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Assessment of Leachate Characteristics and Pollution Index of Ikhueniro Dumpsite in Benin City, Edo State, Nigeria

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Abstract: *This study characterizes the leachate quality and pollution index of Ikhueniro dumpsite in Benin City, Edo State. Leachate was collected from leachate wells at different parts of the dumpsites and thoroughly mixed to provide a homogenous representative sample for each sampling site. The sample was analysed for a number of standard physical and chemical properties using Standard Methods. The result of the analysis showed that the values of electrical conductivity, total dissolved solid, total suspended solid, sulphate, nitrate, chloride, turbidity, nickel, copper, chromium, zinc, iron, lead, cadmium and manganese were above FMENV limit; while dissolved oxygen was below detectable limit in Ikhueniro dumpsite leachate. The LPI values for the different sample locations L1 and L2 were computed to be 6.71 and 37.93 respectively with a mean value of 22.31. These LPI values were also compared with the LPI standard (7.38) for treated leachates. The comparison showed that Ikhueniro dumpsite in Benin City has high pollution potentials. The study recommends continuous monitoring of leachates and upgrade to an engineered landfill to forestall possible pollution problems of other components of the environment such as water bodies in future.*

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I. Introduction

In Nigeria, the propensity of residents to generate waste seems to have heightened in recent times. This is due largely to accelerated industrialization, urbanization, and population growth; which have elicited strong international and national concerns about the possible environmental, health and safety effects of living in the vicinity of these wastes (Ikem *et al*., 2002). Landfilling and or open dumping of wastes are very common methods of managing these wastes (Edger and Smith, 2006; Petruzzelli *et al*., 2007). This is because it is the cheapest and most convenient way of disposing municipal solid wastes. However, all efforts to get rid of waste also pollute the environment to some extent.

Landfill leachate produced as a result of organic dissolution from MSW landfill sites is generally heavily contaminated and consists of complex waste water that is very difficult to deal with (Longe and Enekwechi, 2007). Many factors influence the leachate composition including the types of wastes deposited in the landfill, composition of wastes, moisture content, the particle size, the degree of compaction, the hydrology of the site, the climate, age of the landfill and other site specific conditions such as landfill design and type of liner used if any (Ehrig, 1989; Eckenfelder, 2000; Speight, 1996; Longe and Balogun, 2010). Most waste landfills and dumpsites in Nigeria have not been designed to protect the environment from pollution. They are unlined and are located in public places surrounded by residential quarters and in wetlands or other areas with seasonally high-water tables. Classically unlined sanitary landfills and open dump are all known to release large amounts of hazardous and otherwise deleterious chemicals into nearby groundwater, surface water and soil as well to the air, via leachate and landfill gas (Allen, 2001).

The environment can be polluted by leachates from these dumpsites which occur at the end of the decay of solid waste, mixed with precipitates of surface water. As a result, surface water collection system (rivers, creeks, and lakes), subsurface collection system (groundwater reservoirs) and solid system (different soil layers) become vulnerable to pollution from the dumpsite. A number of incidences have been reported in the past where leachates have contaminated the surrounding soil and polluted the underlying groundwater aquifer or nearby surface water (Lee and Jones-Lee, 1994; Christensen *et al*., 2001; Ikem *et al*., 2002). It is therefore expedient that a comprehensive study be carried out on the assessment of pollution levels from Ikhueniro dumpsite, taking into account related parameters, which provide the overall perspectives of the pollution of the dumpsites. The LPI can be used to report pollution changes in specific landfill overtime. The trend analysis so developed for the landfill can be used to assess the post closure monitoring periods. The LPI can also be used to compare contamination potential of different landfills in a given geographical area or around the world. Other uses of LPI include ranking of landfill sites based on its contamination potential, resource allocation for landfill remediation, enforcement of standard, scientific research and public information (Kumar and Alappat, 2003a).This paper was aimed at determining the pollution potential of Ikhueniro dumpsite, with a view of advising relevant authorities on dumpsites that require immediate attention in terms of introducing remediation measures.

