(RESEARCH ARTICLE)

The study of the effects of airborne fungal spores in allergic and pathogenic infections in Akoko environment, Ondo State, Nigeria

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Abstract

Fungal spores and hyphal fragments have been associated with out-door allergens and constitute human, animal and plant pathogens with long history of epidemiology. Airborne fungal spores of Akoko environment during the months of October 2016 to September 2017 were trapped and analyzed palynologically to determine the genera with allergic and pathogenic implications. Very high concentrations of these aerospora were documented. Out of 35 fungal spore type identified, the most commonly documented genera were species of *Nigrospora*, *Endophragmiella*, *Ustilago*, *Botryodiplodia*, *Curvularia*, *Pithomyces*, *Corynespora* and *Venturia* among others. The availability of these airborne fungal spore types is not only a reflection of their degree of abundance in the atmosphere, but an indication of the availability of host plants and other spore sources in the region. Statistical analysis shows that there was significant difference in the mean monthly fungal spore recorded. Multiple comparisons (using DMRT) showed that the mean fungal spores recorded in the month of October was significantly different ($P < 0.05$) from that recorded in the month of July but not significantly different from those recorded for other months. Seasonal variation showed that the highest mean monthly fungal spore abundance were more from June - July and October - December due to higher sporulation activities by the fungi. This study would provide relevant information that could be useful in monitoring the frequency and intensity of fungal allergies and other pathogenic disease conditions of plants, animals and humans in the study environment and proffer adequate measures for safety health and environment.

Keywords: Airborne; Allergy; Akoko environment; Fungal spores; Pathogenic infections

1. Introduction

Fungal spores are small eukaryotic unicellular, bicellular or multicellular reproductive bodies, cells or fragments adapted to survive in unfavourable environmental conditions. They may also be described as haploid dispersed reproductive bodies of non-embryophytic plants, having a very resistant outer wall (perine) and frequently occurring as fossils from Silurian to Holocene [1]. The spores arise from saprophytic or parasitic organisms (fungi) and are present in the air throughout the world, often as dominant biological components [2]. Fungal spores are among the most abundant airborne organic particles and least well known aeroallergens in Nigeria [3-4] and in countries where aeroallergens have been investigated [2], [5]. The spore wall which is made up of two layers (exosporium and endosporium) consists chemically of acetyl-glucosamine polymers (chitin) and β -glucomannans often with waxes and mostly coated with extracellular polysaccharides [2].

At maturity, the spores are discharged from the spore bearing structures into the atmosphere mostly by the action of wind, rainfall and bio-trigger mechanisms. According to Lyon *et al.* [6], the spore concentration measured in the atmosphere is as a result of a wide range of complex interrelated environmental and biological variables. Some fungi are associated specifically with certain plants and this plays a role in the type of spore that is release into the

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atmosphere. Agricultural crops, farm produce and organic wastes support massive population of fungi whose spores are released from the spore bearing cells either by active or passive mechanisms following seasonal periodicity in the maximum release of spores. Some spore types attain high concentration during the rainy or wet season (wet-weather air spora), while others are released in high concentrations during the dry season (dry-weather air spora). Since the sporulation and release of spores depend on the weather, their concentration in the air therefore fluctuates according to the prevailing meteorological conditions [7-8].

Rainfall is one of the major critical factors that have been reported to clean the atmosphere of biological particles though in some cases it has led to the release and increase in concentration of fungal spores in the atmosphere. Troutt and Levetin [8] recorded low concentration of *Alternaria* and *Cladosporium* in the air during periods of rainfall as against high concentration during the dry season while Chakraborty *et al.* [9] recorded a general reduction in spore concentration during periods of rainfall. However, given the fact that rainfall exerts significant effect on the growth and sporulation of fungi, studies have shown that the number and diversity of some spore types released into the air increases with the amount of rainfall suggesting that the spores may have been discharged by the mechanical effect of rainfall [6], [10]. Furthermore, Burge and Rogers [2] pointed out that during long gentle drizzles, more fungal spores are released than are washed out, often leading to much higher concentrations of spores during gentle rain than on sunny days without rain.

