

Original Article

## Chemical Health Assessment of Agricultural Soils in Isialangwa North, Abia State, Nigeria



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Angelica N. Udi & Michael A. Okon\*

Department of Soil Science and Technology, School of Agriculture and Agricultural Technology,  
Federal University of Technology Owerri

\*Corresponding author's email: [michaelaokon@gmail.com](mailto:michaelaokon@gmail.com), orcid no: 0000-0003-4868-3923

Angelica N. Udi [angelicajames65@gmail.com](mailto:angelicajames65@gmail.com) orcid no: 0009-0007-9865-0763

**Editor:** Dr. Sunday N. Obasi  
National Open University of Nigeria

**Received:** May 10, 2025

**Accepted:** June 10, 2025

**Published online:** June 15, 2025

Peer-review: Externally peer-reviewed



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**Conflict of Interest:** The authors have no conflicts of interest to declare

**Financial Disclosure:** The authors declared that this study has received no financial support

**Keywords:** Soil health, Tropical soils, Chemical soil attributes, Soil fertility

### ABSTRACT

Healthy soils are very vital for cultivation of crops. This study therefore assessed chemical health attributes of agricultural soils in Abia State, southeastern Nigeria. Surface soil samples were collected randomly at depths of 0-20cm using free survey technique from three communities namely; Isingwa, Ngwaukwu and Ntigha. Soil samples were collected and subjected to routine laboratory soil analyses. Data generated were analyzed using ANOVA and significant means separated using FLSD at 5% probability level. The chemical health statuses of the soils were determined using chemical soil health indicators given by USDA, (2006). These attributes were further subjected to the ranking scheme of Zakir et al., (2022) which ranked soils from 0 to 3 with soil health classes of healthy, sub-healthy, weak and degraded respectively comparing them with ratings of soil properties. Results showed that the  $\text{CaCO}_3$  content of the study area were ranked 2 generally and considered weak. For ECEC, the soils of Isingwa and Ngwaukwu were degraded and ranked as 3 but Ntigha was ranked 2 and rated weak. For sodium saturation, the soils were healthy and ranked 0. In respect to pH, the soils in all study locations were weak generally and ranked 2. The soils were generally ranked 2 and rated weak with respect to soil organic matter. The overall ranking of the chemical attributes of the study area was 2 indicating that the soils were generally weak in chemical health. Regenerative agriculture is therefore recommended for the study area.

### 1.0 INTRODUCTION

A survey by Pretty (2008) suggested that, food production of the world has drastically increased since 1960s which has also increased per capita of agricultural production and the utilization of inorganic fertilizers and machinery. The increased inputs of inorganic Phosphorus and Nitrogen fertilizers to agricultural soils have negatively affected human health by negatively affecting soil biodiversity and quality of soil water (Cordell et al., 2009). Soil management practices and land use can

lead to changes in soil and alter its functioning (Li et al., 2021). Soil has been and is currently being rapidly degraded at a global scale due to a range of invasive anthropogenic activities with concomitant adverse effects on human and ecosystem health and this is because soil is a non-renewable resource at a human non-temporal scale meaning that soil loss and degradation cannot be recoverable with a human life span (Yang et al., 2020). Soil management is important to all agricultural systems yet there is evidence of widespread degradation of agricultural



soils in the form of erosion, loss of organic matter, contamination, compaction, increase in salinity and other harms (European commission, 2002). This degradation sometimes occurs rapidly and obviously (Kibblewhite *et al.*, 2008). All these have led to the debate around the question “**What is soil health?**”

Soil health is a term used to describe the quality or well-being of the soil. Soil health is presented as an integrative property that reflects the ability of soils to respond to agricultural intervention, so that it continues to support both the agricultural production and the provision of other services (Kibblewhite *et al.*, 2008).

Environmental impacts on agriculture and the agricultural potentials of cropping systems are both strongly influenced by soil health (Ros *et al.*, 2022). Healthy soils are more sustainable, and provide nutrients for plants, captures and retains water, and provides a more robust habitat for microorganisms than an “unhealthy” soil (Karlen *et al.*, 2003). Healthy soils are soils which can sustain cropping under conditions of minimal plant stress (Magdoff, 2001).

