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ASSESSMENT OF CHARCOAL PROCESSING TECHNOLOGY USED FOR COMMERCIAL CHARCOAL PRODUCTION IN NASARAWA STATE, NIGERIA.

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Abstract
Deforestation and Forest degradation is one of the major environmental problem ravishing the world today, Charcoal production involves a wholesome dependency on the natural woodlands which contributes to deforestation, leading to the loss of valuable resources and dangerous interference with the environment. The adverse effect of deforestation is climate change through the release of large amounts of greenhouse gases that fuel global warming. Charcoal production reduces the bio-productivity of ecosystems by disrupting the habitats of thousands of species, and gradually transforms forest lands into barren deserts. Consequently, by impoverishing our natural environments, in the long run deforestation affects our lives and economy negatively. Over the years, sustainable management of forest resources has been of primary concern due to its potential impact on biological diversity and importance in maintaining global ecological function.
The most used technology in the production of charcoal for commercial and domestic purposes in Nasarawa state of Nigeria is the use of Kiln which is economically ineffective and environmentally unfriendly. Production processes from cutting down of trees, to logging, stocking, covering, burning, separation and bagging. Results in dangers to the biodiversity, such as introducing excess carbon dioxide into the atmosphere, which can affect the health of producers, introduction of toxic substance into the soil which affects the structure of the soil and exposure of bare surfaces which can lead to erosion. This study based on the concept of sustainable forest management and theory of common good,

aim at exposing the effect of this technology and suggests sustainable solutions. Primary and secondary data will be utilized and analyzed using statistical, inferential and Geospatial techniques. It is recommended that recommends that traditional and religious leaders should e used to enlighten the charcoal producers on the effect of the used technology and also a more efficient and less harmful technology should be invested in.

KEYWORDS; Charcoal Production, Kiln, Environment, Technology

INTRODUCTION:

The impact of wood fuel and its derivative (charcoal) gotten from forested woodlands, on the energy requirements of developing nations cannot be ignored. It supplies about 95 percent of the cooking energy needs in the developing countries (Food and Agriculture Organization-FAO, 2011). In spite of the benefits derived from the forest , the world's forest is rapidly depleting due to the rate of dependence on the savannah woodlands and it has exposed it to degradation, these has attracted concerned sectors of the world government i.e. United Nations, world Health Organization, Red cross in finding ways to curtail this increasing menace against nature.

Charcoal has remained a source of energy for several purposes in both rural and urban centers globally. It is now an export commodity in Africa, with a large market in the Europe, USA and Asia. The prices range from $170 -$300/ton depending on the packaging. Tropical Africa accounts for 70% of the exports and the market is all year round with a slight drop between July and September (Essiet 2009, The Thy consulting 2011).According to The Food and Agricultural Organization (FAO, 2011) of the United Nations, over 40million metric tons of charcoal are consumed globally, approximately 2.4billion people rely on wood and charcoal for domestic consumption. Charcoal provides 82% of urban and 34% of rural household energy in Kenya (RoK, 2004). The charcoal industry in Kenya employs over 700,000 people directly who support over 2 million dependants (Muchiri, 2008). In Tanzania, the income from the sale of charcoal was also found to be above the minimum wage paid to most of the government and private sectors employees (Mndeme, 2008). This makes it difficult for initiatives to mitigate the effects to have recognizable success unless alternative source of energy, income and sustainable production technologies are adopted by producing communities.

William and Pinto (2008) pointed out that the business of trading in charcoal has now become a very lucrative venture in Nigeria, whether as a retailer, wholesaler or supplier. Charcoal can be produced year round. However, charcoal production and export peaks during the dry season (from November to May). Production and export of charcoal during the wet season could be rejected by buyers because of the high moisture content (more than 10%) that usually characterized the charcoal produced during this period. Seasons influence charcoal production and utilization. In Europe, the sales season starts from May to August, order is made from September to May. Though some big time importers in Europe buy all year round. In countries like Kuwait, Israel and some Asia countries, demand is all year round (Nash and Luttrel 2007). This research discusses the production and marketing of charcoal in relation to place (distribution) and price in Nigeria.

