RESEARCH PAPER

POLLUTION IMPACT OF CEMENT PRODUCTION ON AIR, SOIL AND WATER IN A PRODUCTION LOCATION IN NIGERIA

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ABSTRACT
Environmental pollution caused by the activities of Ewekoro Cement production facility of the West African Portland Cement (WAPC, Plc), Ogun State, Nigeria was studied at some terrestrial and aquatic receptor locations within the catchments area of the production plant which has been in operation for over 40years. Air, water and soil samples of the adjoining villages (Ajobiewe, Olapeleke, Alaguntan and Wasinmi) were analyzed. High particulate matter depositions were recorded for all the sampling locations. Dusts emitted from the cement factory were rich in heavy metals. Heavy metals concentration at Ajobiewe, Olapeleke and Alaguntan were significantly ($p<0.05$) higher compared with those obtained at Wasimi – the farthest location from the pollution source, which served as control for particulate and soil sampling. The distribution of heavy metals in the soil sampled followed in decreasing order of Mn>Ni>Fe>Cr>Zn>Cu>Co>Pb>Cd. Heavy metals concentrations were significantly different ($p<0.05$) at the closest locations around the plant compared to Wasinmi (the control). Basic cations and anions in the water samples from the 3 rivers draining the area were within internationally recommended values for irrigation except the electrical conductivity (EC) and nitrate (NO_3^-) in Alaguntan River which were found to be above the maximum permissible limits by 5.41% and 64.30% respectively. Comparatively, heavy metals concentration were significantly higher ($p<0.05$) in samples from Alaguntan River than in corresponding sample from Elebute and Itori Rivers. Heavy metals concentration in these rivers were high compared to similar rivers at other places with no cement production. These elevated heavy metal levels may be a limitation to using the rivers for irrigation.

Keywords: *Cement production, Pollution, Heavy metals, Particulate deposition, irrigation.*

INTRODUCTION

Environmental pollution is a direct result of human, social and industrial activities which often initiates undesirable changes in the ecosystem, creating some imbalances in physical, chemical and biological dynamics of the environment. Generally, industrial activities rank higher among contributors to environmental degradation. Metal mining, smelting and meat processing, oil and gas exploration, petrochemical manufacturing and such other industrial activities have severe impact on the fragile ecosystem. These negative impacts on the environment are from direct results of production activities or by the release of waste and by products which often are toxic in their untreated states.

Cement manufacturing is known to emit about 500 – 1700kg of particulate matter daily (ETPI, 1991). A study in the United States of America reported a dirt level ranging from 26-114mg/ m^3. (U.S. Census Bureau, 2000). Studies have shown that soil, ambient air and surface water within the vicinity of a cement factory are seriously degraded (Farmer, 1993). Andrey (1987) reported an incidence of elevated concentration of Fe, Mg, Pb, Zn, Cu, Be, Tetraoxosulphate VI and HCl among cement plant wastes. Similarly, Sivakumar and Britto, (1995) and Jalken *et al.* (2000) reported an elevated deposit of alkali earth metal and heavy metals such as As, Pb, Ni, Co, Zn, Cu and Phosphorous from cement dust and other particles with attendant environmental risks.

There is a statistical significant relationships between symptoms of respiratory effects in humans to their proximity to cement kilns with CO_2, Cl, F, SO_2 and other sulphur oxides sources. (Legator *et al.* 1998). Volatile organic compounds and micro pollutants are usually released from cement factories (Vans Oss and Padovani, 2003). Ponsby *et al*. (2000), W.H.O (1999) and Wang *et al. (*1997) have all shown the negative impact of cement manufacturing activities on humans and the environment. Similarly, studies on the effect of cement dust on biosynthetic processes in plant also revealed reduction in chlorophyll and carotenoid content, impairing carbon IV oxide exchange and plant photosynthesis rate. (Lepedus *et al*., 2003; Cesar and Lepedus, 2001).

Also, cement production have been known to contribute to pollution of streams and rivers from the degraded runoff discharges from atmospheric deposition of contaminated particulate matter, cooling water, leachates from stock piles raw material and effluents from quality control laboratories. These sources are among those identified by El Fadel *et al*. (2005); World Bank (1998) and Perfitini *et al*. (1989). Pollutants in water can remain in solution or deposited to form part of drainage sediments. Water quality is dependent on the total dissolved substances and these substances when dissolved in water react to change its chemical composition. Gaiero *et al.* (1997) stressed that heavy metals in river sediments are considered more sensitive than dissolved contamination as an indication of pollution.