It has been reported that spore types released during rainfall are different from those that are released in the periods before rainfall, an indication of qualitative distinction in “wet-air spora” and “dry-air spora”. Investigations at different heights have also shown that spore release and the level of concentration in the atmosphere during periods of rainfall varies with height. Palynomorphs trapped at two different heights, recorded more fungal spores at the lower height [3]. The explanation was that the spore cloud released from host plants increased the atmospheric spore concentration with the result that the net values in spore concentration decreased progressively with increase in height due to the wash-out effect of rainfall.

Many fungi depend exclusively on wind movement for the release and dispersal of their spores. Many dispersal models predict that the particles of the size of pollen and spores will be deposited close to the surface of leaves (< 100m). Wind gusts may be important especially in dislodging spores from surfaces, either by direct sweeping of the surface or by causing adjacent surfaces to rub together [11]. Gusts also affect removal by bringing the spores near impact surfaces and by increasing their inertia so that impaction occurs [2]. Wind speed of various magnitudes contributes in increasing the concentration or abundance of fungal spores in the air. Waggener [12] reported that wind speed of 3 m/second for 15 seconds on a stationary leaf would remove 20% of spores of *Helminthosporium maydis*, while Aylor and Lukens [13] affirmed that in the course of over several hours in the morning, wind velocity of 1.0 m/sec speed released 60-75% of the spore of the same species whether the leaf was stationary or swaying. The spore contents of the atmosphere have been directly correlated with higher wind velocities. Lyon *et al.* [6] reported that maximum winds that approach the upper limits of the range of velocities were correlated with decrease in spore numbers in the atmosphere at a lower height. This was attributed to higher wind velocity which removes spores more rapidly and creates a sharp peak in spore concentrations in the atmosphere. Consequently, the sharp peak in spore concentrations decreased to levels below those maintained for longer periods with lower maximum wind velocities.

Temperature and relative humidity also influence the concentration and the rate at which the spores are discharged into the atmosphere. Relative humidity and temperature were reported to be among the most important factors involved in the release and dispersal of fungal spores [14]. However, Street and Hamburger [15] reported an inverse relationship between air-spore counts and mean temperature, dew point and humidity.

Studies of air-spores have led to the belief that fungal spores appear ubiquitous with varying concentration in the air irrespective of time and season. According to Gregory [16], the fungal spores do not present a defined seasonal prevalence pattern and often are distributed in a cosmopolitan fashion that does not follow geographic distribution. Recent studies have shown that individual fungal species sporulate and discharge more spores at certain seasons of the year which coincides with availability of host materials [17]. *Cladosporium*, *Nigrospora*, *Dreschelia* among others are favoured by the dry season for spore release while *Ustilago*, *Venturia* and *Pithomyces* among others release more spores during the wet or rainy season [2-3] [17]. Fungal spores floating in the atmospheric air can result in a variety of adverse health effects including allergic reactions and infectious diseases in man. Amplification of plant pathogens, bio-deterioration of equipment, buildings and storage materials are mostly as a result of airborne fungal spores.

Over the preceding years, asthma attacks have been related to spore abundance in the air. Skin tests reactivity to mold extracts has been demonstrated with positive result in many individuals [9] [18]. A skin prick test study of the allergenic potency of some fungal extracts by Chakraborty *et al.* [9] showed that *Aspergillus* sp., *Dreschelia* sp., *Fusarium* sp.,

Periconia sp., *Curvularia* sp., *Cladosporium* sp., *Ganoderma* sp. and *Nigrospora* sp. elicited a wheal reaction on the skin (itchy reddened swelling on the skin). Substantial evidence has been demonstrated to show that major groups of fungi contain allergenic substances [19-20].

Cashel *et al.* [21] suggested the possibility of synergistic interaction occurring due to overlapping effects of different types of fungal spores. Cutten *et al.* [22] pointed out that prolonged exposure to one allergic spore type creates a base level of susceptibility which can easily be increased with the addition of other spore types. The exposure to higher concentrations of aeroallergens or allergic proteins may also lead to more severe allergic responses [23-25]. Changes in meteorological factors can also affect the aeroallergen production and consequently the prevalence or severity of allergic illness via sensitivity and response pathways [26].

The allergic reactions associated with fungi sensitivity have been recognized as far back as 1926 [27]. Surveys conducted in various places showed that sensitivity to fungi is common particularly among asthmatic patients [27]. A possible correlation between the appearance of mold spores in the atmosphere and asthma attack have been widely reported [28-29].