However, tackling deforestation and forest degradation requires a good understanding of the players in the extraction forest resources, what drives them and the roles they play and the technology they use. In the process, other possibilities – including alternative pathways that might treat and value carbon as part of complex, lived-in landscapes, or respond more adaptively to less equilibrium people–forest relations, are excluded. (Leach and Scoones 2013).

Saving Nasarawa's forest from the chainsaw and axe of encroaching humanity is essential to the health and productivity of much of the national economy as forests' are known to play the roles of watersheds, defenses against soil erosion and regulators of local weather conditions.

Given the observed growing significance of charcoal in rural and urban livelihoods, particularly in Nasarawa state, the attention of several authors has been recently drawn to the environmental consequences of its production. Through this study, the communities would also be educated and enlightened on the knowledge they have and don't have about resultant effects of commercial charcoal production. This would encourage them to adopt more environmentally friendly approaches to charcoal production such as modern kiln technologies which will not take away their source of income but also will not cause much harm on the forest woodlands in the study area. Omoakin *et al.*

(2015) observed that the increasing use of firewood and charcoal is an indication that the general welfare of the people is yet to improve substantially Impact on ecosystem comprises the deforestation impact like loss of bio-diversity and millions species of habitat's endangering of plants and animals also depletion forest reserves meant for the purpose of protecting environment which serves as shield from direct impact of downpour of rain, high temperature and wind that will result of erosion, flood and other environmental instability. About 80% of earth land animals and plants home is forest and charcoal production which contributes highly to deforestation in Nigeria has a grievous impact to their home which is forest. Another impact on our ecosystem the green house gas release during the production process and the carbon dioxide in particular released from dead vegetation that decomposes in the ground as a result of tree cutting and other vegetation damage during this process.

MATERIALS AND METHODS

This study was carried out in Nasarawa State. However, three Local Government Areas (Akwanga, Doma and Karu) which are home to extensive woodlands were selected for the study based on the three senatorial zones of the State. From each of the local government areas, two communities were selected from each. Aricha and Gudi were selected from Akwanga LGA, Idadu and Agwashi from Doma and Saningye-Panda and Songo-Gitata from Karu LGA.

This study is for three years but 18 years spanned Global Forest Change Image which provided data on tree cover loss and change from year 2001 to 2018 was used.

The assessment of tree removal for charcoal production was limited to the aboveground biomass and the effects of commercial charcoal technology on the environment and alternative economic activities to its production were determined in the study

Sustainable Forest Management

According to FAO (2020), Sustainable forest management (SFM) is defined as a "dynamic and evolving concept, which aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations". Forests and trees, when sustainably managed, make vital contributions both to people and the planet, bolstering livelihoods, providing clean air and water, conserving biodiversity and responding to climate change. International Tropical Timber Organization-ITTO (1992) defined the concept it as: "the process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment" and "the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems" (proposed by the second ministerial conference for the protection of the forest: MCPFE, 1993). The concept of sustainable development (Keiner 2004) is taken into consideration in numerous economy sectors, with forestry being no exception. Forests are extremely important in the ecology of the Earth. They produce multiple environmental benefits including biodiversity conservation, carbon sequestration, and protection against desertification. Appropriately managed forests can enhance the provision of wood and non-wood forest products for millions of people. At the same time, forest ecosystems play a key role in mitigation of climate change effects.

The Theory of Collective Goods

The *theory of collective goods* explains that collective goods such as woodlands have unique characteristics of non-excludability and non-rivalry in their use (Maiangwa *et al.,* 2007). However, as pressure sets in as a result of either increase in population of producers, increase in rate of production or increase in competing uses of woodland, the woodlands begin to lose their character of non-rivalry and problems of degradation arise. The theory assumes that if the use of woodland for charcoal production becomes competitive and no conservation measures are put in place, it suffers degradation. Critical to this theory is the detection of the onset of competition for woodland. In many cases, management fails to detect that critical point and later realizes that the cost of sustaining the woodlands is unbearable (Rose, 1991). Consequently, management begins to manage a bad case of Business as Usual (*BAU*), which does not sustain the woodland but worsens the degradation of the resource. From the theory, the solution to sustaining the resource requires users to be responsible for the degradation but users will only honor their obligation at the time the use of the resource is lucrative and not when competition makes the resource expensive to obtain and business becomes less lucrative.