This study evaluates the impact of cement production in a local community of Ewekoro, Ogun State in South western Nigeria with a view to quantify the status of air, soil and water within the neighborhood.

MATERIALS AND METHODS

The Ewekoro Cement plant, one of the leading cement manufacturing factories in Nigeria was chosen for this study. Cement production activities have been on for over four decades in this location. The factory utilizes wet and semi -wet production technology with the annual cement production varying between 254,000 and 479,000 metric tons (WAPC,2000). It is located 5km from Ewekoro town ($6^0$55'N, $3^0$12'E) in the Ogun State of South western Nigeria. A number of farm settlements preexisted the company and the cement production factory. These include Wasinmi and Itori to the north, Elebute and Alaguntan to the east and Olapeleke to the west of the factory within 10km radius. (Figure 1). The catchment of the cement factory is drained perennially by Alaguntan, Elebute and Itori rivers. The farm settlements were named after these rivers because of their importance to agricultural activities in the area. Although, the rivers are ungauged and the capacity undetermined, local farmers have relied on the discharges of these rivers to support their irrigation farming activities during the dry season. They are major tributaries to

Ewekoro river which drains into the Ogun River, the major river of the Ogun-Osun River Basin.

Ewekoro town is located within the tropical rainforest vegetation belt of Nigeria with annual mean temperature of $30^0C\pm10^0C$, relative humidity 65±10% and average rainfall of 1500mm±120mm (Oguntoyinbo *et al*., 1983). The average wind speed at a height of 10m above ground level was 1.0m/s between January - March and 0.72m/s between May-November (IITA, 2000). The deposition of cement dust and other particulate matter over the catchment was therefore very noticeable and of serious concern to the local community.

Sampling Sites

Various sites were considered suitable for sample collections based on their location upstream and downstream of the cement factory. The Alaguntan, Elebute and Itori Streams (Fig.1) were selected for surface water pollution studies. For the soils and air pollution, Ajobiewe village (0.1km South), Olapeleke (1.0km West), Alaguntan (1.5km East) and Wasinmi (9.5km North, and the farthest from the factory) were selected as sampling sites.

Soil Sampling

Soil samples from four farming villages (Ajobiewe, Olapeleke, Alaguntan and Wasinmi) were collected. Twenty random samples taken at a depth of 0-20cm from different location were taken bulked together and thoroughly mixed in a composite for each of the location. The composite samples were put in clean airtight plastic container for laboratory analysis.

Water Sampling

The Alaguntan, Elebute and Itori Streams were sampled weekly for 3 weeks during the usual period of high irrigation activities. Ten (10) 1 litre samples of water were taken using clean dry 1-litre wide mouthed transparent glass bottle at interval of 20m apart along each of the river courses at a depth of 15cm from the surface. The collected samples were mixed into a composite for each stream and appropriately labeled for laboratory analysis within the 72hours of sampling. The sample bottles were previously soaked in soap solution treated with 5% HNO_3 for 24Hours and rinsed severally with distilled water prior to use (DWAF, 1992; DWAF, 1999).

Air Sampling

Samples of air in Ajobiewe, Olapeleke, Alaguntan and Wasinmi villages were sampled for particulate matter deposition. Ten clean Petri dishes, 12-20cm diameter previously weighed and labeled were carefully placed on rooftop of residential buildings for three weeks at each of the sampling locations. The Petri dishes were previously soaked in soap solutions treated with 5%HNO_3 for 24hours rinsed severally with distilled water and dried in oven prior to use. Similarly, treated clean brush and scoop were used to remove the deposited dust from the Petri dishes into a clean air tight plastic container for each of the locations and were appropriately labeled for analysis. The Wasinmi village is the farthest from the factory location and therefore considered as the control in this study.

The samples were subjected to Flame Photometry and Atomic Absorption Spectophotometry (AAS) analysis (APHA, 1992). The analysis were done within 72hours after sample collection, thus there was no special need for pretreatment for storage (Chapman and Kimstach, 1996). All the analyses were done at the Analytical Laboratory of the International Institute of Tropical Agriculture (IITA) Ibadan.

