International Journal of Innovative Agriculture & Biology Research 9(1):1-10, Jan.-Mar., 2021
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The Role of Non-pollen Palynomorphs in Quaternary Palaeoecological Study of Akoko Environment, Ondo State, Nigeria

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ABSTRACT
Non-pollen palynomorphs such as algal cysts, arthropods/ parts, bryophyte remains, charred plant particles/ tissue, diatom frustules, dinoflagellate cysts, fungal hyphae, fungal spores are usually encountered when analyzing palynological preparations. The non-pollen palynomorphs were collected with Modified Tauber Sampler using simple random sampling technique and analyzed palynologically. Results showed a grand total of 84,710 non-pollen palynomorphs consisting of 73,629 fungal spores, 3,535 charred plant tissues, 3,191 arthropods, 2,962 diatom frustules, 1,014 pteridophyte spores, 132 algal cysts, 120 dinoflagellate cysts, 87 plant tissues, 27 bryophyte parts and 13 fungal hyphae were documented. Some of this non-pollen palynomorphs have been associated with out-doors allergens while fungal spores and hyphal fragments constitute human, animal and plant pathogens with long history of epidemiology. Diatoms and dinoflagellates cysts are useful palaeoecological indicators species with distinct ecological tolerance and autecological information; and have been implicated in environmental analysis. Charred plant particles serve as indicator of bush fire and can be used in monitoring the intensity and frequency of indiscriminate bush burning. This study is aimed at ascertaining and evaluating the taxa of non-pollen palynomorphs in the studied environment and the results is anticipated to provide useful insight into climatic and vegetation shift within the context of palaeo-environmental reconstruction for safety health and environmental sustainability.
Keywords: Akoko, non-pollen palynomorphs, palaeoecological, palaeoenvironmental, Nigeria

1. INTRODUCTION

The term palynomorphs is used in describing particles of size between five and five hundred micrometres, found in rock deposits (sedimentary rock) and composed of organic material such as chitin, pseudochitin and sporopollenin (Traverse, 1988). Palynomorphs form a geological record of importance in determining the type of prehistoric life that existed at the time the sedimentary formation was laid down (Traverse, 1988). Examples of palynomorphs are diatoms, dinoflagellates, acritarch, pollen grains and spores (Traverse, 1988). The study of these palynomorphs is called Palynology.

Palynology was first developed in Northern Europe, and it is here that pollen and spores have been studied most intensively. European palynologists have emphasized species identification of palynological forms (pollen grains and spores, among others) and they have used the ecology of individual species as a basis for interpretation. The climate, soil and even the degree of openness of the vegetation with the environments of modern populations of these same species of plants were also studied, analyzed and interpreted palynologically (Bhattacharya *et al*., 2011).

Palynomorphs are particles of biological origin arising from plants and animals some of which were released after disintegration of the organisms (Sowunmi, 1987). In a *sensu stricto* palynomorphs consist of bio-particles whose outer wall consist of resistant complex organic polymer such as sporopollenin, chitin, pseudochitin or other complex compounds (Ige, 2017). However, in most recent times, it has included siliceous particles such as diatom frustule because of their relevance in

vegetation and environmental interpretations (Essien, 2019a). Palynomorphs therefore include pollen grains, fungal spores and hyphal fragments, pteridophyte spores, diatom frustules, charred plant and other plant particles, arthropod/ zooclasts moults and parts as well as animal hairs (Melia, 1984; Ige and Essien, 2019b).

These palynomorphs vary in quantity and diversity from place to place. Of these palynomorphs, fungal spores have been reported to be more abundantly represented particularly during the wet seasons, followed by pollen grains (Agwu and Osibe, 1992; Ige and Essien, 2019a). The diatom frustules and charred plant particles were more abundant in the air during the dry seasons and early rainy seasons. As we go back in geological history, pteridophytes become increasingly important and their spores are indispensable part of the microfossil record (Traverse, 1988). The distribution of these palynomorphs is influenced by the two major wind systems in Nigeria. The North East trade wind carry loads of particles as well as cold dry harmattan winds from the Sahara desert through north to the southern part of Nigeria. The South West monsoon associated with rainfall carries moisture packed particles from the south to the northern part of Nigeria (Essien, 2019a).

