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The Environmental, Ecological and Medical Impact of Airborne Pollen Grains, Spores of Fungi and Pteridophyte and Other Atmospheric Palynomorphs in Akoko Division, Ondo State, Nigeria

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Abstract: *The study of atmospheric pollen content of an area is important in providing information on vegetation and environmental status, safety health and sustainable development. This study is aimed at ascertaining and evaluating the taxa of palynomorphs present in the atmosphere of the studied environment and the results is anticipated to provide useful data that would also proffer adequate measures for safety health and environmental sustainability. The airborne palynomorphs were collected with Modified Tauber Sampler using simple random sampling technique and analyzed palynologically. Results showed a total of 135,371 palynomorphs consisting of 73,629 fungal spores, 50,661 pollen grains, 3,535 charred plant tissues, 3,191 arthropods, 2,962 diatom frustules, 87 plant tissues, 27 bryophyte parts and 13 fungal hyphae were documented. The various ecological indicators species identified confirmed their origin as coming from the Forest- Savanna ecozone that is anthropogenically disturbed. Some of this palynomorphs (pollen grains, fungal spores, hyphal fragments, and insect particles) have been associated with out-door allergens, while fungal spores and hyphal fragments constitute human, animal and plant pathogens with long history of epidemiology. These aero-pollen grains statistically have a significant impact on the health of allergic individuals in the studied area, especially those with upper respiratory tract infection and hay fever symptoms. 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 bush fires.*

Keywords: *Atmospheric palynomorphs; Ecological; Environment; Impact; Medical, Nigeria*

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I. Introduction

Airborne palynomorphs are particles of biological origin arising from plants and animals some of which were released after disintegration of the organisms [1]. 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 [2]. However, in most recent times, it ha**s** included siliceous particles such as diatom frustule because of their relevance in vegetation and environmental interpretations [3]. The airborne 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 [4, 5, 6].

These bioparticles are constantly released into the air from various sources from where they travel to various distances. These airborne palynomorphs vary in quantity and diversity from place to place. The relative abundance of the individual components at any point in time is influenced by a number of factors such as density of the source plants, flowering or reproducing season, pollen or spore reproducing season, pollen or spore producing capacity, aerodynamic features of the bioparticles, their size and the role of meteorological factors [7, 8, 9, 10].

Of these airborne palynomorphs, fungal spores have been reported to be more abundant in the air particularly during the wet seasons, followed by pollen grains [1, 6]. The abundance of the pollen grains has been positively correlated with flowering seasons [11, 12]. The diatom frustules and charred plant particles were more abundant in the air during the dry seasons and early rainy seasons. 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 [13].

The airborne palynomorphs have been reported to affect the quantity of air in circulation depending on the constituent particle. Airborne pollen grains, 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 [1, 14]. The fungal spores and the hyphal fragments not only cause diseases of plants but also cause serious infections to man and animals [15, 16, 17, 18, 19].

Airborne 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 [20, 21], while the organic components routinely recorded in air 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 [5, 6, 22, 23].

The various types of particles of biological origin that occur in the atmosphere have wide range of sizes. Most pollen grains from anemophilous plants have typical diameters of 17 to 58μm [24], fungal spores are typically 1μm to 30μm in diameter [25]. Fragments of plants, diatom frustules and animals are of various sizes. The shape, size and density of any particle influence its behaviour 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; and because of the defined sizes of the biological particles and the resultant aerodynamic diameter, they have a wide range of differing deposition velocities [26].

Over the years, these organic particles have been recovered from the air, soil and sediment of all ages [20, 27, 28, 29, 30, 31, 32, 33]. Characteristically, most of these microscopic organic particles are composed of resistant chemical substances such as sporopollenin, chitin, pseudochitin or complex mixtures of other compounds [2, 34].

According to Traverse [34], 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. It also facilitates the process of their deposition as well as lowering of their concentration in the atmosphere [35, 36, 37, 38, 39]. Wind speed and direction equally play significant role in the release, up-thrust, transportation and concentration of airborne palynomorphs in the atmosphere [40, 41, 42]. 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 [4, 28]. Such air movement increases the influxes of atmospheric dust loads and consequently the amount of palynomorphs suspended in the air. Melia [4] reported massive transport of dust filled with palynomorphs from the interior of West Africa to the Gulf of Guinea. Agwu [20] 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.