RESEARCH METHODOLOGY:

Nasarawa state has an approximate land area of about 27,271.50 square kilometers. The State is located in the basement complex of northern central Nigeria between longitude 6°.45'03'' and 9° 45' 03'' of the Greenwich meridian and latitude 7° 45' 00'' and 9° 35' 00'' of the equator. It stands at an elevation of 400 meter above sea level. It was created on October first, 1996 and is undergoing rapid population growth and infrastructural development due to its proximity to the Federal Capital Territory, Abuja. It shares geographical boundaries with Kaduna state in the north, Abuja Federal Capital Territory (FCT) in the west, Kogi and Benue states in the south, Taraba and Plateau states in the east respectively.

The state is a gate way to the Federal Capital of Nigeria for it share border with the centre of unity. It has a population of 1,869,377 and 1,926,221 as the current projected population with a population density of 75/km^2 (190/sg mi) making it one of the most densely populated States in the country (NPC, 2006). Table 3.1 shows the population distribution of the thirteen local government areas that make up the state.

Figure 1;Nasarawa State Showing the LGAs

Source: Geography Department, Nasarawa State University, Keffi**.**

This study adopted a descriptive-survey research design whereby both quantitative and qualitative types of data were collected. Direct and indirect modes of inquiries were employed to seek opinions and knowledge of a sampled population of respondents on commercial charcoal production in Nasarawa State. The descriptive survey design also entailed, description of the characteristics of phenomena, opinions, preferences, and perceptions of people in the study area regarding investigated issues of commercial charcoal production and its sustainability and that of forest/woodland resources. The tools used exposed information on the charcoal process technology used and the obvious resultant effect on the producers and their environment.

The study drew from both primary and secondary sources of data. Preparatory to data collection, reconnaissance survey was carried out in the study area prior to the administration of questionnaire, conducting of interviews and focus group discussion. This enabled familiarization, as well as obtaining of first-hand information about the study area through observation and casual interactions with the people. A questionnaire containing both open and closed-ended questions was used to obtain data for the study; a total 450 copies of the questionnaire were administered to the sampled respondents. Focus Group interviews were conducted in each of the sampled LGA to enlighten those involved in commercial charcoal production on the relevance of the research to them and find out positive and negative impacts of charcoal enterprise and the socio-economic benefits from the industry. The focused group discussion was conducted amongst three groups of producers based on age categories comprising of 8 – 12 participants in each group having younger generation producers (30 years and below), middle age producers (31 – 45 years) and older generation producers (46 years and above). Two FGD sessions per age group were conducted in each of the selected communities in the study Area. FGD data were captured using audio recording and field notes. Physical aspects relevant to the study were observed, measured and recorded using Global Positioning System (GPS) and measurement tools such as weighing scale, chain lever and iron hook. Field observation/measurement helped in the quick capturing of data like the methods adopted for commercial charcoal production, mass of logs the kiln could accommodate per production, quantity/mass of charcoal (in bags) per production and tree density in and around the production area. A multi-stage sampling technique which included: stratified random sampling, purposive sampling and simple random sampling techniques.

Stratified random technique was used in this research to divide Nasarawa state into three stratum basically which fell into the three senatorial districts; Nasarawa West (Nasarawa-Toto, Karu, Keffi, Kokona) Nasarawa North (Wamba, Akwanga, Nasarawa Eggon) And Nasarawa South (Keana, Doma, Lafia, Awe, Obi). This method made it possible to reduce the sample and achieve precision.

Based on the number of producers identified to be involved in commercial charcoal production in each of the six study communities, the Krejcie and

Morgan's sample size determination table (Krejcie and Morgan 1970) was used to select appropriate samples for the study.