The non-pollen palynomorphs are important environmental components of the atmosphere consisting of numerous minute suspended bioparticles with great diversity in size, shape, density and many other physical as well as chemical characteristics. These palynomorphs are organic in origin arising from various sources from both near and distant environments. The inorganic particles commonly recorded include siliceous materials (sand particles), Lead, Tin and Aluminum released mostly from dust storm and industrial activities (Ogden *et al*., 1974; Agwu, 2001) while the organic components routinely recorded in palaeoecological studies comprise of numerous and diverse pollen grains, fungal spores and hyphal fragments, fern spores, charred plant particles, arthropod particles, diatom frustules, opal phytoliths and oil droplets among other miscellaneous materials (Njokuocha and Osayi, 2005; Burge and Rogers, 2008; Essien, 2019b).

The non-pollen palynomorphs have been reported to affect the quality of air in circulation depending on the constituent particle. For example, fungal spores, insect and animal fractions among others have been reported to exacerbate asthmatic reactions or induce various forms of allergic reaction in sensitive individuals (Essien and Aina, 2014; Essien, 2020). The fungal spores and the hyphal fragments not only cause diseases of plants but also cause serious infections to man and animals (Sakiyan and Inceoglu, 2003; Cashel *et al*., 2004; Reid and Gamble, 2009).

Diatoms are unicellular algae with a unique silica shell or frustule, which is readily preserved in sediments. Diatom frustules are often abundant and well represented and preserved in palynological preparations (Essien, 2020). Fragments of diatom frustules, animals and plants particles are of various sizes. The shape, size and density of any of these particles influence its behavior in the atmosphere. Hence the rate at which these particles are deposited from the atmosphere by decrease in turbulent deposition can be related to the velocity which is a function of the aerodynamic diameter; because of the defined sizes of the biological particles and the resultant aerodynamic diameter, they have a wide range of differing deposition velocities (Nicholsen, 1988).

Over the years, these non-pollen palynomorphs have been recovered from the air, soil and sediment of all ages (Khandelwal, 1988; Hooghiemstra *et al*., 1986; Agwu and Beug, 1982; Ballouche and Neumann, 1995; Sowunmi, 2004). Characteristically, most of these palynomorphs (microscopic organic particles) are composed of resistant chemical substances such as sporopollenin, chitin, pseudochitin or complex mixtures of other compounds (Moore and Webb, 1978; Traverse, 1988).

According to Traverse (1988), these complex resistant chemical compounds form the basic building of the resistant walls of most palynomorphs. They also provide the structural framework on which the morphological features of palynomorphs are formed. These features are highly relevant in their identification, transportation, buoyancy and germination (for pollen and spores).

The upthrust of palynomorphs into the atmosphere may occur by natural release mechanisms, through the action of raindrops, turbulent winds or anthropogenic activities among others and fruiting of fungi has been associated with release and dislodgement of spore bearing structures. Wind speed and direction equally play significant role in the release, up-thrust, transportation and concentration of non-pollen palynomorphs in the atmosphere (Essien, 2014, Essien, 2020). In the dry season during the harmattan, the North East trade wind which moves latitudinally, transport palynomorphs including dust from the north to the southern part of Nigeria (Adeonipekun and John, 2011). Such air movement increases the influxes of atmospheric dust loads and consequently the amount of palynomorphs

suspended in the air. Melia (1984) reported massive transport of dust filled with palynomorphs from the interior of West Africa to the Gulf of Guinea. Agwu (2001) was able to relate the high percentage of charred grass cuticle in the air in the Niger Delta to long distance transport from the savanna vegetation of Northern Nigeria.

The use of palynomorphs in environmental studies is primarily in its application to the study of vegetational history. The study of vegetation and the way in which it has been altered and developed in the course of time indicates past changes that have occurred in our terrestrial environment. Variations in climate and in the intensity of human activity in historic and prehistoric times have made their mark upon vegetation, and these have left a record of those changes in the form of vast quantities of palynomorphs which have survived in contemporary sediments (Roberts, 1998; Ige and Essien, 2019c).

The Quaternary is the current period of geologic time, beginning 1.6 MYBP. The Quaternary is the second period of the Cenozoic era, which began about 2 million years ago, following the Tertiary period, and includes the present. It is subdivided into two epochs- the Pleistocene and Holocene. The beginning of Quaternary is usually based on the onset of a worldwide cooling. During the period, four principal glacial phases occurred in Europe and North America, in which ice advanced towards the equator, separated by interglacials during which conditions became warmer and the ice sheets and glacials retreated. The last glacial ended about 10,000 years ago. The Quaternary Period encompasses the last ~2.6 MYBP during which time Earth's climate was strongly influenced by bi-polar glaciation (Hoorn, 1997).