II. Material And Methods

Description of study Area

The dumpsite used for this study is operated by Edo State Waste Management Board (EDSMA) and referred to as Ikhueniro dumpsite. The landfill site is along the Benin – Lagos bypass road (Figure 1). It's geographically located on 6.32668^{o}N, 5.74605^{o}E and it is on about half an acre of land. The site receives waste from the entire Benin City and is accessible by tarred road. It is surrounded by residential, commercial and industrial set-ups and the dumpsite is made up of domestic, market, commercial, industrial and institutional origins. The wastes are of different types, ranging from organic to inorganic, hazardous and non-hazardous. Waste brought here by PSP (Private Sector Partnership) collection trucks from different parts of the city are dumped haphazardly without segregation. Sorting of metal and plastic containers waste is carried out by private individuals for recycling. The site is characterized by landfill fires mostly due to spontaneous combustion which are prevalent in the dry season.

Geologically, Edo State is characterized by the Niger Delta sedimentary rocks. Lithostratigraphically, these rocks are divided into the oldest Akata Formation (Paleocene), the Agbada Formation (Eocene) and the Youngest Benin Formation (Miocene to Recent). The formation of the so called proto-Niger Delta occurred during the second depositional cycle (Campanian-Maastrichtian) of the southern Nigerian basin. However, the modern Niger Delta was formed during the third and last depositional cycle of the southern Nigerian basin which started in the Paleocene. The geologic sequence of the Niger Delta consists of three main Tertiary subsurface lithostratigraphic units, which are overlain by various types of Quaternary deposits.

The climate of the study area is that of tropical rainforest with distinct wet and dry seasons. The wet season is characterized by a period a prolonged period of rainfall which extends from April to October, while the dry season is characterized by a period of dry hot weather. This season extends from November to March including the harmathan period. The mean annual rainfall ranges from 2000mm (inland) to over 4000mm at the coast (Akpokodje, 1987). Hazel (1988) estimated the average precipitation in the area to be about 3114 x 10^{12} litres, based on an average rainfall of 240cm per annum. The vegetation comprises predominantly of red mangrove, *(Rhizophora racemosa*), plantain trees (*Musa* sp.), Oil palm trees (*Elaeis guinensis*) and Nipa palm (*Nypa fruticans*).

Collection and laboratory analysis of dumpsite leachate

Raw leachate was collected from different leachate wells at different parts of the dumpsites and thoroughly mixed to provide a homogenous representative sample for each sampling site. This was transferred to the laboratory in pre-cleaned 4 litre plastic containers and stored at 4^{o}C until use. The sample was analysed for a number of standard physical and chemical properties according to procedures outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998; USEPA, 1996).

Parameters such as pH, Temperature, electrical conductivity, total dissolved solid (TDS) total suspended solids (TSS) and DO, were determined at the time of sampling in the field with a digital CS-C933T Multimeter (TOPAC INSTRUMENTS INC). Chemical oxygen demand (COD) was determined by the titrimetric method and biological oxygen demand (BOD_5) was determined using the incubation method at 20ºC for five days (APHA, 1998). Phosphate was determined colorimetrically by the ascorbic acid-molybdenum blue method (Eaton and Franson, 2005). Chloride (Cl^-) was analysed by titrating a known volume of water sample with standardized 0.014N mercuric (II) nitrate solution. Nitrate was determined by the phenol disulphunic acid method (Marczenko, 1986). Sulphate was determined gravimetrically.

Leachate for heavy metal analysis was filtered and digested with 10ml of concentrated analytical grade nitric acid to 250ml of water sample. The solutions were evaporated in a crucible to approximately 5ml, then filtered into 20ml standard flask and made up to the mark with distilled water (Ademoroti, 1996). The leachate extract was analysed for metals (nickel, chromium, copper, zinc, iron, lead, cadmium, manganese, arsenic and vanadium) was carried out with a Varian 220 (Spectra AA) Atomic Absorption Spectrometry (AAS); while the leachate pollution index was determined as described by Bhalla *et al*. (2014).