Airborne palynomorphs have over the years aroused much scientific interest amongst biologist because the constituent particles have remained significant environmental contaminants as well as indices for monitoring particle movements in the air. In certain circumstances, the air quality is affected by the types and concentration of these bio-particles that may impact negatively on public health, crop survival and yield [23, 43, 44]. In fact some of the particle components of these palynomorphs: pollen grains, fungal spores and fragments, not only constitute health hazards to man, animals and plants, but have been applied in floristic delineations, aeroallergens, changes in the dynamics of genotypes, palaeo-vegetation and palaeo-environment as well as in models for predicting climatic changes [17, 20, 33, 44, 45, 46, 47]. Of the airborne palynomorphs, pollen grains and spores of fungi and pteridophyte are the most widely studied [13]. This may be attributed to their application in resolving a lot of environmental health issues and matters relating to vegetation and plant pathology. Because they are direct product of plants, their production and availability are predisposed to changes in environmental factors that affect their parent sources. The interaction between vegetation and climate is so strong that investigation on airborne pollen affords the opportunity of assessing vegetation-climatic relationship. It is partly on this basis that pollen and spores have successfully been used in designating floristic zones, monitoring of transgression in aridity and palaeo-vegetation reconstruction.

The quantity and quality of annual airborne palynomorphs have been reported to vary substantially with seasons, places and heights and this has been attributed to the primary vegetation sources, differential pollen and spore production, flowering or reproducing season, density, mode of dispersal and the prevalent meteorological factors [35, 43, 46, 48, 49, 50].

Studies in airborne palynomorphs, particularly pollen grains and spores in Nigeria [1, 3, 5, 20, 23, 46, 50] and in other West Africa countries [4, 42] shows that species composition, differential pollen and spore production, source vegetation and meteorological conditions are among the important factors that determine the concentration, distribution pattern and release of pollen grains and spores into the atmosphere.

Studies in aerobiology have shown that variations exist in the vertical profile of pollen and spore concentration in the air. Although increase in pollen grains has been correlated with increased heights, the pollen components have been largely derived from trees [27, 50]. Similar studies on vertical profile of fungal spores showed that the large multicellular spores were most common at the lower heights while the smaller sized spores were recorded in greater abundance at the higher levels [51, 52].

This study is aimed at ascertaining and evaluating the taxa of palynomorphs present in the atmosphere of the studied environment and the results is anticipated to provide useful data that would also proffer baseline information for safety health and environmental sustainability.

II. 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 purposely 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 [53].

At each site, a pollen trap (Modified Tauber Sampler) was mounted according to the methods of Tauber [54, 55], Pardoe *et al*. [56] and Giesecke *et al*. [57]. 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 recharged with the above mentioned chemical solution. This procedure was repeated bi-monthly from October 2016 to December 2017 (dry season and rainy seasons' samples) for one year. 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 [58, 59]. 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 analyzed 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 [59], Bonnefille and Riollet [60], Sowunmi [61] and Shubharani *et al*. [62]. 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.

III. Results and Discussions

Results of this study showed a total of 135,371 palynomorphs consisting of 73,629 fungal spores, 50,661 pollen grains, 3,535 charred plant tissues, 3,191 arthropods, 2,962 diatom frustules, 87 plant tissues, 27 bryophyte parts and 13 fungal hyphae were documented (Table 1).

Table 1: Cumulative monthly atmospheric palynomorphs recorded in the study area (Oct., 2016- Sep., 2017)

Palynomorphs	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN	JUL.	AUG.	SEP.	TOTAL
Algal cysts	11	18	0	0	0	13	66	14	10	0	0	0	132
Athropods/ parts	117	123	315	252	107	1,071	333	350	185	83	150	105	3,191
Bryophyte	0	0	0	0	0	10	10	7	0	0	0	0	27
Charred plant tissue	73	219	1441	602	163	320	202	260	198	28	8	21	3,535
Diatom frustules	130	156	293	299	378	520	821	193	108	23	22	19	2,962
Dinoflagellate cysts	60	12	2	0	0	9	21	11	5	0	0	0	120