Table 1 Sample Size Determination

Akwanga	Aricha	85	70
	Gudi	85	70
Doma	Agwashi	55	48
	Idadu	90	73
Karu	Songo-Gitata	120	92
	Saningye-Panda	130	97
Total			**450**

Source: Reconnaissance Survey/ Krejcie and Morgan (1970)

RESULTS AND DISCUSSION

Kiln Locations and Density

Figure 2 show the spatial locations of the kilns while pictures1- 2 presents the density of the kilns in each location. Figure 3 shows that the production area of Akwanga LGA where a total of 61 kilns were identified, had a kiln density range of 1 to 4 kilns per 100m by 100m grid cells (10,000m^2 or 1 hectare) and an approximated average density of 2 kilns. Furthermore, figure 4 revealed that the kiln density in Doma production area with a total of 31 kilns, ranged between 1 and 3 kilns per hectare while the average density stood at 2 kilns per hectare. Spatial Distribution of Kilns in the Sampled Production Areas.

Distribution of Roles in Commercial Charcoal Production by Gender and Age Group

The chi-square and cross-tabulation result of the test of association between the roles commonly performed by commercial charcoal production and their gender and ages are presented in tables below.

Table 4.11: Chi-Square Result of Commercial Charcoal Production Roles by Gender

	Value	Df	Asymp. Sig. (2-sided)

Pearson Chi-Square	162.379[a]	5	.000
Likelihood Ratio	199.728	5	.000
Linear-by-Linear Association	94.163	1	.000
N of Valid Cases	450		
a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 17.12.			

Table 4 Roles and Gender Cross-tabulation

		Gender				
LGA	**Role**	**Male**	**%**	**Female**	**%**	**Total**
Akwanga	cutting of tree	23	100	0	0	23
	Stacking of logs	34	81	8	19	42
	Covering of stacked logs with sand/grasses	43	35.2	79	64.8	122
	Burning and monitoring of charcoal	40	31.3	88	68.8	128
	Raking and separation of dirt/debris from newly formed charcoal	24	27.6	63	72.4	87
	Packing/bagging of charcoal	42	33.1	85	66.9	127
Doma	cutting of tree	37	100	0	0	37
	Stacking of logs	43	100	0	0	43
	Covering of stacked logs with sand/grasses	49	51	47	49	96
	Burning and monitoring of charcoal	60	52.2	55	47.8	115
	Raking and separation of dirt/debris from newly formed charcoal	24	33.3	48	66.7	72
	Packing/bagging of charcoal	44	48.4	47	51.6	91
Karu	cutting of tree	44	100	0	0	44
	Stacking of logs	70	97.2	2	2.8	72
	Covering of stacked logs with sand/grasses	82	51.3	78	48.8	160
	Burning and monitoring of charcoal	97	52.7	87	47.3	184
	Raking and separation of dirt/debris from newly formed charcoal	44	55	36	45	80
	Packing/bagging of charcoal	73	45.6	87	54.5	160
Total	cutting of tree	104	100	0	0.0	104

	Stacking of logs	147	93.6	10	6.4	157
	Covering of stacked logs with sand/grasses	174	46.0	204	54.0	378
	Burning and monitoring of charcoal	197	46.1	230	53.9	427
	Raking and separation of dirt/debris from newly formed charcoal	92	38.5	147	61.5	239
	Packing/bagging of charcoal	159	42.1	219	57.9	378

Source: Data Analysis 2018

Charcoal Production Process

The time taken by charcoal producers to complete a cycle of charcoal burning process is a good indicator of the magnitude of commercial charcoal production in a given area. It actually determines the frequency of production as well as that of tree cutting for the activity. Table 4.9 presents the responses on time taken to complete a charcoal burning process in the study area.

Table 4. Time for Complete Charcoal Burning Cycle

Period (days)	Akwanga		Doma		Karu		Total	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
2 – 3	30	20.00	0	0.00	0	0.00	30	6.67
4 – 5	30	20.00	23	15.33	15	10.00	68	15.11
6 – 7	43	28.67	57	38.00	55	36.67	155	34.44
8 – 9	47	31.33	70	46.67	80	53.33	197	43.78
Averages	**5.93**		**7.13**		**7.37**		**6.98**	

Source: Field Data Analysis 2018

Table 4 shows that the period for one complete cycle of charcoal burning process varied among the producers with range values of 2 to 9 days and a mean value of approximately 7 days. Majority (197, 43.78%) of the commercial charcoal producers claimed that they take a minimum and maximum of 8 and 9 days respectively to accomplish a cycle of charcoal production. This category was closely followed by 155 (34.44%) producers whose production cycle ranges between 6 and 7 days, while 68 (15.11%) and 30 (6.67%) comprised of those producers who take 2.5 days and 4.5 days to complete one cycle of charcoal production.. Charcoal production in the earth brick and metal kilns were observed in their study as against the case in this study.