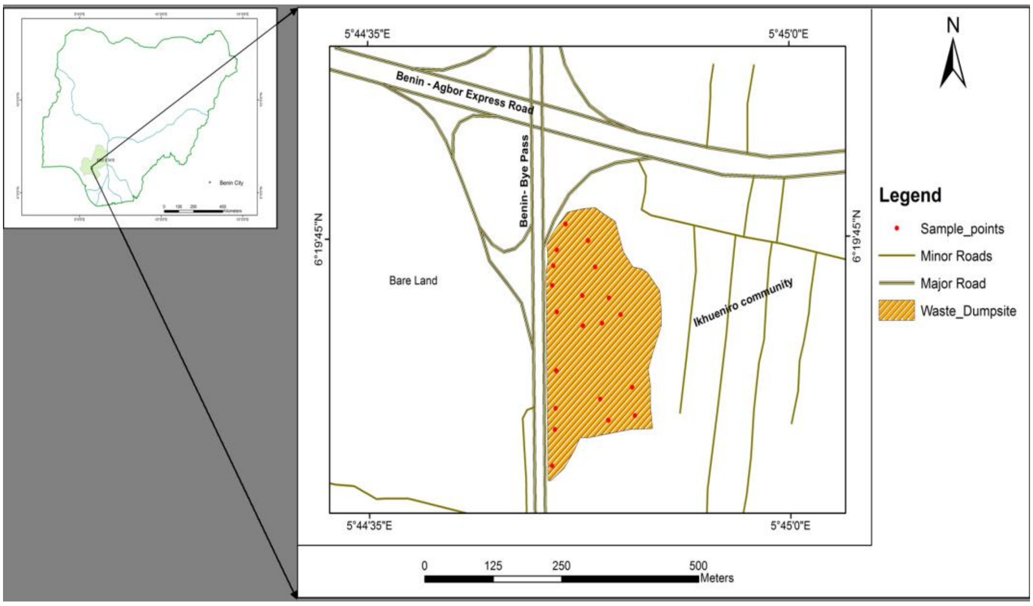

Fig 1: Map of Benin City showing Ikhueniro waste dumpsite (Insert: Map of southern Nigeria showing Edo state).

Statistical Analysis

All statistical analyses were conducted with Statistical Package for Social Scientists (SPSS) and Microsoft Excel computer software. Data are presented as mean ± SE (n=5/sex). One-way ANOVA was used to determine the differences among various groups. When the corresponding F test for differences among the treated group means was significant pair wise, comparisons between treated groups and corresponding negative control were determined using multiple comparison procedure of the Dunnett post-hoc test and differences were considered significant at $p<0.05$, $p<0.01$ and $p<0.001$ levels of significance. Two-way ANOVA was used to determine the significance of the independent effect of leachate and sex and their interactions on toxicity.

Calculation of Leachate Pollution Index (LPI):

The data from the analysis of samples were used. The 'P' values or sub-index values for all the parameters analyzed were computed from the sub-index curves based on the concentration of the leachate pollutions obtained during the analysis. The 'P' values were obtained by locating the concentration of the leachate pollutant on the horizontal axis of the sub index value where it intersected the curve was noted.

The 'P' values obtained for the parameters analyzed were multiplied with the respective weights assigned to each parameter. The LPI for each of the dumpsite leachate was calculated using the equation of Kumar *et al* ….14 shown in equations below.

$$LPI = \sum_{i=1}^{n} w_i p_i \qquad (1)$$

Where,
LPI = the weighted additive leachate pollution index, *wi*= the weight for the *Ith*pollutant variable, *pi* = the sub index value of the *I* th leachate pollutant variable, $n = 18$ *and* $\Sigma wi = 1$.
However, when the data for all the pollutant variables included in *LPI* is not available, the *LPI* can be calculated using data set of the available pollutants by the equation
Where

$$LPI = \frac{\sum_{i=1}^{m} w_i p_i}{\sum w_i} \qquad (2)$$

Where pollutant parameter for which data is available in this study as, m < 18 (16) and Σ wi<1

III. Result

The results obtained from the physico-chemical analyses of leachate of the Ikhueniro dumpsite are presented in Table 4.1, while LPI derived from Kumar and Alappat computation is presented in Table 4.2.

Again, results obtained during this study ranging from behavioural, haematological, and biochemical changes in the Wister rats are also presented below.