In assessing soil health, soil health indices used depends on its ability to detect changes in soil management practices, use of standard sampling techniques, statistical models (Chu, 2019). Measuring soil health indicators on every dimension helps in identifying and finding solutions to issues causing soil illness (Pozza and Field, 2020). USDA (2006) gave different soil attributes which can be useful in assessing the health status of soils. The chemical attributes given were; carbonate content, Effective cation exchange capacity, sodium saturation and soil reaction). Soil chemical indicators are:

**Soil Reaction:** Soil pH refers to hydrogen ion concentration in the soil solution, which represents the acidity and alkalinity levels of soils (AUSVEG and HAL, 2009). Soil pH can influence availability of nutrients in soils. It has a scale of 1–14. Soil pH of 7 is neutral, while soil pH lower than 7 means that soils are acidic, and soil pH greater than 7 means that the soils are alkaline. The soil pH which is optimal for absorption of soil nutrients is between 6.5 to 7 (Sarkar *et al.*, 2018). Most soil nutrients will be available for crop use within this range. However, in soil pH below 6.5 or greater than 7.5, some elements even when they are present in soils will become less available (Idowu *et al.*, 2019). Soil pH can be said to be the master soil variable which influences many soil chemical, physical and biological processes and properties that influence biomass yield and plant growth (Minasny *et al.*, 2016).

**Sodium Saturation:** Sodium saturation is the quantity of sodium which is a percentage of the cation exchange capacity. Soils which have high percentage of sodium are referred to as sodic soils. Sodic soils tend to lose aggregation and disperse, prevent water

infiltration, and have poor aeration (AUSVEG and HAL, 2009). Sodium becomes problematic when the quantities of exchangeable sodium in soils become too high in relation to magnesium and calcium ions (Idowu *et al.*, 2019).

**Effective Cation Exchange Capacity (ECEC):** ECEC is the ability of the soil to hold nutrients through electrostatic forces. It is an important chemical property of agricultural soils, which reflects not only the surface properties of soil colloids, but also the retention and supply ability of soil fertility (Surekha *et al.*, 2017). ECEC is used in evaluating soil fertility, crop growth and pollutants partition and transport in soils (Sharma *et al.*, 2013). Soils with high ECEC are more fertile compared to soils low in ECEC (Sarkar *et al.*, 2018). Major basic cations are Calcium ( $\text{Ca}^{2+}$ ), Magnesium ( $\text{Mg}^{2+}$ ), Potassium ( $\text{K}^+$ ) and Sodium ( $\text{Na}^+$ ) while major acidic cations are Aluminium ( $\text{Al}^{3+}$ ) and Hydrogen ( $\text{H}^+$ ) (AUSVEG and HAL, 2009).

**Carbonate Content:** Carbonate is a natural part of many soils in the world (Zamannian *et al.*, 2016). Carbonates are classified into Primary (Lithogenic) which are also known as geogenic carbonates which are gotten from parent materials- weathered carbonate rock such as limestones, gaize, dolomite etc (Guo *et al.*, 2016). Secondary carbonates include compounds of anthropogenic origin and may be an admixture in natural soils. (Bartminski *et al.*, 2022). The determination of carbonates in soils is very useful in diagnosing soil status and also used in differentiating criterion in family level of soil taxonomy (Soil survey staff, 2006). Soils rich in carbonate are often used interchangeable with calcareous soils but they are not only associated with limestone soils but all soils containing carbonates like  $\text{CaCO}_3$ ,  $\text{MgCO}_3$ ,  $\text{NaCO}_3$  etc (Kowalsaka *et al.*, 2019).

Due to the rapid degradation in the fertility and health status of our soils, there is need to always investigate and evaluate the soils. This project was very necessary because it will provide a guide for the quantitative and qualitative soil health evaluation of selected agricultural soils of Isialangwa North LGA in Abia State, Southeastern Nigeria which will guide in soil management for improved crop productivity. The objective of this study was therefore to determine the chemical health status of selected agricultural soils in Isialangwa North LGA and to determine their relationship with other selected soil properties in the study area. The objective of this study was therefore to determine the chemical health status of selected agricultural soils in Isialangwa North LGA and to determine their relationship with other selected soil properties in the study area.