Furthermore, there were disparities in the period taken to complete a burning process across the three LGAs sampled for the study. In Doma and Akwanga LGAs, it was revealed that the period taken to complete a cycle of charcoal burning process ranges between 4 and 9 days. Approximately 7 days was recorded as the mean burning period in both LGA with majority (46.67% and 53.33% respectively) of the producers completing their burning cycle on an average of 8.5 days. Those who completed charcoal burning process on average of 6.5 days accounted for 15.33% and 10% of the respondents in Doma and Karu respectively. Conversely in Akwanga, completion charcoal burning process ranged from 2 – 9 days with an approximated average of 6 days. The high proportion (30, 20%) of the respondents in Akwanga claimed to complete a burning cycle in 2 – 3 days and 4 – 5 day, each. This could be due to the types and moisture content level of the type of woods used for production of charcoal in the area. A particular tree (Pasaga) which was not identified in the other two LGAs was found to be among the preferred tree species for charcoal burning in Akwanga. The implication of shorter burning period is increased pressure on woodlands as the entire process of commercial charcoal production begins with identifying and cutting of preferred tree species.

Focus Group Discussion revealed that charcoal production process in the study area starts with the identification of preferred or suitable trees. The identified trees are then felled or harvested, grouped by diameter and stacked at the burning site or transported over a distance to the production site. The wood is then heaped on a relatively flat plain up to a reasonable height and covered with a layer of grass/leaves (and metal aluminum materials in some cases) and then sand, leaving two very small openings for fire to be lit and smoke exit respectively. Fire is then lit from the openings. After the fire had gone round the stacked wood, the hole is sealed with small sticks and grasses. The process is then closely monitored both day and night for about one week for the entire heap to be converted into charcoal. In order to allow proper ventilation and sustained burning during the carbonization process, sequence of openings is created in the earth mound. The process is known to be completed once smoke from the pile stops and cools. The producer rakes and separates the dirt and debris from the newly formed charcoal and the charcoal is then packed in synthetic bags for sale.

The entire process from suitable tree identification and bagging of charcoal was estimated to usually take up to 2 – 3 weeks. The stages involved in commercial charcoal production are depicted in plates 1, 2 and 3.
Plate 4 Stages of Charcoal Production Activity in the Study Area

Charcoal Processing Technology

Table 4.15: Charcoal Processing Technologies used in the Study Area

Technologies	AKWANGA	DOMA	KARU	Total
Traditional Earth Mound Kiln	140	121	189	450
Metal Kiln	0	0	0	0
Earth brick Kiln	0	0	0	0
Others	0	0	0	0
Total	**140**	**121**	**189**	**450**

Source: Field Data Analysis 2018

Table 4.15 shows that all charcoal production in the study area was completely traditional as all the respondents claimed to use the traditional earth mound. This was further verified through field observation as shown in plates 4.5, 4.6 and 4.7. This finding corroborates that report of Food and Agriculture Organization-Somalia Water and Land Information Management FAO-SWALIM (2009) that charcoal production in Africa is largely practiced using traditional methods with the pit and the earth clamp being the most widely practiced. This was further confirmed by *Beatrice et al.,* (2015) who noted that throughout the developing world, charcoal is produced using earthen kilns or mounds for carbonization referred to as the traditional earth mound technology. According to Lurimuah (2011), this technology has been criticized as not being technically efficient as it is believed to waste raw material. It is also labor intensive and destroys vegetation at the production sites. It has been reported that the brick and metal kilns are relatively more efficient and effective given that they minimize wood waste and enhances the quantity and quality of charcoal produced (Energy Commission, 2010). Notwithstanding their edge over the traditional earth mound, local commercial producers have been discouraged from using them due to the initial investment cost of obtaining them. A discussant during FGD at Saningye-Panda community stated that: *"many of us are aware of the existence* *of the modern technologies but the cost of acquiring or setting them up has been a major limiting factor to embracing them".*

