Assessment Of Environmental Radioactivity In Selected Dumpsites In Port Harcourt, Rivers State, Nigeria

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Abstract: Radionuclide concentration of soil samples from selected dumpsites within Port Harcourt, Rivers State, Nigeria was determined. *In-situ* measurements were carried out using Radalert Nuclear Radiation Monitor and a Geographical Positioning System (GPS). Two soil samples each from ten selected dumpsites were collected. Gamma Ray Spectrometry analysis was carried out on the samples to determine specific activity using NaI(Tl) scintillation detector. The measured *in-situ* equivalent dose rate ranged from 0.891 mSv/yr to 1.592 mSv/yr with an average of 1.261±0.693 mSv/yr for all the locations with seven locations having values below the internationally permissible threshold. The activity concentration of the soil samples obtained through gamma spectrometry analysis ranged from 32.21 Bq/Kg to 100.10 Bq/kg for ^{232}Th, 29.16 Bq/Kg to 61.18 Bq/Kg for ^{238}U and 222.15 Bq/Kg to 1166.99 Bq/Kg for ^{40}K with an average of 62.61±18.97 Bq/Kg, 41.96±5.53 Bq/Kg and 643.10±5.94 Bq/Kg for ^{232}Th, ^{238}U and ^{40}K respectively. Air absorbed dose rate calculated ranged from 57.05 nGy/hr to 123.10 nGy/hr with an average value of 86.71±12.86 nGy/hr for the locations which is higher than the world-average value of 55 nGy/hr for soil. The equivalent radiation exposure obtained using the radionuclide concentration for the locations is between 0.50 mSv/yr and 1.08 mSv/yr with an average of 0.76±0.11 mSv/yr which is below the permissible threshold of 1.0 mSv/yr for soil. Generally, the radiation burden and associated risk posed by the municipal wastes on the studied environment and scavengers is minimal.

Keywords: Absorbed Dose, Effective Dose, Gamma Spectrometry, Radioactivity, Specific Activity.

1. INTRODUCTION

IT is an established fact that radiation is present everywhere on the surface of the earth and has been since the formation of the earth [22]. In addition, human activities, which produce different forms of radiations, have made the flora and fauna (most especially man) to be exposed to these radiations [3]. Most radiation in the world is caused naturally through cosmic and terrestrial sources. Most of human exposure to natural radiation comes from radon in the rocks and soil. The radiation dose actually was a lot higher thousands of years ago than it is today and life still existed and thrived. The worldwide average background radiation dose is 2.4 mSv per year [14]. Unnecessary exposures to these radiations have shown to have detrimental effects on plants, animals and humans. Jibiri *et al.,* [10] revealed that staple food stuffs consumed in Nigeria contain traces of radionuclide. As a result of this, the refuse dumpsites are viable recipients of containment of radioactive materials [6]. Avwiri *et al.,*[1] stated that disposal of wastes without adequate management; particularly the radioactive contaminants can expose the populace to radition hazards. The contamination of soils and vegetations by heavy metals at dumpsites has been a major concern for all [17].

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It has been established that over time, high and excessive accumulation of heavy metals in soil may finally contaminate the food chain [9]. Indiscriminate dumping of municipal wastes– industrial (non-hazardous), commercial and household – such as food waste, paper, polyethene, textiles, scrap metals, glasses, wood, plastic, insecticides containers, bulbs, paints etc. at street corners and gutters, which produces some radioactivity is very common and on the increase. Open dumping of municipal solid waste (MSW) are the major causes of environmental degradation and public health concerns in many developing countries including Nigeria [15]. These waste dumps may contain a mixture of general waste and toxic, infectious or radioactive wastes and are susceptible to burning and exposure to scavengers [15]. Radionuclides in municipal waste come from various sources. For instance, K-40 is found in coal (used in cooking), production and usage of fertilizer and foodstuffs (such as bananas) amongst others. K-40 indeed fills an important dietary requirement, ending up in our bones, which makes humans have about 65 Bq/kg of K-40 [24]. ^{226}Ra and ^{228}Ra isotopes are important progenies of the ^{238}U and ^{232}Th series respectively. When in human body, the radioisotopes behave chemically and physiologically like calcium and are deposited in the bones. ^{226}Ra, which has a chemical similarity to calcium, is a bone-seeking radionuclide and accumulates in calcareous tissues [23]. ^{226}Ra contamination of food chains is “moderate” with composition of about 99% of the total body content in human bones [8]. There is a high retention and accumulation of ^{226}Ra in bones with time under conditions of chronic intake. Levels of ^{226}Ra observed in human bones from several urban locations ranged from 0.03 Bq Kg^{-1} to 0.37 Bq Kg^{-1} [5]. The main source of gamma exposure for the observed population is naturally occurring radionuclides, especially ^{40}K, which is found in soil, water, meats and high-potassium foods like bananas. Unfortunately, there seems to be no clear cut guidelines at the national or state levels on how to manage these dumpsites in a sustainable manner, particularly in the developing countries like Nigeria where the burden of environmental pollution seems to be high. The need to establish a data base (reference level) for environmental