Characterization of Ikhueniro dumpsite leachate

In Table 4.1, the physico-chemical properties of Ikhueniro dumpsite leachate samples were as follows: pH ranges from 7.73 - 8.13, Total dissolved solid (TDS) ranges from 416 - 4840mg/l, electrical conductivity ranges from 586-6840µS/cm, Phosphate ranges from 2.98 - 15.97mg/l, while Sulphates ranges from 10.81 - 37.47mg/l. Others are Chlorides which ranges from 50.16 - 415.18mg/l, Biological Oxygen Demand (BOD) ranges from 8.11 - 51.92mg/l, Chemical Oxygen Demand (COD) ranges from 20.28 - 128.80mg/l, Lead ranges from 0.019 - 0.291mg/l and Zinc ranges from 0.043 - 1.393mg/l. The rest are Iron which ranges from 3.871 - 11.376mg/l, Manganese ranges from 0.965 - 1.835mg/l, Chromium ranges from 0.041 - 1.273mg/l and Copper (mg/l) ranges from 0.011 - 0.079mg/l. Comparing the physical and chemical composition of the leachate to federal ministry of environment (FMENV) water limit pH, temperature, arsenic and vanadium in the leachate were within FMENV limit. On the other hand, the values of electrical conductivity, total dissolved solid, total suspended solid, sulphate, nitrate, chloride, turbidity, nickel, copper, chromium, zinc, iron, lead, cadmium and manganese were above FMENV limit; while dissolved oxygen was completely absent in Ikhueniro dumpsite leachate.

Leachate pollution Index of Ikhueniro dumpsite

Leachate contamination potential of Ikhueniro waste dumpsite as determined by leachate pollution index was presented in table 4.2. Comparing the physical and chemical characteristics of the dumpsite leachate with the leachate disposal standards; it was observed that total dissolved solids, chloride, biochemical oxygen demand, lead, zinc and chromium were high; as against chemical oxygen demand and copper which were lower than the standard. However, based on the evaluation of leachate pollution index, the LPI for L1 and L2 were found to be 6.71 and 37.93 respectively with a mean value of 22.31 when the mean value was compared to the compared to the treated leachate standard of 7.38, it showed that the dumpsite has high pollution potentials.

Table 1: Physical and chemical characteristic of Ikhueniro dumpsite leachate

	Parameters	Dumpsite leachate	Min	Max	FMEnv
1.	pH	8.01 ± 0.35	7.66	8.35	6.5-8.5
2.	Temperature (°C)	30.55 ± 0.85	29.70	31.40	35
3.	Electric conductivity (µs/cm)	16810.00 ± 10490.00	3400.00	13100.00	-
4.	Total dissolved solid (mg/l)	8250.00 ± 4850.00	3400.00	13100.00	500
5.	Total suspended solid (mg/l)	175.00 ± 25.00	150.00	200.00	<10
6.	Dissolved oxygen (mg/l)	0.00 ± 0.00	0.00	0.00	7.5
7.	Biochemical oxygen demand (mg/l)	74.90 ± 10.47	64.43	85.37	-
8.	Chemical oxygen demand (mg/l)	182.26 ± 31.18	151.08	213.43	-
9.	Phosphate (mg/l)	67.61 ± 11.65	55.96	79.26	<5
10.	Sulphate (mg/l)	125.56 ± 22.05	103.52	147.61	500
11.	Nitrate (mg/l)	55.82 ± 12.31	43.51	68.12	10
12.	Chloride (mg/l)	5213.00 ± 3425.57	1787.43	8638.57	200
13.	Turbidity (mg/l)	169.52 ± 27.42	142.10	196.93	5.0
14.	Nickel (mg/l)	0.18 ± 0.09	0.09	0.28	0.05
15.	Chromium (mg/l)	3.59 ± 1.78	1.81	5.36	0.05
16.	Copper (mg/l)	0.93 ± 0.40	0.53	1.34	0.1
17.	Zinc (mg/l)	10.03 ± 5.69	4.34	15.72	1.0
18.	Iron (mg/l)	9.50 ± 2.09	7.42	11.59	1.0
19.	Lead (mg/l)	0.59 ± 0.35	0.24	0.94	0.05
20.	Cadmium (mg/l)	0.39 ± 0.22	0.17	0.62	0.01
21.	Manganese (mg/l)	0.11 ± 0.05	0.06	0.15	0.05
22.	Arsenic (mg/l)	0.03 ± 0.02	0.01	0.05	0.2
23.	Vanadium (mg/l)	BDL	0.00	0.00	-