RESULTS AND DISCUSSION

Particulate Matter Deposition

Particulate matter deposition constituted major atmospheric pollution issue in the cement plant and the auxiliary environment. This can be attributed to dust released during quarry activities, dust re-mobilization from vehicular traffic

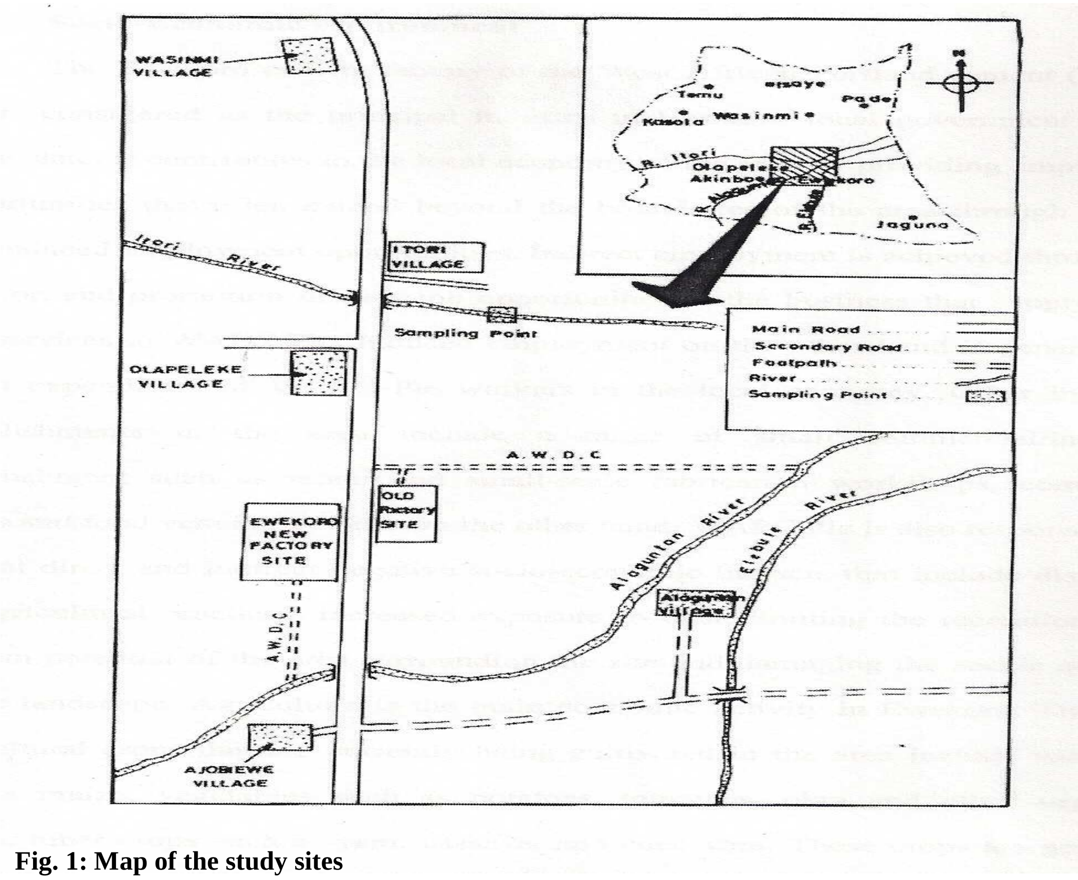

Fig. 1: Map of the study sites

Table 1: Particulate Matter Deposition Rate

Location	Rate of Deposition ($\mu g/cm^2.day$)
Ajobiewe	699
Olapeleke	134
Alaguntan	96
Wasinmi	58

on paved and un-swept paved road, wind action on open piles of clinker and kiln stack losses. High values of particulate matter deposition were recorded with the highest being 699 µg/ cm^2day at Ajobiewe and the least being 58µg/ cm^2day at Wasinmi (Table 1). These values indicate a differential deposition rate which may be due to location and distance from the cement factory, wind action, and gravity. The distances to the pollution source in order of closeness were Ajobiewe, Olapeleke, Alaguntan and Wasinmi. It was discovered that the concentration of the investigated heavy metals in the particulate deposits decreased with increasing distance from the pollution source (Table 2). In all the cases (Mn, Fe, Zn, Cu, Pb, Ni, Cr, Co ,Cd), the impact of the produced dust on the environment decreased with increased distance from the pollution source. Wasinmi which was the control recorded the lowest concentration of heavy metals in particulate deposit while Ajobiewe the closest recorded the highest in all cases. Generally, concentration of heavy metals at Ajobiewe (the closest location to the pollution source was Fe>Zn>Mn>Cr>Co>Cu>Pb>Ni>Cd while at Wasinmi (the farthest-control),