The vegetation of an area is an integral and basic component of the ecosystem and is sensitive to changes. The essence of writing on and/ or studying the vegetation of the Quaternary is because at this period (the Quaternary), palynomorphs is abundantly produced and well preserved; and is also identifiable to various taxonomic levels. If a sample of the sediment is examined, the palynomorphs spectra obtained will form an index of the vegetation. When two or more series of the palynomorphs spectra are obtained from various locations, it is possible to detect and compare the spatial and temporal changes in the vegetation around the studied area (Essien, 2019).

In the Quaternary, however, palynomorphs can be directly referred to extant vegetation due to the proximity of Quaternary period with the present, proving "Present is key to the past". Palaeoecological studies, therefore, is an extremely powerful tool for the investigation of floristic and climatic changes that took place in the recent past (i.e. Quaternary) (Ige, 2017).

This study is aimed at ascertaining and evaluating the taxa of non-pollen palynomorphs in the studied environment and the results is anticipated to provide useful insight into climatic and vegetation shift within the context of palaeo-environmental reconstruction for safety health and environmental sustainability.

2. MATERIALS AND METHODS

Forty locations were randomly selected within the four Local Government Areas of Akoko division, Ondo State, Nigeria as sampling sites. The sampling sites for the study were purposively selected to reflect as far as possible the Local Government Area of the study. In choosing the sites, consideration was also given to urbanization, accessibility and safety of the sampling (experimental materials) instruments among others (Patton, 1990).

At each site, a pollen trap (Modified Tauber Sampler) was mounted according to the methods of Tauber (1974; 1977), Pardoe *et al*. (2010) and Giesecke *et al*. (2010). Prior to this, a mixture of glycerol (65 ml), formalin (30 ml) and phenol (5 ml) was poured into each of the trap. The positions of the traps at various locations were recorded using a Global Position System (GPS). The solutions in the trap prevented the palynomorphs from drying up, kill insects and also prevented the decay of dead organisms. The trap was left to stand throughout the duration of the study period. Fortnightly of each month, solution collection was done. The traps were washed with water to remove any contaminants and were then refilled with the above mentioned chemical solution. This procedure was repeated bi-monthly from October 2016 to December 2017. The palynomorphs were recovered through centrifugation at 2000 r.p.m (revolution per minute) for 5 minutes and supernatant decanted each time. The precipitates were washed twice with distilled water and recovered through centrifugation. The sediments were treated with glacial acetic acid to remove water before acetolysis (Erdtman, 1969; Agwu and Akanbi, 1985). The recovered precipitates were washed with glacial acetic acid and finally

washed twice with distilled water, centrifuged each time and decanted. The recovered palynomorphs were stored in a plastic vials in glycerin and ethanol solution (2:1).

The palynomorphs were analysed palynologically and microscopically with Olympus microscope at x400 magnification for counting and Leica microscope at x1000 magnification for detailed morphological studies. Palynomorphs identification, counting and classification were done with the help of reference descriptions and photomicrographs from Agwu and Akanbi (1985), Barnett and Hunter (1998), Bonnefille and Riollet (1980), Sowunmi (1995) and Shubharani *et al*. (2013). In addition, prepared slides of palynomorphs samples in the Palynological Research Unit; Department of Plant Science and Biotechnology, Adekunle Ajasin University, Akungba- Akoko, Nigeria were used.

3. RESULTS AND DISCUSSION

The results of the study of the role of non-pollen palynomorphs in Quaternary Palaeoecological study of Akoko environment, Ondo State, Nigeria showed that the following particulate entities: spores of pteridophytes and fungi, diatom frustules, fungal hyphae, arthropods (insects and insect parts), plant tissues and bryophyte parts as well as charred plant particles were recorded at varying quantities and qualities. The summary of the non-pollen palynomorphs documented in the study area is presented in Table 1 while he cumulative monthly non- pollen palynomorphs recorded in the study area is given in Table 2.