Data on the composition and concentration of airborne fungal spores are important tools for allergic and source of plant pathogen diagnosis. It is a known fact that inhalation of mold spores can induce allergic respiratory symptoms [29]. In the United States, allergies and asthma cost more than \$30 billion annually on health care systems and loss of productivity. This was because about 54.6% of the people were reported to test positive for an allergic response to one or more allergens and more than 34 million diagnosed with asthma [30].

A periodic and continual check on the atmospheric pollen and spores content is essential, partly in order to establish the general role of fungal spores incidence, abundance and distribution, finding areas and seasons which are comparatively safe for allergic persons. The aim of this study was to identify the different fungal spore genera of biological importance present in the atmosphere of the study environment.

2. Material and methods

Twenty locations comprising forty sampling points were randomly selected within the four Local Government Areas of Akoko division, Ondo State, Nigeria, as sampling sites. The sampling sites for the study was purposely selected to reflect (represent) 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 [31].

At each site, a pollen trap (Modified Tauber Sampler) was mounted according to the methods of Tauber [32 - 33], Pardoe *et al.* [34] and Giesecke *et al.* [35]. 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 and/or recharged with the above mentioned chemical solution. This procedure was repeated bi-monthly from October 2016 to September 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 [36]. 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 [37], Bonnefille and Rioulet [38], Barnett and Hunter [39] and Kremp and Kawasaki [40]. In addition, prepared slides of pollen and spores samples in the Palynological Research Unit; Department of Plant Science and Biotechnology, Adekunle Ajasin University, Akungba- Akoko, Nigeria were used.

2.1. Statistical analysis of data

The mean monthly fungal spores' counts as well as the locations were subjected to analysis of variance (ANOVA). Means were separated using Duncan Multiple Range Test (DMRT) at $P < 0.05$ level of significance. All analyses were performed using the IBM SPSS Statistics Version 22.0.

3. Results and discussion

3.1. Airborne fungal spores

Fungal spores were the dominant component of the airborne palynomorphs recorded in the study. Out of thirty-five (35) fungal spore genera identified, those that were commonly encountered were species of *Nigrospora*, followed by *Endophragmiella*, *Ustilago*, *Botryodiplodia*, *Curvularia*, *Pithomyces*, *Corynespora*, and *Venturia* among others (Table 1). The variations in monthly fungal spore abundance/ distribution and at the locations respectively are shown in Figures 1 and 2. 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. They serve as inocula for fungal infection or as saprophytes.

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 and few fungal hyphae 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. Similar finding were reported by Njokuocha and Osayi [41] who opined that these airborne fungal spores are released from dead organic matter, infected plants and other sources through the impact of man on the environment. The airborne spores and hyphal/ mycelial fragments are major sources of inocula in plants infected by pathogenic fungi.

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 mushroom, 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 [2]. 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-spore (*Corynespora* sp., *Curvularia* sp., *Pithomyces* sp.) and wet air-spore (*Endophragmiella* sp., *Nigrospora* sp., *Neurospora* sp., *Ustilago* sp., *Venturia* sp.). Similar spore constitutions have been reported in airspora investigations in Nsukka and Anyigba by Agwu *et al.* [3], [42 – 43] and in related studies in other part of the world [8], [10], [14], [44 – 47].

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. The month of July recorded the highest amount of annual rainfall. 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 (Figure 1). Similar findings have been reported by previous authors [6], [8], [10] and [48].

Statistical analysis shows that there was significant difference in the mean monthly fungal spore record (Table 2). Multiple comparisons (using DMRT) showed that the mean fungal spores recorded in the month of October was significantly different ($P < 0.05$) from that recorded in the month of July, but is not significantly different from those recorded in the months of November, December, January, February, March, April, May and June (Table 2).

Variation in cumulative monthly fungal spore abundance is shown in Figure 1. The statistical analysis showed that the highest period of fungal spore abundance was recorded in the month of July and was significantly different from those of other months.