## 2.0 MATERIALS AND METHODS

### 2.1 Description of the study area

This study was carried out in Isialangwa North Local Government Area in Aba, Abia state, in Southeastern Nigeria. This is one of the largest and populous cities in southeastern Nigeria. The study area lies within latitudes 05°45'N and 06°00'N and longitudes 07°31'E and 08°09'E with an area of around 6,320sq.km. The study area is a humid tropic with annual rainfall range of about 2500mm to 3000mm with peaks in July and September. The annual temperature range is 27°C and 35°C. The rainy season and dry season pattern of the area is (February / March - November) and (November - February/March) respectively. The study area has a lowland topography and the soils are formed from coastal plain sand (Benin formation). Tropical rainforest is the vegetation of the area with variety of plant species arranged in layers with emergent plants towering above other plant species. Common plant species in this area include: Cassava (*Manihot esculanta*), Plantain (*Musa paradisiacal*), Mango (*Mangifera indica*), Oil palm (*Elaeis guineensis*) and Raffia palm (*Raphia hookeri*). Farming is the major socio-economic activity of the people in the area. Soil fertility is by bush fallowing, although inorganic fertilizers are used to supplement the nutrient requirement. Farmers of the area predominantly practice rain-fed agriculture Ridging and mounds are the dominant farming methods on the soil while both distant and compound farming systems exist in the communities.

### 2.2 Pre-field Studies

A reconnaissance visit was carried out in order to acquire reliable information about the sampling sites and to obtain information from the land owners about the study sites. A free survey technique was used to locate sampling locations. Three locations of Cassava cultivated lands were located; Isingwa 5°22'46"N and 7°21'53"E, Ngwaukwu 5°21'39"N and 7°21'46"E and Ntigha 5°25'11"N and 7°22'32"E. The three locations were geo referenced using Hand Held Global Positioning System (GPS) Other equipments used for the field work includes: Ruler, spade, Munsell Color chart, Machete/cutlass, Camera, Biro, Notebook, Soil auger, Core sampler, Coring knife, Plastic trowels, sampling bags and labels.

### 2.3 Field Studies

Soil samples were collected randomly with soil auger in 5 replicates from three different Cassava cultivated locations in Isialangwa North at a depth of 0-20 cm.

### 2.4 Sample Preparation

Soil samples collected were air-dried at room temperature and sieved with a 2mm mesh, bagged, well-labeled, and then taken to the laboratory for soil routine analyses and soil health analysis.

### 2.4.1 Soil Health

The chemical health statuses of the soils were determined using chemical soil health indicators as shown by USDA, 2006 guided by the rating scheme of Zakir *et al.*, (2022). The chemical soil health indicators given by USDA (2006) are shown below;

**Table 2.1 Soil chemical health Indicators**

GROUPING TYPE	SOIL INDICATORS
CHEMICAL ATTRIBUTES	Carbonate content Effective cation exchange capacity Sodium saturation Soil reaction

Source: USDA (2006)

Laboratory methods for Chemical Soil Health Indices:

- I. Carbonate Content:** 10g of air-dried soil was weighed into a conical flask and 25ml of 1M HCL was added and swirled for 1hr. The mixture was added in a 100ml volumetric flask and made up to volume with distilled water and filtered. 20ml of the clear filtrate was added to a conical flask followed by 5ml of water and allowed to boil. 6drops of bromothymol blue was added and 0.2MNaOH was used to titrate until the blue colour persists for 30s (ASTM, 2014)
- II. Effective Cation Exchange Capacity (ECEC):** This was determined from the summation of total exchangeable acids and total exchangeable bases according to Brady and Weil (2002) and expressed in cmol/kg
- III. Sodium Saturation:** This was calculated according to the method of USLS (1954).  

$$\text{Sodium saturation} = \frac{\text{Na}}{\text{ECEC}} \times 100 = \%$$
- IV. Soil Reaction (pH):** This was determined in water using a pH meter in soil/liquid suspension of 1:2.5 according to Thomas, (1996).

### 2.5 Evaluation method of health degree

The evaluation method of the health degrees of the soil samples were assessed using the health levels and grading of Zakir *et al.*, (2022) as shown in Table 2.2 below;

**Table 2.2 Soil Health Assessment**

Soil health ranking	classes
0	Healthy
1	Sub healthy
2	Weak
3	Degraded

0= (Healthy Soils): Soils in good condition with no significant limitation to function as an ecosystem.