All values are expressed as Mean ± S. E., BDL**:** Below detectable limit

Table 4.2: LPI of Leachates from Ikhueniro dumpsite

	Leachate Pollutant Parameters	Samples Results			Variable Weight (W_i)	Pollutant Sub Index Value (P_i)			Overall Pollutant Rating wi.pi			Leachate Disposal Standards
		L1	L2	LM		L1	L2	LM	L1	L2	LM	
1.	pH	7.66	8.35	8.01	0.055	5	5	5	0.275	0.275	0.275	NS
2.	Total Dissolved Solid (mg/l)	3400	13100	8250	0.050	8	31	16	0.400	15.500	8.000	2100
3.	Total Suspended Solid (mg/l)	150	200	175	-	NA	NA	NA	NA	NA	NA	NS
4.	Electrical Conductivity (µS/cm)	6320	27300	16810	-	NA	NA	NA	NA	NA	NA	NS
5.	Phosphate (mg/l)	55.96	79.26	67.61	-	NA	NA	NA	NA	NA	NA	NS
6.	Sulphate (mg/l)	103.52	147.61	125.56	-	NA	NA	NA	NA	NA	NA	NS
7.	Chloride (mg/l)	1787.43	8638.57	5213.00	0.049	10	75	46	0.490	3.675	2.254	1000
8.	Biological Oxygen Demand (mg/l)	64.43	85.37	74.90	0.061	7	9	8	0.427	0.549	0.488	30
8.	Chemical Oxygen Demand (mg/l)	151.08	213.43	182.26	0.062	9	9	9	0.558	0.558	0.558	250
10.	Nickel (mg/l)	0.09	0.28	0.18	0.052	5	5	5	0.260	0.260	0.260	NS
11.	Lead (mg/l)	0.24	0.94	0.59	0.063	5	9	7	0.315	0.567	0.441	0.1
12.	Zinc (mg/l)	4.34	15.72	10.03	0.056	5	10	8	0.280	0.560	0.448	5.0
13.	Iron (mg/l)	7.42	11.59	9.50	0.045	5	5	5	0.225	0.225	0.225	NS
14.	Manganese (mg/l)	0.06	0.15	0.11	-	NA	NA	NA	NA	NA	NA	NS
15.	Chromium (mg/l)	1.81	5.36	3.59	0.064	10	35	20	0.640	2.240	1.280	2.0
16.	Copper (mg/l)	0.53	1.34	0.93	0.050	6	8	7	0.300	0.400	0.350	3.0
17.	Arsenic (mg/l)	0.01	0.05	0.03	0.061	5	8	5	0.305	0.488	0.305	NS
	TOTAL				**0.667**				**4.475**	**25.297**	**14.884**	
	***LPI* Value using Equation 2**								**6.71**	**37.93**	**22.31**	

Where; L1=Location 1, L2=Location 2, LM=Location Mean, NA = Not Available, NS = No Standard

IV. Discussion

Conductivity of water is a numerical expression of the ability of an aqueous solution to carry electric current. This ability is a function of the presence of ions` (cations and anions), their total concentration, mobility, valency and the temperature of measurement. In this study, high values of conductivity were recorded in the leachates, which may be attributed to high concentrations of cations and anions such as sulphate, nitrate and chloride present in the leachate. Higher values of electrical conductivity has been be reported by Aiyesanmi and Imoisi (2011) when they studied leaching behavior in three dumpsites in Benin City. According to the authors, the high electrical conductivity may be associated with high dissolved salts and metals in the leachate.

Total solids are a measure of all the suspended, colloidal, and dissolved solids in a sample of water. This includes dissolved salts such as sodium chloride (NaCl) and solid particles such as silt and plankton. High concentrations of total dissolved solids in the leachate may be associated with the presence of large amount of anions and cations indicating presence of inorganic materials (Munir *et al*., 2014). A similar finding has been reported by Kundiri *et al*. (2017) when they characterized leachate from dumpsites in Maiduguri, Borno State. Leachate with high dissolved and suspended solids, when released into the aquatic environment may be harmful to aquatic life. This is because they decrease water quality, inhibit photosynthetic processes and eventually lead to increase of bottom sediments and decrease of water depth (Ogbeibu and Anagboso, 2004).