Table 1 Cumulative monthly fungal spores counts for the study period (October, 2016 – September, 2017)

S/N	Fungal spore type	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	TOTAL
1	<i>Alternaria</i> sp.	32	18	32	11	21	30	42	107	20	29	1	10	353
2	<i>Aspergillus</i> sp.	0	21	0	32	0	111	86	15	4	17	5	3	294
3	<i>Beltrania</i> sp.	6	13	5	10	0	3	6	10	6	0	0	2	61
4	<i>Botryodiplodia</i> sp.	596	586	496	125	209	261	713	947	2606	817	184	329	7869
5	<i>Cercospora</i> sp.	0	0	19	0	2	7	0	0	0	0	0	0	28
6	<i>Cladosporium</i> sp.	17	31	0	22	5	55	12	13	1	3	1	1	161
7	<i>Cordana</i> sp.	0	18	0	0	0	2	0	7	0	0	0	0	27
8	<i>Corynespora</i> sp.	233	280	733	247	54	71	125	444	192	186	199	103	2867
9	<i>Curvularia</i> sp.	772	576	646	404	311	627	485	425	450	154	91	205	5146
10	<i>Dictyoarthrinium</i> sp.	0	0	17	24	0	0	0	0	6	0	0	0	47
11	<i>Diplococcum</i> sp.	0	0	0	0	0	0	80	2	15	0	0	0	97
12	<i>Dreschelia</i> sp.	52	17	48	32	51	191	75	66	35	27	76	26	696
13	<i>Endophragmiella</i> sp.	1218	1202	2136	1200	793	371	757	1156	1662	2610	1135	1051	15291
14	<i>Epicoccum</i> sp.	0	0	8	0	0	2	4	11	2	2	0	2	31
15	<i>Exosporium</i> sp.	0	0	0	0	5	0	8	2	6	0	0	0	21
16	<i>Fusarium</i> sp.	29	0	5	0	0	0	0	9	4	8	0	1	56
17	<i>Ganoderma</i> sp.	14	7	33	2	8	3	23	57	20	75	73	11	326
18	<i>Glomastix</i> sp.	39	36	46	28	16	14	21	63	46	25	10	33	377

19	<i>Glomerularia</i> sp.	0	0	0	0	4	0	0	0	15	0	0	0	19
20	<i>Histoplasma</i> sp.	0	0	0	0	18	0	0	46	0	0	0	0	64
21	<i>Holerinema</i> sp.	0	0	0	0	37	0	0	63	0	0	0	1	101
22	<i>Murogenella</i> sp.	7	0	0	4	0	0	6	14	2	2	4	3	42
23	<i>Neurospora</i> sp.	292	34	11	17	15	22	47	21	8	5	4	1	477
24	<i>Nigrospora</i> sp.	3933	1821	1141	320	175	54	247	983	2597	5257	822	1148	18498
25	<i>Pithomyces</i> sp.	475	337	301	147	71	914	146	472	619	611	343	206	4642
26	<i>Puccinia</i> sp.	88	0	40	115	228	57	11	3	215	6	0	0	763
27	<i>Stemphylium</i> sp.	5	0	6	2	0	0	2	0	0	0	0	0	15
28	<i>Syncephalastrum</i> sp.	21	54	11	19	7	2	3	5	11	4	5	3	145
29	<i>Tetraploa</i> sp.	209	82	124	47	19	38	67	73	46	22	60	50	837
30	<i>Torula</i> sp.	102	25	12	5	1	7	33	93	55	146	24	91	594
31	<i>Uromyces</i> sp.	35	28	84	27	3	1	1	0	0	253	41	30	503
32	<i>Ustilago</i> sp.	1786	906	1839	918	399	369	493	864	1659	849	498	562	11142
33	<i>Venturia</i> sp.	252	83	29	10	13	9	41	87	407	686	52	89	1758
34	Fungal hyphae	0	0	0	0	0	13	0	0	0	0	0	0	13
35	Unidentified	0	0	8	0	0	270	0	3	0	0	0	0	281
Total fungal spore counts		10213	6175	7830	3768	2465	3504	3534	6061	10709	11794	3628	3961	73642

Figure 1 Variation in cumulative monthly fungal spore abundance

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 (Table 2).