- 1= (Sub healthy): Soils having moderately severe limitations to function as an ecosystem.
- 2= (Weak): Soils with reduced productivity with almost severe limitations to function as an ecosystem.
- 3= (Degraded): Soils having severe limitations to function as an ecosystem.

2.6 Experimental Design: The design that was used for this study was the Randomized Complete Block Design (RCBD).

2.7 Statistical Analysis: The data generated were analyzed using the Analysis of variance (ANOVA) to find the variability of soil properties of the different agricultural soils of the study area. Coefficient of correlation was used to determine the relationship existing between soil chemical health indices with other selected properties of the soils of the study area.

### 3.0 RESULTS AND DISCUSSIONS

The results of the chemical health indicators of the soils of the studied area are presented in figures 3.1 to 3.4 and Table 3.1 and discussed below.

**Calcium carbonate content:** the carbonate contents of the soils of the study area as shown in figure 3.1 below followed this sequence: NT<ISN<NGU. The mean values were 1.24%, 1.49% and 2.10% respectively and there was no significant difference at ( $p=0.05$ ) among the means. This is also shown in their pH levels which followed this sequence NGU>ISN>NT as shown in figure below. The higher the pH, the higher the carbonate content of the soils and this is in corroboration to Suave *et al.*, (1998) which states that carbonate content increases soil pH because it reduces the solubility of trace elements. The calcium carbonate contents of the study area were generally low in the area and were ranked 2 and graded as weak on the basis of calcium carbonate.

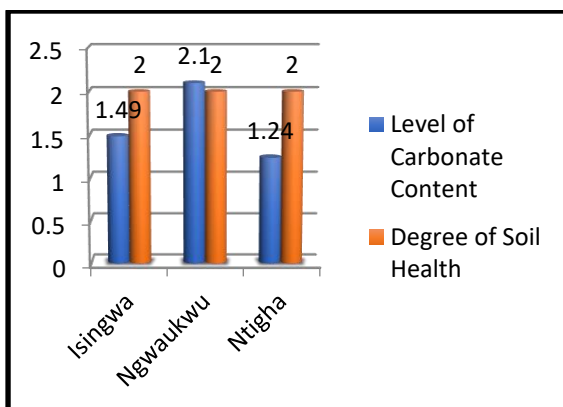


Figure 3.1 Calcium carbonate contents of the soils of the study area

**Effective cation exchange capacity (ECEC):** The results of the ECEC of the soils of the studied area follows this sequence: NT>NGU>ISN with mean values from 7.99cmol/kg, 5.89cmol/kg and 3.98cmol/kg respectively and there was significant difference at ( $p=0.05$ ) between the means. According

to Metson, (1961), Landon, (1991), and FDLAR, (1985), the ECEC values of the soils were low. The relatively low values of effective cation exchange capacity (ECEC) could be attributed to the low activity clay characteristics of 1:1 clay minerals, probably dominated by Kaolinite (Adesemuyi, 2014). It could also be as a result of tidal imports, runoff and seepage (Ukpong, 2000). Low ECEC can also be as a result of low chemical weathering activity of the soils of the study area (Okunsami and Oyediran, 1985). The Effective cation exchange capacity of the soils of Isingwa and Ngwaukwu were therefore ranked 3 and rated as degraded while Ntigha ranked 2 and was rated as weak.

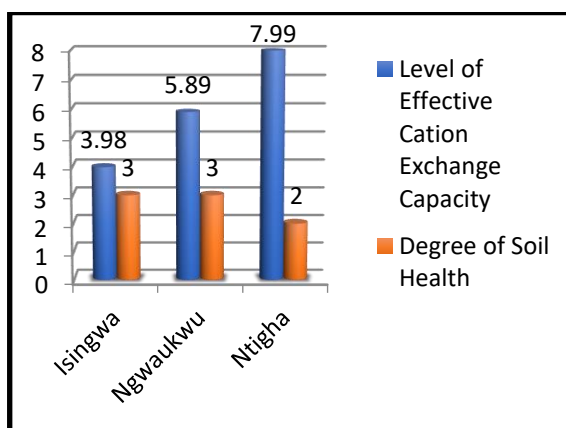


Figure 3.2: ECEC of the soils of the study area

**Sodium saturation:** The saturation of sodium in the soils of the study area ranges from 0.55% - 0.87% in Isingwa, 0.35% - 0.71% in Ngwaukwu and 0.20% - 0.33% in Ntigha with mean values of 0.72%, 0.51% and 0.26% respectively. The highest mean was recorded in Isingwa and lowest in Ntigha. The soils differed significantly ( $p=0.05$ ). The results showed that sodium contents were low in the area according to FAO (1979), meaning that the soils were not saturated with sodium and they were not sodic soils and thus were ranked 0 and graded as healthy.