Fungal hyphae	0	0	0	0	0	13	0	0	0	0	0	0	13
Fungal spores	10213	6175	7,830	3,768	2,465	3,491	3,534	6,061	10709	11,794	3,628	3961	73,629
Plant tissue	0	0	0	0	0	81	6	0	0	0	0	0	87
Pollen grains	5,788	9,297	8,416	4,343	1,945	3,406	2,628	3,557	2,225	1,530	1,926	5,600	50,661
Pteridophyte spores	127	114	25	22	19	22	75	83	54	25	26	422	1,014
Grand Total	16,519	16,114	18,322	9,286	5,077	8,956	7,696	10,536	13,494	13,483	5,760	10,128	135,371

3.1. Fungal spores

Fungal spores are of cosmopolitan distribution and constitute a large proportion of total airborne palynomorphs recorded in most aeropalynological studies. On the basis of the present study, a very high concentration of fungal spores (cumulative count of 73,629 with 54.08% of grand total palynomorphs) and few fungal hyphae (13) were documented. The abundance of these airborne fungal spore genera is not only a reflection of the degree of abundance of the spores in the air, but an indication of the availability of host plants and other spore sources in the region. The high annual concentration record of fungal spores and their complete dominance over other biological particles in this study compares favourably with the findings of [6, 23, 27, 63, 64, 65].

Similarly, the high number of spore genera identified coupled with the numerous unidentified spores reflects to a large extent the diversity of spore-bearing fungi and that of the host plants. Moreso, it has been reported that many fungi such as some species of mushrooms, rusts and smuts are host-specific growing in close association with specific plant species and may not be found in the absence of the host [22]. Among the fungal spore types identified, those of *Corynespora* sp., *Curvularia* sp., *Endophragmiella* sp., *Nigrospora* sp., *Neurospora* sp., *Pithomyces* sp. and *Ustilago* sp. are the most common and dominant spore genera identified in this study. Studies have also shown that these spore genera belong to the dry air-spora (*Corynespora* sp., *Curvularia* sp., *Pithomyces* sp.) and wet air-spora (*Endophragmiella* sp., *Nigrospora* sp., *Neurospora* sp., *Ustilago* sp., *Venturia* sp.). Similar spore constitutions have been reported in air-spora investigations in Nsukka and Anyigba (Nigeria) by Agwu *et al*. [6],Njokuocha and Agwu [52], Essien *et al*. [65] and in related studies in other part of the world [29, 39, 66, 67, 68, 69, 70].

Table 2: Percentage composition of palynomorphs recorded in the study

S/N	Palynomorphs	Quantitative counts	% of grand total
1	Algal cysts	132	0.09
2	Arthropods	3,191	2.36
3	Bryophyte remains	27	0.02
4	Charred plant tissues	3,535	2.61
5	Diatom frustules	2,962	2.19
6	Dinoflagellate cysts	120	0.09
7	Fungal hyphae	13	0.009
8	Fungal spores	73,629	54.39
9	Plant tissues	87	0.06
10	Pollen grains	50,661	37.42
11	Pteridophytes spores	1,014	0.75
	Grand Total	135,371	

The statistical analysis showed that the highest period of fungal spore abundance were recorded in the month of July and was significantly different from those of other months. The analysis also showed that the mean monthly fungal spore abundance recorded in the month of June differs significantly from those in the months of November, December, January, February, March, April, May, July, August and September except October. The highest count which 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. The month of July recorded the highest number and amount of annual rainfall (Table 3). 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 airborne spora and consequently the quantity trapped. Seasonal variation showed that the highest mean fungal spore abundance were more from June- July and October - December than from August - September and the dry period of January - April due to higher sporulation activities by the fungi. Comparatively, similar findings have been reported by previous authors [22, 36, 39, 68]. The lower counts recorded in the months of January, February and March may be explained in relation to the fact that many of the spores bearing fungi have released most of their spores and the prevailing dry condition did not favour sporulation. Secondly, 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.