radioactivity of dumpsites and identify spatial locations likely to be radiologically hazardous to the populace necessitated this research. Port Harcourt, a city in South-South, Nigeria and the capital of Rivers State is highly populated with its geographical coordinates at 4° 47' 21" North, 6° 59' 55" East. Port Harcourt is the nerve centre of the Nigeria oil industry and other manufacturing industries: Total Nig. Ltd, AGIP, Schlumbeger, Halliburton Energy Services (Nig) Ltd, Nigeria Bottling Company and Pabod Breweries amongst others. This industrial status of the city has resulted in the emergence of numerous and uncontrolled dumpsites in markets and residential areas have been poorly managed. Scavengers and nearby residents spend several hours daily in search of recyclable materials.

2. METHODOLOGY

In-situ measurement of radioactivity was carried out in ten selected dumpsites as shown in Table 1 using Nuclear Radiation Monitors (Radalert (100) and Digilert) alongside sample collection. Furthermore, Table 1 below shows the list of dumpsites /locations considered as well as the associated waste. Twenty (20) soil samples were collected from the ten (10) selected dumpsites (two samples from different points in each dumpsite). The samples were prepared using standard methods [7]. The samples were kept in the Centre for Energy Research and Development, Ile-Ife laboratory for twenty-eight (28) days to allow for secular equilibrium and to enhance Radon-226 production [4]. The soil samples were analysed using the Gamma Spectrometer (a 3" X 3" NaI(Tl) scintillation detector) at the Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife, Nigeria. The detector is enclosed in a 100 mm thick lead shield. IAEA – 375 reference soil standard was used for energy and efficiency calibration. The counting time for each of the samples was 25, 200 seconds (seven (7) hours). The photopeaks observed with regularity belong to those headed by ^{238}U – and ^{232}Th- series in addition to the non-series ^{40}K. Details of the analysis are as previously reported ([13], [18]). The absorbed dose rate, D (nGy/hr), from the samples in all the sampling locations were calculated using the relationship derived by Beck *et al.,* (1972) for soil samples due to the concentrations of ^{238}U, ^{232}Th and ^{40}K which is given as:

$$D = 0.042A_{c(K)} + 0.429A_{c(U)} + 0.666A_{c(Th)} \quad \text{.....(1)}$$

Where $A_{c(K)}$, $A_{c(U)}$ and $A_{c(Th)}$ are activity concentrations (in Bq/Kg) for K-40, U-238 and Th-232 respectively. Also, the dose equivalent rate of each sample was calculated using the relation by [16].

$$Sievert = Gray \times w_R \quad \text{.....(2)}$$

Where, w_R is the radiation weighing factor, which is a measure of the relative hazard of an energy transfer by emitted radiation and equals unity for gamma radiation. While the Gamma Radiation (Air) Absorbed Dose Rate (nGy/yr) is obtained by converting the Absorbed Dose rate in nGy/hr using the relation. The UNSCEAR threshold for air absorbed dose rate is 92 nGy/yr. The results of equivalent and air absorbed dose rates calculated from the *in-situ* average dose rates (obtained from the three readings per location taken) for the locations are presented in Table 2.

Table 1. The list of dumpsites considered and the associated wastes.