Table 1: Summary of the palynomorphs present in the study area

S/N	Non-pollen Palynomorphs	Quantitative count	(%) of grand total
1	Algal cysts	132	0.15
2	Arthropods	3191	3.76
3	Bryophyte remains	27	0.03
4	Charred plant tissues	3535	4.17
5	Diatom frustules	2962	3.49
6	Dinoflagellate cysts	120	0.14
7	Fungal hyphae	13	0.02
8	Fungal spores	73629	86.91
9	Plant tissues	87	0.10
10	Pteridophyte spores	1014	1.19
	Grand Total	84710	

Table 2: Cumulative monthly non- pollen palynomorphs recorded in the study area (October, 2016 - September, 2017)

S/N	Non-pollen Palynomorphs	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	TOTAL
1	Algal cysts	11	18	0	0	0	13	66	14	10	0	0	0	132
2	Arthropods/ parts	117	123	315	252	107	1071	333	350	185	83	150	105	3191
3	Bryophyte	0	0	0	0	0	10	10	7	0	0	0	0	27
4	Charred plant tissue	73	219	1441	602	163	320	202	260	198	28	8	21	3535
5	Diatom frustules	130	156	293	299	378	520	821	193	108	23	22	19	2962
6	Dinoflagellate cysts	60	12	2	0	0	9	21	11	5	0	0	0	120
7	Fungal spores	10213	6175	7830	3768	2465	3491	3534	6061	10709	11794	3628	3961	73629
8	Fungal hyphae	0	0	0	0	0	13	0	0	0	0	0	0	13
9	Plant tissue	0	0	0	0	0	81	6	0	0	0	0	0	87
10	Pteridophyte spores	127	114	25	22	19	22	75	83	54	25	26	422	1014
	GRAND TOTAL	10731	6817	9906	4943	3132	5550	5068	6979	11269	11953	3834	4528	84710

3.1 Algal cysts and Bryophyte remains

Some algal cysts and bryophyte particles were distinguished and recorded in the study. Others remain distinct from the charred ones and were recorded as part of the non-pollen palynomorphs present in the study area. They serve interpretational purposes in environmental reconstruction. An increase in this plant debris in the study is an indication of increasing dryness and the arrival of long distance transported materials from Northeast (NE) trade wind otherwise known as Harmattan. Similar findings have been reported by Agwu and Osibe (1992) and Njokuocha and Osayi (2005).

3.2 Arthropods/ parts

These represent the various parts, whole and molts of insects and insect parts recorded in the study. A total of 3,191 arthropods/ parts were documented in this study. These particles or the organisms themselves are mostly airborne; they are buoyed by strong wind as well as by movement during nuptial flight. They occurred in the air throughout the year and at all locations. Some of these organisms or their parts have been reported by Gallup *et al*. (1987) to be vectors of parasites while their parts are responsible for all forms of allergy when inhaled through the nose as well as the exacerbation of asthmatic conditions.

3.3 Charred Plant Particles

These are charred particles of grasses, weeds, herbs and trees released during domestic or wild fire incidence that are wafted into the atmosphere. They mostly constitute of charred cuticles, epidermal layers, cells and other plant tissues. A total of 87 plant tissues and 3,535 charred plant particles were documented in this study. A reasonable quantity of them was trapped at all the locations and was recorded throughout the study duration especially during the dry period of the year. They serve as indicator of bush fire and can be used in monitoring the intensity and frequency of bush fires. Findings agree favourably with the report of Agwu (2001), Morley and Richards (1993) who demonstrated the application of 'Charred Gramineae Cuticle' as a key identification of late Cenozoic climate changes in the Niger Delta of Nigeria. Although the results showed that the charred plant particles were trapped all through the year from the atmosphere, higher quantities of these particles were trapped from the period of the early to the late dry season (November to May). This could be due to annual bush fire that herald the onset of farming, activities of cattle herdsmen that want to stimulate fresh grass re-growth as well as people that engage in hunting expedition to flush out wild animals. Similar findings have been reported by Agwu *et al*. (2004) and Njokuocha and Osayi (2005).

3.4 Diatom frustules

This refers to the cell wall that has been preserved in sediment. The Diatom frustules were among the consistent particles recorded in this study and they represent an aspect of algal microflora in Akoko environment. They occurred in reasonable quantities throughout the period of study and were recorded at all the locations and may be associated with dry ponds, drying of seasonally flooded places and loose dry soils that provide habitat to these algae. During prolonged dryness in Akoko environment, ponds and other water logged areas dry up and expose the fresh water algae (diatoms) to dust storms/ strong harmattan winds. The whirl winds waft up the dried mud into the air current (wave) causing an unusual increase in the atmosphere. An increase in fresh water diatom frustules in the airspora of Akoko environment is an indication of increasing dryness and the arrival of long distance transported materials from Northeast (NE) trade wind otherwise known as Harmattan. Findings corroborated favourably with the report of Nwankwo (1990) and Hooghiemstra and Agwu (1986). In environmental analysis, diatoms are useful palaeoecological indicators and have distinct ecological tolerance; they are not indestructible, and may be physically or chemically eroded, and they provide a substantial amount of autecological information (Essien, 2020).