Table 2: Concentration of heavy metals in the sampled particulate deposited

Elements (μg/g)	Locations			
	Ajobiewe	**Olapeleke**	**Alaguntan**	**Wasinmi**
Mn	70.2	53.11	45.92	15.91
Fe	1147.19	756.89	726.31	715.5
Zn	345.08	297.64	270.9	198.01
Cu	38.17	29.66	21.58	12.55
Pb	36.9	18.91	10.82	9.15
Ni	33.05	25.1	18.22	15.75
Cr	55.12	26.04	17.54	11.11
Co	38.5	29.12	14.05	7.13
Cd	28.45	21.75	11.07	2.08

Fe>Zn>Mn>Ni>Cu>Cr>Pb>Co>Cd. At all the locations Cd concentration was the least while Fe was the highest recorded concentration. By simple proportion from (Tables 1 and 2), the rate of deposition of Pb was 0.0058mg/m^2 at Ajobiewe while at Wasinmi it was 0.0530 μg/m^2 or 0.000053μg/m^2. This is equivalent to deposition of 0.0530g of Pb in every square kilometer per day. Pb and Cd have been found to be carcinogenic.

Similar trends have been reported in particulate matter deposited in areas surrounding the Jordan cement factory in the city of Fuhais, Jordan (Ziadat *et al*. 2006). In addition to the contribution from raw materials, the elevated concentration of Fe and Mn in the particulate deposited may be attributed to metal from wear machine parts. Zn elevated concentration may be linked with remobilization of dust by wind from disintegrated galvanized rooftops in the area while the exhaust emission from traffic and power generation from fossil fuel may have influenced the concentration of Pb as can be seen in Ajobiewe and Wasinmi which were very close to the major Lagos-Sango-Abeokuta road. The Duncan Multiple Range Test (DMRT) showed that the obtained concentration of heavy metals in Ajobiewe, Olapeleke and Alaguntan were significantly ($p < 0.05$) higher when compared with the values obtained at Wasinmi (the control) location. The value of Fe at Alaguntan was not significantly different ($p < 0.05$).

However, the heavy metals concentration in soil studied are of the order of μg/g. The reason for this is because the particulate deposition is heavily laden with polluted metals which are easily and quickly moved by runoff into the receiving rivers from the soil surface. Nevertheless, it is clear from this study that the closer to the pollution source the greater the risk of elevated concentration of pollution (Gilbert, 2006; Meybeck *et al*. 1996), thus the less environmentally fit such location may be especially for agricultural purposes.

Soil Quality Parameters

The particle size distribution of the soil sample collected from the study area is shown in Table 3. The soil quality parameters are reported in Table 4. The soil pH values were found to be between 10.96 at Ajobiewe and 7.39 at Wasinmi. This is indicative of alkaline soil. The other two locations have 8.03 and 7.46 in the order of their closeness to the pollution source. The general observation is that the pH of the study locations is Alkaline. The levels of Nitrogen (N) and Organic Matter (OM) in the soil show same trends. Ajobiewe soil has the highest concentration of N (0.87g/kg) while Wasinmi soil recorded the least concentration (0.21g/kg). This may be because of intense farming activities in Wasinmi and Olapeleke villages. Percentage OM was also highest in Ajobiewe samples and least in Wasinmi because of limited agricultural activities in the former as compared with the latter.