S/N	Location	Name	Associated Wastes
1	University of Port Harcourt Teaching Hospital Dumpsite	UPTH	Medical and office wastes including used syringes, plasters, bandages, pharmaceuticals, plastics, paper etc. are being dumped at the site.
2	Eneka Dumpsite	ENK	Domestic non-hazardous waste mainly from offices, operational and residential locations and wastes arising from estate management activities, including but not limited to garbage (cardboard/paper), garden waste, food, plastics, metals (tins/ cans) and trash (Uwakwe (2012)).
3	Eneka – Igwuruta Road waste dumps	EGR	Market, residential and commercial wastes which include food, glass, plastics, ashes, paper, nylon, tin cans etc.
4	Elele waste dump	ELE	Market waste and residential waste such as sugarcane molasses, scraps of metals (from used items like vehicles, household electronics (television sets etc)), ashes, cattle dung and other animal wastes (bones) from a small abattoir in the area.
5	Trans Amadi Industrial Layout (Slaughter Area)	SL	Wastes from the market, abattoir (animal wastes- bones, fur, hooves etc), plastics, human wastes and other waste sediments deposited by Woji river along its banks.
6	Woji Side of Woji River	SLB	Wastes from industrial activities like building construction, welding (metal scraps), small market wastes and other commercial wastes around the vicinity.
7	University of Port Harcourt Post Graduate Hostel waste dump	PGH	Household waste generated in the hostel which include packaging materials, paper, kitchen waste, plastics, wood, spoilt electronic gadgets etc.
8	University of Port Harcourt OFRIMA Block waste dump	OFR	Science laboratories and office wastes such as waste papers, used chemicals (solvents), wood, broken glasses and apparatus, wastes from guinea pigs and rabbits, sawdust and wood shavings.
9	Rumuodomaya Market waste dump	OK	Different wastes including market, household and agricultural wastes dumped there are vegetables, rotten tubers and fruits, potatoes, nylons, packaging materials and ashes. In addition, there is an abattoir near the market which generates wastes from cattles and other animals killed in the market.
10	Eliozu Reclaimed Dumpsite	ELS	Mixture of medical, industrial, commercial, market, household and agricultural wastes which include tin cans, textiles, leather, damaged electronics, glass, wood, food.

Table 2: Results of Dose Rates from the *In-situ* Measurement

S/N	Sample	Average Dose Rate (mR/hr)	Average Equivalent Dose Rate, E(mSv/yr)	Average Air Absorbed Dose Rate (nGy/hr)
1	UPTH	0.018±0.003	1.578±0.237	180.00±30
2	ENK	0.018±0.003	1.592±0.239	181.67±30
3	EGR	0.017±0.003	1.476±0.221	168.34±30
4	ELE	0.015±0.002	1.286±0.193	146.67±20
5	SL	0.011±0.002	0.979±0.147	111.67±20
6	SLB	0.013±0.002	1.169±0175	133.33±20
7	PGH	0.017±0.003	1.519±0.227	173.32±30
8	OFR	0.010±0.002	0.891±0.137	101.67±20
9	OK	0.011±0.002	0.950±0.142	108.34±20
10	ELS	0.013±0.002	1.169±0.175	133.34±20

3. RESULTS AND DISCUSSION

The *in-situ* equivalent dose rates (mSv/yr) range from 0.891 mSv/yr to 1.592 mSv/yr for OFR and ENK dumpsites respectively with an average of 1.261±0.693 mSv/yr for all the locations. Fig. 1 shows the *in-situ* average equivalent dose rates for each location compared with the [21] threshold. The air absorbed dose rates obtained range from 101.67 nGy/hr to 181.67 nGy/hr for OFR and ENK dumpsites respectively. These values are comparable to what Tubosun *et al.,*(2013) reported in which in-situ radioactivity value for a rare metal pegmatite mining field in Sepeteri was 0.18 μSv/hr (1.57 mSv/yr) which is above the UNSCEAR threshold of 1.0mSv/yr for the general public (non-radiation workers). Of all the ten locations studied, only three locations (SL, OFR and OK) have their equivalent dose rates below the permissible limit. Comparing the in-situ results in this work with that of [11] in which the radioactivity and radiation hazard indices of Cauvey River, Tamilnadu, India were assessed and the *in-situ* mean

