11.025±1.03[d]	3.260±0.05[c]

Legend: C= Control, E= East, W= West, N= North, S= South. Values are represented as means of four (4) replicate determination ± standard deviation, (n=4). Values in the same column bearing different superscripts are significantly different (p<0.05).

Table 6 shows the urease soil enzymes activity. The test samples showed significant decrease ($p<0.05$) at both depths 0-5cm and 5-10cm respectively when compared to the control.

DISCUSSION

The nutritional composition of the test samples of sweet potato *Ipomea batata* harvested from crush rock mining site, Okue–Ishiagu Ebonyi state as were shown in Table 3.1, recorded fluctuations in percentage (%) moisture content of sweet potatoes from 60.040±0.08 to 60.540±1.67, %ash content (0.920±0.18 to 1.600±0.17), %fibre (1.025±0.24 to 1.970±0.01), %protein (4.310±0.32 to 5.580±0.05), %fat (1.260±0.03 to 1.175±0.16), %carbohydrate (30.765±0.21 to 30.980±0.30), vitamin A (4.525±0.12 to 5.005±0.03), vitamin E (0.237±0.11 to 0.260±0.18), vitamin C (15.575±0.06 to 16.015±0.04), vitamin B_1 (0.325±0.22 to 0.344±0.13) and vitamin B_2 (0.020±0.07 to 0.028±0.07) respectively. %Mc, %protein and %vitamin C increased significantly ($p<0.05$) at the test samples when compared to the control with a significant ($p<0.05$) decrease recorded for %ash, %fat and %fibre contents, while %CHO, Vit. A, Vit. E, Vit. B1 and Vit. B2 had no significant difference ($p>0.05$) when compared to the control. The above result shows that sweet potato (*Ipomea batata*) has carbohydrates as the most abundant nutritional composition and this agrees with the reports of Sawicka *et al.* (2014). Table 2 shows dehydrogenase enzyme activities of the soil from crush rock mining site-Ishiagu.Soil enzymes have been proposed as useful indicators of soil quality.They play important role in chemical changes involving soil nutrients.Dehydrogenase enzyme is an oxidoreductase enzyme which catalyzes the transfer of electrons from one molecule, the redundant, also called the electron donor, to another, the oxidant, also called the electron acceptor. It is known to oxidize soil organic matter by transferring protons and electrons from substrates to acceptors. These processes are the part of respiration pathways of soil microorganisms and are closely related to the type of soil and soil air-water conditions (Kandeler, 1996). Its activity on soil from crush rock mining site, Okue-Ishiagu Ebonyi state as recorded in Table 3.2 significantly ($p<0.05$) decreased at both depths (0-5cm to 5-10cm) when compared to the control with the highest value for the test samples recorded at 0-5cm depth on the west quadrant as 5.280±0.02 and least value recorded at 5-10cm depth on the east quadrant as 2.205±0.12. A decrease in dehydrogenase enzyme activity with increase in soil depth was also recorded. This could be as a result of Zn (a strong antagonist for dehydrogenases) metal evaluated from this study area, which is responsible for inhibitory effect on this enzyme activity. [26], [27].[28] findings reported that heavy metals reduced the activity of soil dehydrogenase by 10-90%.It is worthy to note that lower dehydrogenase activity has also been reported for polluted soils [29]. However, the decrease in soil dehydrogenase activity when compared to the control could be attributed to decline in microbial activities which is as a result of the mining activities in the study area. Table 3 shows a decrease in acid phosphatase activity with increase in soil depth, with the highest enzyme

activity on the test samples reported on the east qaudrant (3.285±0.05) at 0–5cm depth while its least activity was recorded on the north quadrant (1.300±0.07) at 5–10cm depth. From the Table 3.3, recorded values for the text samples significantly decreased ($p<0.05$) when compared to the control. Phosphatases are broad group of enzymes capable of causing hydrolysis of esters and anhydrides of phosphoric acid. Acid and alkaline phosphatases serve as indicators of the microbiological redox system [30].Phosphatases are involved in the biochemical cycles of phosphorus in the soil. [26] Hydrolysis and release of free phosphate in the soil is catalyzed by phosphatase enzymes which are actively secreted into the soil by many plants and microbes in response to phosphorus demand [31]. In Table 4, alkaline phosphatase activity recorded a significant decrease ($p<0.05$) on the test samples for all depths 0-5cm and 5-10cm respectively. Decrease in enzymes activity with increase in soil depth was also observed to occur. The highest enzyme activity was recorded on the east quadrant with a mean value of 3.395±0.17 while the least was recorded on the north quadrant with a mean value of 1.490±0.29. A similar observation was reported by [32] on "Impact of cassava mill effluent on soil physicochemical and microbial community structure and functions. The decrease in the activity of these phosphatases could be attributed to heavy metals accumulation in the quarry site. Heavy metals decreases the phosphatase synthesis during the composting process [33].Microorganisms have to cope with the toxic Pb during their growth in Pb-contaminated substrates and the exposure of microorganism to metals always inhibit microbial growth and activity [34]. A significant decrease ($p<0.05$) was recorded on the test samples in Table 5, for soil depths 0-5cm and 5-10cm respectively. Its mean values for all quadrants on the top soil (0-5cm) ranged from 0.425±0.13 to 2.100±0.54 while that of the bottom soil (5-10cm) ranged from 0.165±0.02 to 1.810±0.18. This result is in agreement with the findings of Nwaugo *et al.* (2006). Hydrogen peroxidase is another key oxidoreductase associated with aerobic microbial activities. It decomposes hydrogen peroxide into molecular oxygen and water, thus alleviating its toxicity to soil microorganisms [35]. Table 6 shows the urease assay on soil from Crush Rock mining site, Okue-Ishiagu Ebonyi state. At both depths, the test samples significantly decreased ($p<0.05$). A decrease in mean values with increase in soil depth was also recorded. Mean values of soil urease activities ranged from 9.390±0.87 to 40.850±0.55 on the top soil for all quadrants under investigation while that of the bottom soil for the test soil and control ranged from 2.560±0.02 to 26.550±0.17. The increase in mean values of urease enzymatic activities in the study area could be as a result of its sensitivity to soils polluted with heavy metals. This result agrees with the findings of [36] on his report on 'microbial enzyme-catalyzed processes in soils and their analyses." However, this could be as a result of factors such as cropping history, organic matter content of the soil, soil depth, soil amendments, heavy metals and environmental factors [37].

CONCLUSION

Crush Rock mining activities in Okue-Ishiagu, Ebonyi State, have led to significant reductions in soil enzyme activities, indicating soil degradation. Moreover, the nutritional composition of Ipomea batata, a staple crop in the region, has been adversely affected by mining activities, with alterations in key nutritional parameters. These findings underscore the urgent need for sustainable mining practices and soil conservation efforts to mitigate the environmental and agricultural impacts of mining in the region.

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