EFFECTS OF CHARCOAL PRODUCTION TECHNOLOGY

Cumulatively, the obvious effects of commercial charcoal production in the study area include the following:

- **Exposure of bare surfaces:** As a result of indiscriminate felling of trees for commercial charcoal production and the digging of holes to burn the stacked logs a lot of surfaces have been left bare. This has in turn made vast swaths of land vulnerable to wind and rainfall runoff which cause erosion in the area. The erosion problem created by commercial charcoal production in the area is compounded by heavy logging trucks that compact already thin soil and prevent new plant growth. Logging roads leave deep tire marks that erode at an accelerated pace and deposit a high volume of sediment into streams and rivers. According to some of the interviewed respondents, erosion problem in the area has caused the soils to become dry and nutrient-deficient as there is no longer vegetation to hold water and nutrient in place. They pointed out that this has resulted in food production shortages owing to the drastic decline in land productivity for agriculture over the years, increased cost agricultural production (i.e., purchase of fertilizers). It was also observed that erosion has caused most of the terrain in the area to become grossly uneven.

An abandoned production site

- **Depletion of vegetation:** Owing to the pressure on the environment through commercial charcoal production most of the rich natural woodland the study Area has been highly degraded. They are now characterized with unhealthy and scanty vegetation cover. Forest soils and vegetation have a large capacity to absorb, transform and accumulate various pollutants of environment. Vegetation acts as an effective sink for a number of undesirable constituents of the environment. However, deforestation due to commercial charcoal production has not only destroyed this sink but also reduced soil's capacity to eliminate pollutants in the area.
- **Loss of biodiversity:** The heat from the fire and smoke at production sites has made the environment inhabitable for animal and plant species, forest naturally supports biodiversity by providing habitat for wildlife, Most of the

exploited tree species in the study area are not being replanted. Thus these tree species which are continually being exploited year in and out are now at the verge of extinction. According to some interviewed respondents, a good example of the situation is the Senagalia genuses (Gum trees) specie which reportedly used to exist in very large quantity in the study area but are now almost in extinct. They also noted that the loss of biodiversity as a result woodland exploitation for fuel wood has affected their economic activities by taking out hunting out of the equation. Hunting activities have been drastically reduced in the study area because a large proportion of the woodland vegetation that was inhabited by different species of wildlife has been depleted. This has in turn, resulted in extinction of these vast species of fauna as they no longer found the environment safe and conducive for habitation.

- **Health effects:** Interview with some of the respondents in the study area revealed that most of the women as well as some men in the study area are infested with respiratory diseases and eye problems resulting from emitted smoke in the course of charcoal production. These health problems could lead to more severe health issues like cancer and eye blindness. They also pointed out that most of the trees (such as; *Pterocarpus erinaceus*-moninga, *Parkia biglobossa*-Locust bean, and *Burkai Africana)* that of high medicinal value are fast disappearing due to fuel wood exploitation in the area. Though this has received less attention as a problem of deforestation, it is a very serious problem created by deforestation because forests foster medicinal conservation. With forest biotopes being irreplaceable source of new drugs, deforestation can destroy genetic variations (such as crop resistance) irretrievably.

CONCLUSION

Based on the findings of the study, it was concluded that commercial charcoal production has over time become an indispensable means of livelihood among rural settlers in Nasarawa State. However, the production process has remained undeveloped with the traditional earth mound kiln being the only charcoal processing technology adopted by the producers. Though cost effective in comparison to other technologies, the traditional earth mound has been proven to be both inefficient and ineffective towards sustainable utilization of savanna woodland resources in the state. The inefficiency of commercial charcoal production technology in the study area has resulted in the depletion of woodland forests in Nasarawa State. The most endangered species due to commercial charcoal production were *Anogeissus leiocarpus* (Marke), *Erythrina senegalensis* (Madri) and *Prosopis Africana* (Kirya).A more ecoefficient technology should be employed.

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