absorbed dose rate of 96.10 nGy/hr was obtained; the higher range of values obtained in this work is likely attributed to various radionuclide sources which are dumped in the sites most especially organic materials with high ^{40}K content such as charcoal, animal bones, rotten fruits (bananas) and the likes. The result of Gamma Ray Spectrometry technique showing specific activities of the soil samples is presented in Table 3 below. The specific activity of ^{40}K ranges between 222.15 Bq/Kg and 1166.99 Bq/Kg for SLB and OK respectively with an average of 643.10±5.94 Bq/Kg for all the locations. These results are similar to that obtained by [1] in which K-40 activity ranges between 105.6 Bq/Kg and 570.1 Bq/Kg for the selected points in Eliozu reclaimed dumpsite (ELS). The gamma absorbed dose rate calculated using the gamma spectrometry results in Table 4 ranges between 57.05 nGy/hr and 123.10 nGy/hr for SLB and OK respectively with an average of 86.71±12.86 nGy/hr. This average is above the world average of 55 nGy/hr for soil. Comparing the average gamma absorbed dose rate of 38.17±12.45 nGy/hr reported by [1] for Eliozu dumpsite (ELS) to 85.09 nGy/hr obtained for the same dumpsite in this work is relatively high and this may be attributed to high average activity concentration of ^{40}K, ^{238}U and ^{232}Th compared to that of earlier study. This discrepancy can be likely linked with increase in the amount of decomposed wastes at the site with time as soil samples were observed in the two cases. The results obtained agreed to some extent with that of [12] for soils around Olusosun dumpsite in Lagos State. Similar high values of gamma absorbed dose rate were also reported in another work by [19]. On the other hand, the equivalent dose rate calculated using the same gamma spectrometry result ranges from 0.50 mSv/yr for SLB to 1.08 mSv/yr for OK with an average of 0.76±0.11 mSv/yr. Fig. 2 shows the equivalent dose rates obtained from average specific activity of radionuclides in the locations compared with the [21] threshold. Fig. 2 shows that the equivalent dose rates for the locations fall below UNSCEAR 1.0 mSv/yr threshold except OK (with 1.08mSv/yr) which is slightly above the limit. The slightly high equivalent dose rate of OK is likely due to the presence of an abattoir (associated with animal bones and related waste, charcoal etc) and other market wastes which contain high amount of ^{40}K. These values of *in-situ* radioactivity measurements, absorbed dose rate and equivalent dose rate for the locations imply a reasonably low radiation burden on the environment. Comparison of the results with that obtained for Eliozu reclaimed dumpsite by [1] revealed the same low level activity in the dumpsite (as reported) which suggests that the immediate environment has been impacted with radionuclides from different wastes dumped on the site. The results obtained are comparable to works done on similar sites and also serve as baseline data for locations where similar work has not been done.

4. CONCLUSION AND RECOMMENDATION

Soil samples from ten dumpsites in Port Harcourt have been analysed using the Thalium Drifted Sodium Iodide Gamma Spectroscopy in addition to *in-situ* radioactivity measurements carried out. The activity concentrations of Th-232, U-238 and K-40 obtained were used to determine some radiometric parameters. The *in-situ* mean equivalent dose rates below permissible limits were observed for SL, OFR and OK dumpsites while the remaining locations have their values above the standard. On the other hand, the equivalent dose rate calculated using the gamma spectrometry results were all below the 1.0 mSv/yr threshold except for OK dumpsite which is very slightly above the limit. The results correlates with that obtained in previous works for Eliozu reclaimed dumpsite and Eneka dumpsite. Based on these findings, the potential risk posed by wastes in most of the studied dumpsites to the environment (human, plants and animals) is minimal except for few locations where the risk due to radiation is significant and may be increasing with time.