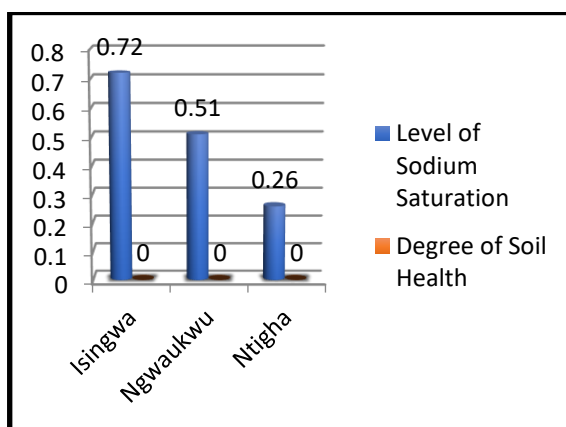


Figure 3.3: Sodium saturation of the soils of the study area.

**Soil reaction:** The results in figure 3.4 below showed that the pH of the soils ranged from 5.02-5.91 with mean values of 5.48, 5.78, and 5.23 in Isingwa, Ngwaukwu, and Ntigha respectively. According to FDALR (1985) and Bruce *et al.*, (1982), they range from strongly acidic to moderately acidic. The high amount of rainfall and the coarse texture of the soil caused the leaching of some amount of base cations causing the exchangeable complex of the soils to have high acidic cations (Nkwopara *et al.*, 2017). In general, all the soils of the area were acidic since pH values were less than 7 (pH<7). The mean Soil pH of the three locations were significantly different at (p=0.05). The acidity of soils could be due to the nature of the parent material which is coastal plain sands (NRCRI, 2003). The pH of a soil influences the efficiency of plant growth in the soil as well as the bioavailability of crop nutrients and the activity of microorganisms (Diallo *et al.*, 2015). pH range of 5.6-6.5 is suitable for crop production (Landon, 1991). The significant difference may be associated due to the impact of climatic factors. (Osujieke *et al.*, 2018). The soils in all study area were therefore generally ranked 2 with regards to soil pH and rated as weak.

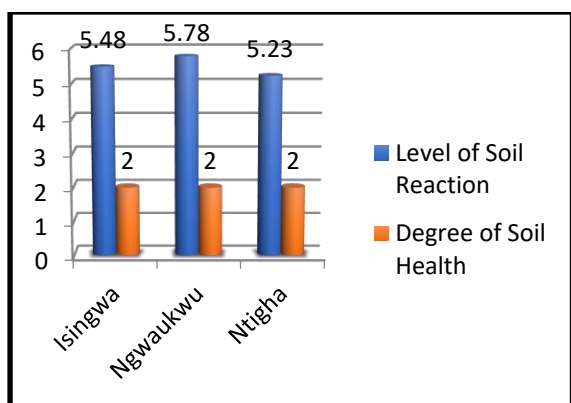


Figure 3.4: Soil reaction of the soils of the study area

#### Overall soil health rating

The mean results of all the chemical attributes of the study area as shown in Table 3.1 below showed that the soils were ranked 2 each for Isingwa, Ngwaukwu and Ntigha respectively. Generally, all the soils in the study area were considered weak based on the chemical overall attributes in the study area which implies that the crops will not perform optimally if the soil chemical health is not improved.

Table 3.1 Overall ratings of the chemical properties of the soils of the study area

locations	Overall ratings of soil chemical properties
ISINGWA	2
NGWAUKWU	2
NTIGHA	2
Mean	2

#### 3.1 Correlation between Soil Chemical health Indices with Selected Soil Physico-Chemical Properties of the study area.