Table 3: Mean meteorological data for the study area

Parameter / Month	Temperature (^{0}C)	Relative humidity (%)	Rainfall (mm)	Light intensity (W/m^2)	Wind direction (degrees)	Atmospheric pressure (mbar)	Wind speed (m/s)
October	27.04	81.63	4.86	158.85	182.25	969.86	0.99
November	27.34	71.89	0.28	178.40	175.24	968.98	0.95
December	27.32	62.59	1.14	172.56	173.81	968.54	0.89
January	27.30	55.68	1.46	153.85	168.98	968.62	0.98
February	29.97	67.83	1.30	170.39	162.81	967.93	1.28
March	30.29	68.71	0.33	176.79	157.22	967.81	1.36
April	29.05	75.34	0.26	169.88	169.43	968.20	1.37
May	28.91	79.38	0.46	167.24	181.48	969.28	1.17
June	28.10	81.73	0.10	145.26	180.26	971.01	1.20
July	26.69	67.96	177.86	100.87	168.73	971.05	1.26
August	25.85	62.17	11.14	114.62	123.11	970.60	1.38
September	26.97	76.36	4.59	80.63	174.75	970.72	0.93

Sources: Department of Geography and Planning Sciences, Adekunle Ajasin University, Akungba-Akoko and the Centre for Atmospheric Research, National Space Research and Development Agency, Federal Ministry of Science and Technology, Akungba, Nigeria. (www.carnasrda.com)

3.2. Pollen grains

A total of 182 pollen types were identified across the study locations. These pollen types belong to 74 angiospermic plant families, and 1gymnosperms. Out of the 74 plant families encountered, 66 families belong to the dicotyledonous plants, 6 to monocotyledonous plants, 1 to the gymnospermous plants and 1 was unidentified (Indeterminata).

However, in absolute counts, the cumulative monthly pollen record showed that a total of 50,661 pollen grains were recorded with the highest monthly pollen counts of 9,297 recorded in November, followed by December (8,416), October (5,788), September (5,600) and the least recorded in August (1,926) and July (1,530) respectively (Table 1).

Statistical analysis of the mean monthly pollen counts showed that there was a significant difference ($P<0.05$) in the monthly pollen abundance. The multiple comparison using DMRT showed that the quantity of pollen counts recorded in November was significantly different ($P<0.05$) from those recorded in the months of March, April, May, June, July, August, September, October, January and February, but not significantly different from the pollen counts recorded in December. There was no significant difference between the quantity of pollen recorded in December and other months. Equally, statistical analysis of pollen record at the study locations showed that there was significant difference ($P<0.05$) between the abundance of pollen grains recorded at the study locations.

Airborne pollen exhibits seasonal fluctuations in quantity as well as composition. Unspecified numbers and type of pollen grains remain airborne after the flowering season. It is also possible that pollen grains that had already fallen on the ground were refloated or these extra seasonal pollen grains may have come from plants which continued flowering out of the season, examples are Poaceae and *Elaeis guineensis* [1].

The frequency of pollen grains generally depends on the distribution and density of local vegetation *vis-à-vis* the rate of pollen production. Pollen grains are generally found during their respective pollination period. Wind pollinated plants produce a large number of smooth-walled pollen grains which are often inconspicuous, colourless and lacking nectar. Such pollen grains are mostly found in the air and are potentially more allergic than the insect pollinated i.e. entomophilous plants. Some of the dominant aeropollen grains identified in this study have been proven to be perennial or seasonal causes of allergy. Example of such pollen types associated with allergic manifestations is shown in Figure 1 and data for allergy-related cases are presented in Table 4.

It is worthy to note that cases of Conjunctivitis, Dermatitis, Rhinitis and Upper respiratory tract infection were reported all through the study period; whereas allergy was reported in other months of the study except March, April and June; Bronchitis were reported in all other months of study except March while Hay fever was reported in the months of October, November, December and July only [15].

Results showed that a total of 3,826 patients were diagnosed of seven allergy-related cases. Highest reported cases of allergic manifestations were recorded in the month of October while the least reported cases were recorded in August (Table 4).