Dissolved oxygen was below detectable limit in Ikhueniro dumpsite leachate. The very low level of DO may be attributed to the high levels of microbial activities. This was as a result of increased degradation of organic matter which increased the consumption of oxygen (Piyush *et al.*, 2012). Similar very low Concentration of DO has been reported by Hossain *et al*. (2014) and DCC and JICA, (2004); in the leachate sample collected from Rowfabad landfill at Chittagong, Bangladesh and Matuail Landfill site, Dhaka.

BOD and COD represent the amount of oxygen required for the biological and chemical decomposition of either organic or inorganic matter respectively under aerobic conditions at a standardized temperature in surface water (e.g. lakes and rivers) or leachate (WHO, 2011). High BOD and COD values recorded in the leachate were indications of a high level of pollution, which could result in high biodegradation activity by microbes. The findings is consistent with the report of Hossain *et al*. (2014) and DCC and JICA, (2004); in the leachate sample collected from Rowfabad landfill at Chittagong, Bangladesh and Matuail Landfill site, Dhaka. BOD and COD vary inversely with dissolved oxygen and high values of both are detrimental to aquatic life (Jha *et al.*, 2008).

Nitrates and phosphates have often been cited as limiting nutrients in aquatic systems and as indices of eutrophication in lakes, rivers and reservoirs (Chukwu *et al*., 2008). In this study nitrate and phosphate were higher than FMENV limit. Similarly, Raghab *et al*. (2013) reported an increased value of nitrate and phosphate in Borg El Arab landfill in Alexandria, Egypt. Nitrate and phosphate plays a vital role in the biological metabolism of aquatic organisms (notably phytoplankton and macrophytes). Increased Nitrate and phosphate in it will impact negative environmental effects such as hypoxia, oxygen depletion among others, to the water. This induces reductions in specific fish and other animal populations.

The higher concentration of heavy metals in Ikhueniro dumpsite leachate when compared to federal ministry of environment (FMENV) water limit may be associated with the type of waste deposited at the dumpsite. Similar findings have been reported by Sani *et al*. (2013) when they studied heavy metal bioavailability in the leachate from dumpsites in Zaria Metropolis, Nigeria; stating that the ground water within vicinity of the dumpsites were greatly at the risk of being polluted by these toxic heavy metals. Heavy metals have been known to bind with important enzymes and inactivate them. They can also displace biologically important metals, such as Calcium, Zinc and Magnesium, interfering with a variety of the body's chemical reactions (Ahameda and Siddiqui, 2007). However, exposure of heavy metals may cause blood and bone disorders, kidney damage, decreased mental capacity and neurological damage (NIEHS, 2002).

The Leachate Pollution Index is a tool used for assessment of dumpsite leachate quality; and was formulated using Rand Corporation Delphi Technique (Kumar and Alappat, 2003a). The LPI represents the level of contamination potential of a given landfill. It is a single number ranging from 5 to 100, which expresses the overall contamination potential of a landfill based on severe pollution parameters at a given time. It is an increasing scale index, where a higher value indicates a poor environmental condition (Kumar and Alappat, 2003b). The higher mean leachate contamination potential of Ikhueniro waste dumpsite may be as a result of type of waste that is received by the dumpsite coupled with the prolonged use of the dumpsite which may have led to the saturation of the topsoil leading to the retaining of the most contaminants on the leachate produced from the waste. Lower leachate pollution index values have been reported by Agbozu *et al*. (2015) and Asibor and Edjere (2016) from dumpsites in warri, Delta. Although they emphasized the need for continuous monitoring of leachates and upgrade to an engineered landfill to forestall possible pollution problems in future. Kumar *et al*. (2005) has also mentioned that an LPI value greater than 7 (LPI >7), indicates that the leachate is a polluting one and it is also currently operational and is receiving domestic and industrial wastes.

V. Conclusion

Leachate is one of the important problems associated with landfill. This is because it could migrate to contaminate ground and surface water. The result of this study showed that Ikhueniro dumpsite in Benin City has high pollution potentials. The study recommends continuous monitoring of leachates and upgrade to an engineered landfill to forestall possible pollution problems of other components of the environment in future.

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