Table 2 Mean monthly fungal spores abundance recorded during the study period

S/N	Month	Mean fungal spores±S.E
1	October	12.60±3.73 ^{ab}
2	November	4.15±3.29 ^a
3	December	1.45±1.21 ^a
4	January	0.50±0.41 ^a
5	February	0.65±0.51 ^a
6	March	0.45±0.36 ^a
7	April	2.50±1.80 ^a
8	May	4.35±2.23 ^a
9	June	18.95±2.30 ^b
10	July	34.30±11.93 ^c
11	August	2.60±2.45 ^a
12	September	4.45±1.45 ^a
p Value		0.000*

Means not followed by the same letter are significantly different at $P < 0.05$ (DMRT)

* - significant at $p < 0.05$

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.

It has been reported by Njokuocha and Ukeje [49] that fungal spore distribution is ubiquitous, and certain geographical locations may favour the production of great abundance due to the localized conducive micro-environment and the floristic structure which is a reservoir of fungal spores. Such variation in micro-climate may be responsible for the significant difference obtained in the fungal spore counts at the study locations, especially those of Location 10 (Ise Akoko) and Location 6 (Akunnu Akoko) which has the highest and total annual spore counts and mean counts of (19.02 ± 3.45^e) and (18.56 ± 3.51^e) respectively (Table 3). The complex vegetation structure in the study environment consists of woodlands, forests, and abundant grasses that are hosts and major reservoir of fungal spores. Secondly, the wet and humid conditions along the river tributaries 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. Such site-to-site variation is similar to the findings of Adhikari *et al.* [50] in which variation in wet and humid condition in two sections of rural indoor dairy cattle shed led to differences in spore record of the two sections.

Similarly, at the study locations, the ANOVA shows that there was significant difference ($P < 0.05$) in the mean fungal spores abundance recorded. Multiple comparisons (DMRT) showed that the mean number of fungal spore recorded in Ifira was significantly different ($P < 0.05$) from those recorded in Akunnu, Ise, Ipe, Ipesi, Sosan, Ayegunle, Ikaram and Irun, but not significantly different from those recorded at Isua, Auga, Iboropa, Ikare, Akungba, Oke-Oka, Supare, Arigidi, Ogbagi, and Oke-Agbe. However, those fungal spores recorded for Isua, Iboropa, Oke-Oka, Supare, Ogbagi, and Oke-Agbe was not significantly different from those recorded for Ifira, Ipe, Ipesi, Sosan, Auga, Ikare, Ayegunle, Oba, Arigidi, Ikaram and Irun (Table 3). Variations in cumulative fungal spores distribution across the study locations is adequately illustrated (Figure 2).

Table 3 Mean fungal spores abundance recorded at the study locations

S/N	Study location	Mean fungal spores $\pm$ S.E
1	Ifira	12.04 ± 2.48^{bcd}
2	Ipe	4.85 ± 0.94^a
3	Ipesi	4.34 ± 0.94^a
4	Isua	6.69 ± 1.16^{abc}
5	Sosan	4.95 ± 0.76^a
6	Akunnu	18.56 ± 3.51^e
7	Auga	6.18 ± 0.95^{ab}
8	Iboropa	7.83 ± 1.25^{abc}
9	Ikare	12.47 ± 2.59^{cd}
10	Ise	19.02 ± 3.45^e
11	Akungba	15.61 ± 2.97^{de}
12	Ayegunle	4.19 ± 0.67^a
13	Oba	11.81 ± 1.69^{bcd}
14	Oke-Oka	8.97 ± 1.36^{abc}
15	Supare	7.63 ± 1.18^{abc}
16	Arigidi	6.25 ± 0.85^{ab}
17	Ogbagi	8.55 ± 1.38^{abc}
18	Oke-Agbe	7.66 ± 1.26^{abc}
19	Ikaram	5.19 ± 0.91^a
20	Irun	5.22 ± 0.84^a
p Value		0.000*

Means not followed by the same letter are significantly different at $P < 0.05$ (DMRT).

* - significant at $p < 0.05$

Figure 2 Variation in cumulative fungal spore's distribution across the study locations

LEGEND: L1=Ifira, L2=Ipe, L3=Ipesi, L4=Isua, L5=Sosan, L6=Akunnu, L7=Auga, L8=Iboropa, L9=Ikare, 10=Ise, L11=Akungba, 12=Ayegunle, L13=Oba, L14=Oke-Oka, L15=Supare, L16=Arigidi, L17=Ogbagi, L18=Oke-Agbe, L19=Ikaram, L20=Irun