The concentrations of Phosphorous (P) in the soils were generally high. The degree of variation of the P concentration at different locations is shown in fig. 3. The high values of P concentration in all the soil may be due to phosphorous accumulation in the soil over a period of time. The soil pH (alkaline) causes phosphorous compound to have a form that the plant is unable to absorb (Ocak *et al*., 2004). Although P was about 200 times the concentration of Ca in all the locations, the predominance of lime in the area as raw material may have accounted for the high differences in Ca observed in all the locations. This may be a reflection of abundance of lime as raw material for cement production in the area. Increase in the amount of lime is related to the increase in pH of the polluted soil (Fabbri *et al*., 2004; Bayham *et al.*, 2002). However, the electrical (EC) and Sodium Adsorption Ratio (SAR) of the soil solution do not differ in trend and are indicative of a fertile soil.

An inverse relationship was observed between the concentration of heavy metals and the distance of the sampling locations from the polluted source. Similar to what obtained in the particulate deposition, Ajobiewe which is the closest recorded the highest concentration for all the heavy metals while Wasinmi which was the farthest had the least recorded concentration. The observed heavy metals concentration followed the same pattern Mn>Ni>Fe>Cr>Zn>Cu>Co>Pb>Cd. The concentration of heavy metals in soil samples from Ajobiewe, Olapeleke and Algauntan show significant difference when compared with the heavy metals concentration from Wasinmi at $p<0.05$ using the Duncan Multiple Range Test. Generally, the level of organic matter (OM)

Table 3: Particle size distribution of soil samples from studied locations

Sample Location	Sand %	Silt %	Clay %	Textural Class
Ajobiewe	92.6	5.4	2	Sand
Olapeleke	82.6	9.4	8	Loamy Sand
Alaguntan	70.6	15.4	14	Sandy Loam
Wasinmi	93.6	4.4	2	Sand

Table 4: Soil Quality Parameters of the Soil Samples

Parameter	Unit	Ajobiewe	Olapeleke	Alaguntan	Wasinmi
pH		10.96	8.03	7.46	7.39
N	g/kg	0.87	0.25	0.56	0.21
OM	%	8.42	2.45	5.41	2.28
P	g/kg	201.96	228.02	66.56	111.08
Ca	g/kg	1.97	1.92	1.77	1.09
Mg	g/kg	0.93	0.91	1.05	0.51
K	g/kg	0.4	0.38	0.37	0.22
Na	g/kg	0.21	0.2	0.19	0.12
EC	g/kg	0.57	0.41	0.32	0.12
SAR	g/kg	0.18	0.17	0.16	0.13

content for an agricultural land is classified as low (<1.5%) medium (1.5% – 2.5%) and high (>2.5%). Therefore, Table 4 shows that all the soils were adequate in terms of fertility status. Also, the heavy metals in the soils were however found to be very high. High accumulation of heavy metals in the soil can cause undesirable accumulation in the plant tissues and this may be harmful to the plants and the consumer.

Table 5: Heavy metals in the soil of the study locations

Element (mg/l)	Ajobiewe	Olapeleke	Alaguntan	Wasinm
Mn	501.53	490.52	446.51	294.31
Fe	35.53	33.54	32.56	20.13
Zn	26.52	24.56	22.01	14.74
Cu	11.04	9.5	8.53	5.7
Pb	3.71	3.35	3.05	2.01
Ni	43.56	41.52	37.54	24.91
Cr	34.58	32.5	29.01	19.5
Co	6.55	6.52	5.54	3.92
Cd	2.01	1.57	1.03	0.94

Water Quality Parameters

Table 6 shows the Physico-chemical water parameters from the three rivers within the catchment area. The pH of the river water sampled range between 6.68 – 7.79. This agrees with the findings of Kalff and Knoechel (1998), which reported that water from the limestone belt are perpetually rich in Ca, carbonate and bicarbonate ion and have pH range from 6.8 - 9.6. The concentration of Ca and Mg are directly related to the geological formation of the area which is in the Basement Complex.

The TSS comprises inorganic salts (primarily Ca, Mg, K, Na, Bicarbonate, Chlorides and Sulphates) and some amount of organic matter that are dissolved in water. TSS and EC are indicators that give the amount and conducting potential of the ionic species in the water sample. These two parameters were generally low and normal for freshwater stream flowing through terrains with no recorded history of severe pollution. TDS values in Alaguntan, Elebute and Itori rivers are 473.60mg/1, 268mg /l and 339.20mg/l respectively.