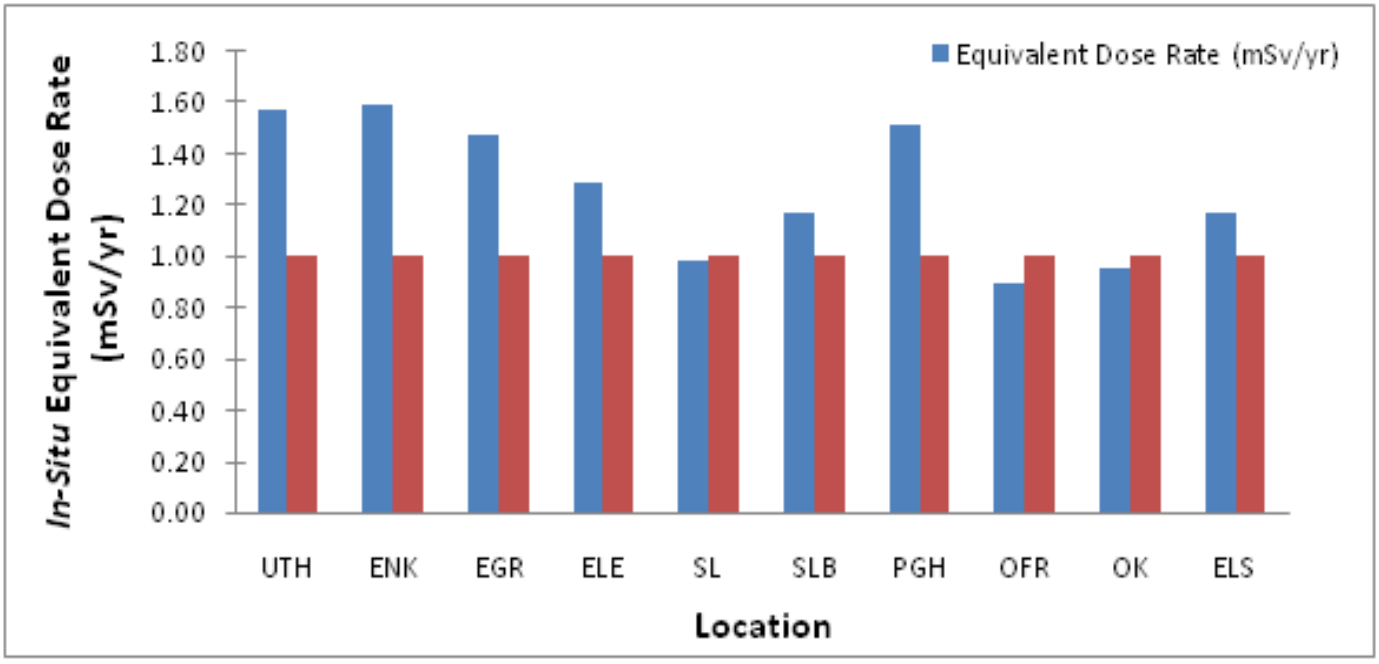

Fig. 1: In-Situ Average Equivalent Dose Rates Compared with the UNSCEAR (2000) Threshold for the Locations

Table 3: Specific Activities of the Soil Samples Obtained from Gamma Spectrometry Analysis

S/N	Sample Name	K-40 ($BqKg^{-1}$)	U-238 ($BqKg^{-1}$)	Th-232 ($BqKg^{-1}$)
1	UPTH 1	721.90± 5.63	61.76±4.84	66.09±16.08
2	UPTH 2	893.33± 6.41	60.59±15.47	33.02±3.14
3	ENK 1	169.86± 2.94	43.98±3.81	94.61±22.33
4	ENK 2	713.25± 5.45	37.00±3.35	79.89±19.36
5	EGR 1	645.61± 4.97	47.26±3.97	60.84±15.46
6	EGR 2	535.52± 4.79	51.55±4.09	139.35±30.53
7	ELE 1	547.32± 4.59	26.35±2.79	39.52±11.38
8	ELE 2	640.90± 5.21	31.97±3.13	24.89±8.53
9	SL 1	849.29±6.21	60.98±4.71	90.50±21.05
10	SL 2	245.35±3.33	33.12±3.08	8.79±5.33
11	SLB 1	165.14± 2.87	34.07±3.25	38.79±11.61
12	SLB 2	279.16±3.41	37.70±3.35	58.28±15.00
13	PGH 1	782.45±5.75	35.69±3.23	12.47±6.14
14	PGH 2	767.51±5.57	40.00±3.56	111.12±25.31
15	OFR 1	439.59±4.02	44.72±3.87	44.98±12.47
16	OFR 2	474.97±4.30	28.35±2.87	81.12±19.11
17	OK 1	1394.25±8.48	46.98±4.00	88.63±20.72
18	OK 2	939.72±6.48	36.79±3.25	79.89±19.27
19	ELS 1	666.85±5.27	47.16±3.91	77.78±18.78
20	ELS 2	990.05±6.74	33.13±3.08	21.51±7.87