Results of the relationship existing among the chemical health indices and soil physico-chemical properties studied are shown in Table 3.2 below. Soil pH had a negative significant relationship with silt (r=-0.532) and a strong and negative relationship with clay (r= -0.670), H<sup>+</sup> and Total exchangeable acidity (r= -0.696) which indicates that as pH increases or decreases, clay content, and exchangeable acidity content decreases or increases. pH also showed a positive significant relationship with Total nitrogen (r=0.544), Ca<sup>2+</sup> (r= 0.631), Mg<sup>2+</sup> (r= 0.597) and a strong positive relationship with pH and sand content (r= 0.715) and %Base saturation (r= 0.795).

Effective cation exchange capacity (ECEC) exhibited a significant and strong positive relationship with H<sup>+</sup> and Total exchangeable acidity (r=0.699), suggesting that as the soil ECEC increases, Total exchangeable acidity also increases. A positive correlation existed between Sodium saturation and %Base saturation and a strong positive correlation with Na<sup>+</sup>. This implies that as Sodium saturation increases, %Base saturation also increases and the Na<sup>+</sup> content greatly increases too. A strong negative correlation existed with H<sup>+</sup> and Total exchangeable acidity (r= -0.740) and ECEC (r= -0.913). There was no significant relationship between Carbonate content and any other physico-chemical properties.

Table3.2 Correlation between soil health chemical indices and soil physicochemical properties

Properties	pH	C.C	ECEC	Na. S
Sand	0.715**	0.277	-0.264	0.288
Silt	-0.532*	0.015	0.291	-0.420
Clay	-0.670**	-0.434	0.173	-0.107
SCR	-0.009	0.186	0.025	-0.236
BD	-0.121	0.030	0.231	-0.254
TP	0.121	-0.030	-0.230	0.254
MC	-0.070	0.294	-0.215	0.362
HC	0.268	-0.137	-0.110	0.234
pH	1.000	0.154	-0.312	0.352
OC	0.470	0.166	-0.157	0.322
TN	0.544*	0.251	-0.099	0.221
AVp	0.395	0.457	-0.225	0.258
Ca <sup>2+</sup>	0.631*	0.406	0.017	0.137
Mg <sup>2+</sup>	0.597*	0.398	0.113	-0.023
K <sup>+</sup>	0.101	-0.003	-0.148	0.013
Na <sup>+</sup>	0.385	0.036	-0.398	0.696**
TEB	0.655**	0.424	0.036	0.114
H	-0.696**	-0.250	0.699**	-0.740**
TEA	-0.696**	-0.250	0.699**	-0.740**
ECEC	-0.312	0.060	1.000	-0.913**
%BS	0.795**	0.292	-0.456	0.540*
%OM	0.466	0.165	-0.158	0.324
SMBC	0.467	0.170	-0.160	0.326

\*\* . Correlation is significant at the 0.01 level (2-tailed).

\* . Correlation is significant at the 0.05 level (2-tailed).

LEGEND: C.C: Carbonate content; ECEC: Effective cation exchange capacity; Na.S: Sodium saturation

#### 4.0 CONCLUSION AND RECOMMENDATIONS

The result of this study revealed the unique characteristics of the soils of the study area. Results



obtained from this work showed the levels of the soil chemical health status of the soils of the study area, and the relationship and variations that exists between them. The area was dominated by sand fractions. The pH levels of the soils were low revealing that they were acidic soils. The soils were also low in organic matter, ECEC and calcium carbonate content. Generally, the soils in Ngwaukwu was found to be healthier than the soils in Isingwa and Ngwaukwu but the overall health status of the study area showed that the soils of the study area were generally ranked 2 and considered weak with respect to soil chemical properties. Based on the findings of this study, it is therefore recommended that soil conservation practices like no till farming, mulch tillage, green manuring, application of organic manures and other practices which add organic matter and improve soil chemical health should be encouraged in the area. This will help to improve not only the chemical health status but also the physical and biological health status of the soils. In addition, the low total Nitrogen content in Ntigha can be remedied by planting of leguminous crops or by Nitrogen fertilization. Finally, liming of the soils of the study area is also recommended since the soils were strongly to moderately acidic and had low carbonate content. This will help to boost the soil pH and the carbonate content necessary for plant growth.

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