3.5 Dinoflagellate cysts

Dinoflagellates are algae with two flagella and it is the cyst that are preserved which is been studied in palaeopalynology. Among the non-pollen palynomorphs encountered in this study were dinoflagellate cysts. According to Traverse (1988), dinoflagellate cysts first appeared abundantly and very recognizable in palaeo-palynological preparations of marine sediments in late Triassic. In the Jurassic, they were very abundant and very fast evolving making them ideal subjects for palynostratigraphy. The occurrence of dinoflagellates cysts in the study environment can be interpreted to indicate changes in wind system, wave or tidal action.

3.6 Fungal Spores/ Fungal hyphae

Fungal spores were the dominant component of the non-pollen palynomorphs recorded in this study and constituted 86.91% of grand total palynomorphs. Few particles of fungal hyphae were also recorded representing the enormous fragments circulating in the atmosphere. A total of 13 fungal hyphae were encountered in this study (Table 1 and 2). They serve as inocula for fungal infection and/ or as saprophytes.

The abundance of these fungal spore genera is not only a reflection of the degree of abundance of the spores in the study area but an indication of the availability of host plants and other spore sources in the region. The high concentration of fungal spores and their complete dominance over other non-pollen palynomorphs in this study compare favourably with the findings of Khandelwal (1988), Calleja *et al*. (1993), Konopinska, 2004 and Essien *et al*. (2013).

The highest period of fungal spores abundance was recorded in July may be attributed to favourably environmental condition that promoted the release of both dry air spora and wet air spora in the area. This period actually favours the growth, production and release of abundant spores especially the wet-air spora. However, the wash out effect of rainfall reduces drastically the concentration of these fungal spores and consequently the quantity trapped; and most of the grasses, weeds and trees that host these fungi have shriveled, died or shed their leaves, hence reducing the major source of the spores.

The complex vegetation structure in the study environment consists of woodlands, forests, and abundant grasses that are hosts and major reservoir of fungal spores. The wet and humid conditions of the study environment constantly induce decomposition of raw organic materials inhabited by successive populations of fungi. All these factors provide suitable conditions and hosts for the growth of fungi and consequently lead to increased spore load in the area.

3.7 Pteridophyte spores

Spore of pteridophytes constituted a very low proportion of the total non-pollen palynomorphs encountered in the study. Due to identification problems, only six fern spore types were identified to generic level while majority of the spores were classified under monolete and trilete. A total of 1,014 fern spores were recorded. The dominant ones are *Nephrolepis exaltata* and *Goniopteris vivapara*. The monolete spores were more abundant than the trilete spores. The results presented in this study showed that a considerable quantity of the fern spores was recorded in the months of April and May and at locations during the early rainy season but declined with the increase in rainfall from July which may be compared to the dry season where only a few pteridophytes sporulate due to unfavourable conditions. Nevertheless, the unusual increase in the abundance of fern spores in the months of October, September and November (Table 2) respectively could be attributed to the action of meteorological factors for example wind; which waft up the dried and already deposited dry airspora into the air current causing an unusual increase in the atmosphere.

4. CONCLUSION

The non-pollen palynomorphs documented in this study reflect to a large extent the phytoecological vegetation of the studied environment. The percentage composition of the grand total non-pollen palynomorphs recorded showed that fungal spores constitute the dominant proportion, with 86.91% followed by charred plant tissues (4.17%), arthropods/ parts (3.76%), diatom frustules (3.49%) among others (Table 1). Some of this non-pollen palynomorphs have been associated with out-doors allergens while fungal spores and hyphal fragments constitute human, animal and plant pathogens with long history of epidemiology. Charred plant particles were part of the non-pollen palynomorphs content recorded as evidence of human impact and this confirm the great influence of anthropogenic activities on the environment as well as the local vegetation.

Disclosure of conflict of interest

The authors declares that there is no conflict of interest.

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