Table 4: The Absorbed Dose and Equivalent Dose Rates Obtained from Average Specific Activity (Bq/Kg) of the Soil Samples

S/N	Sample	Specific Activity (Bq/Kg)				
		K-40	U-238	Th-232	D (nGy/hr)	E (mSv/yr)
1	UPTH	807.62 ± 4.27	61.18 ± 8.10	49.56± 8.19	93.17	0.82
2	ENK	441.56 ± 3.10	40.49 ± 2.54	87.25±14.78	94.02	0.82
3	EGR	590.57 ± 3.51	49.41 ± 2.85	100.10±17.11	112.67	0.99
4	ELE	594.11 ± 3.47	29.16 ± 2.10	32.21± 7.11	58.91	0.52
5	SL	547.32 ± 3.52	47.05 ± 2.81	49.65±10.86	76.24	0.67
6	SLB	222.15 ± 2.23	35.89 ± 2.33	48.54± 9.48	57.05	0.50
7	PGH	774.98 ± 4.00	37.85 ± 2.40	61.80±13.02	89.95	0.79
8	OFR	457.28 ± 2.94	36.54 ± 2.41	63.05±11.41	76.87	0.67
9	OK	1166.99 ± 5.34	41.89 ± 2.58	84.26±14.15	123.10	1.08
10	ELS	828.45 ± 4.28	40.15 ± 2.49	49.65±10.18	85.09	0.75

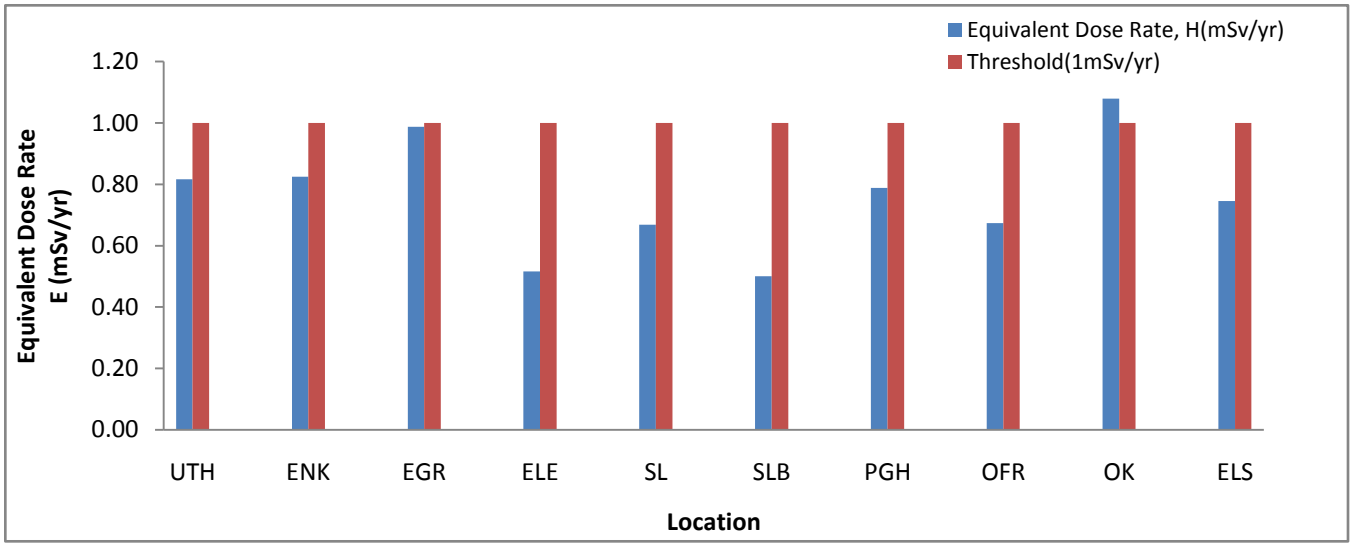

Fig. 2: Equivalent Dose Rates obtained from Average Specific Activity of Radionuclides in the Locations Compared with the UNSCEAR (2000) Threshold

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