Nitrate (NO_3^-N) and phosphate (PO_4^-P) levels obtained in Alaguntan River were 83.93mg/l and 190.80mg/l respectively. In Elebute River, nitrate and phosphate levels were 7.05mg/l and 14.21mg/l respectively and in Itori River nitrate and phosphate concentration were 18.80mg/l and 38.20mg/l respectively. The higher values of nitrate and phosphate recorded in Alaguntan may be traceable to enhanced nutrient status of the River which was probably due to impact from direct effluent received from cement plant. Omatsola and Adegoke (1981) have equally observed that, water quality impairment are direct result of land use characteristic within the catchment of a receiving stream or river on the one hand and the geological formation of the area on the other.

The heavy metals concentrations in water sample from the three rivers are shown in Table 7. Alaguntan River recorded the highest concentration while Elebute river recorded the least concentration for all the heavy metals except Fe. The higher concentration of heavy metals in Alaguntan River may be attributed to the direct effluent received from the cement factory and its closeness to the pollution source (Fig. 1). On the other hand, Itori River may be linked

Table 6: Physico-chemical parameters of rivers within the study locations in relation to quality standard for irrigation

Parameter	Units	Quality Standard for irrigation*	Locations		
			Alaguntan	Elebute	Itori
pH		6.5-8.4	7.79	6.68	6.87
EC	dS/m	0.7	0.74	0.42	0.53
TDS	mg/l	450	473.6	268.8	339.2
OM	mg/l		2.2	2.59	3.52
SAR	mg/l	3	0.7	0.58	0.66
NO_3^-N	mg/l	5.0-30.0	83.93	7.05	18.81
PO_4^-P	mg/l		190.8	14.21	38.2
Ca	mg/l		10.87	7.82	12.49
Na	mg/l	70	3.86	1.65	1.84
Mg	mg/l		50.68	8.59	3.17
K	mg/l		3.5	1.29	2.46
Mn	mg/l	0.2	28.48	7.66	16.37
Fe	mg/l	5	3.79	2.38	1.61
Zn	mg/l	2	0.98	0.21	0.42
Cu	mg/l	0.2	1.02	0.23	0.58
Pb	mg/l	5	0.16	0.04	0.14
Ni	mg/l	0.2	2.48	0.65	1.38
Cr	mg/l	0.1	1.96	0.51	1.06
Co	mg/l	0.05	0.38	0.1	0.2
Cd	mg/l	0.01	0.11	0.03	0.04

**Source: Ayers and Westcott, 1994*

with human activities and flow of sewage. The presence of automobile mechanic workshops in the area might be a source of metal inputs through runoff into the river. The distribution of heavy metals in all the rivers followed the order Mn>Fe>Ni>Cr>Cu>Zn>Co>Pb>Cd. Comparatively, the heavy metal concentrations were however significantly higher ($p<0.05$) in samples from Alaguntan River than in corresponding sample from Elebute and Itori Rivers (Fig. 5). Generally, in all the rivers the observed concentration is higher than the recommended limits for irrigation water except the concentration of Pb and Zn. However, a comparison of the recorded heavy metals concentration world average values carried in solution by major unpolluted rivers as reported by Meybeck *et al*. (1996), Mn, Pb, Zn Cr and Cd were found to be higher while Cu and Fe were found to be less than the world average.

CONCLUSION

Basically, the concentration of heavy metals in all the rivers studied are on the elevated side (in the order of mg/l) and 1000times worse in heavy metals than expected. Therefore, the rural communities who depended on these rivers for drinking and irrigation are exposed to high risk of heavy metal bio-accumulation. Thus it is important to consider the constant

Table 7: Heavy metals concentration in water samples

Element mg/l	Alaguntan	Elebute	Itori
Mn	28.48	7.66	16.37
Fe	3.79	2.38	1.61
Zn	0.98	0.21	0.42
Cu	1.02	0.23	0.58
Pb	0.16	0.04	0.14
Ni	2.48	0.65	1.38
Cr	1.96	0.51	1.06
Co	0.38	0.1	0.2
Cd	0.11	0.03	0.04

monitoring of various industrial activities on the environmental resources beyond the initial Environmental Impact Assessment (EIA) which often are prerequisites to granting of license of operation to industries.

Some urgent action must be taken to reduce the pollutant production especially the particulate dusts in the cement production since particulate deposition has been seen to be primary to the pollution of soil and the rivers in the study area.

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