Table 4: Summary of allergy-related cases recorded in the study (Oct., 2016 to Sept., 2017)

Month	Allergy	Bronchitis	Conjunctivitis	Dermatitis	HF	Rhinitis	URTI	Total
October	21	13	21	43	508	8	310	**924**
November	2	17	45	68	2	23	166	**323**
December	8	11	25	54	1	16	270	**385**
January	21	7	21	35	0	13	411	**508**
February	7	5	11	17	0	8	33	**81**
March	0	0	9	13	0	5	65	**92**
April	0	5	6	22	0	3	98	**134**
May	4	1	9	24	0	6	131	**175**
June	0	1	5	29	0	12	17	**64**
July	3	1	14	11	812	7	27	**875**
August	3	2	11	7	0	3	21	**47**
September	5	13	21	32	0	12	135	**218**
TOTAL	**74**	**76**	**198**	**355**	**1,323**	**116**	**1,684**	**3,826**

LEGEND:
HF: Hay Fever; **URT:** Upper Respiratory Tract Infection
SOURCE: Ige and Essien, 2019

3.3. Pteridophyte spores

Spore of pteridophytes constitutes a very low proportion of the total palynomorphs encountered in the study (Tables 1). 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 (877) were more abundant than the trilete spores (54). The results presented in this study showed that a considerable number of the fern spores were recorded in the months of April and May 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 ferns sporulate due to unfavourable conditions [71]. Nevertheless, the unusual increase in the abundance of fern spores in the months of October, September and November respectively could be attributed to the action of meteorological factors for example wind; which waft up the dried and already deposited dry air-spora into the air current (wave) causing an unusual increase in the atmosphere [13]. Photomicrographs of some selected palynomorphs are presented in figure 1.

3.4. 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 (Tables 1). A reasonable number of them was trapped at all the locations and was recorded from the air throughout the study duration especially during the dry period of the year. They serve as indicator of bush burning and can be used in monitoring the intensity and frequency of bush fires. Findings agree favourably with the report of Agwu [20], Morley and Richards [72] who demonstrated the application of 'Charred Graminae 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, highest number 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 widely reported [6, 23, 73].

3.5. Diatom frustules

The Diatom frustules were among the consistent particles recorded in this study and they represent an aspect of algal microflora in Akoko environment. A total of 2,962 Diatom frustules were encountered in this study (Table 1). They occurred in reasonable numbers 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 air-spora 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 [74] and

Hooghiemstra and Agwu [75]. 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 [1].

3.6. Dinoflagellate cysts

Among the other airborne palynomorphs encountered in this study are dinoflagellate cysts. A total of 120 dinoflagellate cysts were documented (Table 1). Dinoflagellate cysts first appear abundantly and very recognizable in palaeo-palynological preparations of marine sediments in Late Triassic. In the Jurassic, they are very abundant and very fast evolving making them ideal subjects for palynostratigraphy [34]. Dinoflagellates are marine phytoplanktons and their occurrence has been interpreted to indicate transgressive and highstand regimes [75].

Figure 1: Photomicrograph of some selected atmospheric palynomorphs

3.7. Arthropods/ parts

A total of 3,191 arthropods/ parts were documented in this study (Table 1). These represent the various parts, whole and moults of insects and insect parts recorded in the 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*. [76] 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.

3.8. Fungal hyphae and other palynomorphs

Few particles of fungal hyphae were recorded representing the enormous fragments circulating in the atmosphere. Fungal hyphae are among the common palynomorphs trapped in most aeropalynological studies. A total of 13 fungal hyphae were encountered in this study (Table 1). They serve as inocula for fungal infection or as saprophytes.

Also, some bryophyte particles were distinguished and recorded from the trapped particles. Other remains distinct from the charred ones and was also recorded as part of the bioparticles circulating in the atmosphere. Bryophyte remains, algal cysts and uncharred plant tissues (particles) recorded in this study may serve interpretational purposes in environmental reconstruction. An increase in insects and plant debris in any palynological preparation is useful in palaeoecological analysis and 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 [5] and Njokuocha and Osayi [23].

IV. Conclusion

The pollen types identified in this study reflect to a large extent the phytoecological vegetation of the studied environment. Such flora could be properly conserved and their exploitation adequately managed through appropriate biotechnological interventions. The percentage composition of the total airborne palynomorphs recorded showed that fungal spores constitute the dominant airborne palynomorphs, with 54.39% followed marginally by pollen grains (37.42%), among others. Some of this pollen grains, fungal spores, hyphal fragments, and insect particles have been associated with out-door allergens, while fungal spores and hyphal fragments constitute human, animal and plant pathogens with long history of epidemiology. Pollen of exotic plants and charred plant particles were part of the atmospheric palynomorphs content recorded as evidence of human impact and this confirm the great influence of anthropogenic activities on the local vegetation.

Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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