3.2. Allergic and pathologic effects of the identified fungal spores

Much has been reported about the abundance and cosmopolitan nature of fungal spores and their associated allergenic reactions (runny nose, watery and itchy eye) and diseases of humans, domestic animals and plants. In fact, they constitute very serious danger to immune-compromised patients. Some of the fungal spores identified in this study have been reported by several authors to cause allergies such as rhinitis, hay fever (pollinosis) and exacerbation of asthmatic attack as well as pathogenic infections of the respiratory tract (Table 1). Other spores identified are among the invasive airborne fungal spores that have been implicated in nosocomial (hospital) infection of patients with solid organ transplants, those treated for leukaemia and recipients of allergenic stem cell transplants [9], [18], [21], [27], [51 – 53]. Such spore genera identified included the species of *Alternaria*, *Aspergillus*, *Dreschelia*, *Cladosporium*, *Curvularia*, and *Nigrospora* among others.

These fungal spores that float in the atmosphere in large numbers have been reported to enter human nostrils, eyes, mouth or come in contact with the skin eliciting certain sensitization or irritation that promotes itching and inflammation of the affected organs. The spores and their hyphal fragments were also reported to be the main cause or exacerbation of some respiratory disorders such as asthma, allergic reactions and pathogenic infections of the respiratory tract [4]. Some invasive airborne fungal spores have been associated with nosocomial infections of patients with tissue or solid organ transplant/ surgery [27], [51]. The sensitization caused by the spores has been linked to the presence of chemical compounds such as protein, glycoprotein and proteases enzyme [54] localized in the wall and cytoplasm of the spores. In some cases, carbohydrate portions of the fungal extracts also show allergenic activity, although most IgE (Immunoglobulin E) binding activity is associated with the protein components. The direct cause of this allergy is said to be histamine given off by the white blood cells during the interaction between the antigen and antibody [55].

The sensitization to fungi is a major risk factor for the development of asthma and other bronchial diseases. Also, the risk of death from asthma has been correlated with the presence of fungal spores in the atmosphere [56]. Of the fungal spores, *Alternaria* sensitivity has been shown to be a risk factor for asthma attacks. It could lead to severe and potentially fatal asthma, particularly in areas where the spores occur in predominant quantity in the atmosphere [57 – 59]. It has been demonstrated that inhalation of either *Alternaria* or *Penicillium* spores can induce both immediate and late phase asthma in sensitive individuals [60].

Generally, it has been shown that many airborne fungi are allergenic and an inhalation or exposure to their spores may result in adverse health effects such as rhinitis or asthma [61 – 62].

Pathologically, most fungal species identified in this study have also been associated with diseases of many agricultural crops and wild plants in Nsukka and many other places [17], [63]. Such diseases are loose smut of wheat, maize smut (*Ustilago* sp.), leaf blight and spots, purple blotch, damping-off and scab caused by *Alternaria* sp., *Dreschelia* sp., early

leaf blight of tomato (*Cladosporium* sp.) and cassava blight (*Alternaria* sp.) among others [64 – 65]. Most of these fungal pathogens showed multiple and whole plant host ranges, while some others are saprophytic on agricultural produce. Their prevalence in the atmospheric air is a reflection of their entrenchment and serious threats to agricultural crops, their produce as well as wild plants.

4. Conclusion

Exposure to fungal allergens is considered to occur more frequently from outdoor environment, though indoor contact also occurs. Exposure to indoor fungal allergens is considered to be a reflection of the fungal spores arising mostly from the outdoor environment which invades the indoor through the openings in the house. Both indoor and outdoor fungal spore exposure are considered important and may cause asthma, hay fever and hypersensitive *Pneumonitis* in sensitive individuals and increase the chances of contracting any of the invasive mycoses. Airborne fungal pathogens are of major interest because of their associated plant diseases leading to agricultural losses. They cause diseases such as loose smut of wheat (*Ustilago tritici*), maize smut (*Ustilago maydis*), leaf blight and spots (*Alternaria* sp., *Curvularia* sp., and *Dreschelia* sp.). Others include early blight of tomato (*Cladosporium*, sp.), Cassava blight (*Alternaria* sp.) and damping-off disease of tomato (*Fusarium* sp.), among others. Some species of *Aspergillus*, *Torula*, *Dreschelia*, *Fusarium*, *Curvularia*, *Alternaria* and *Rhizopus* have been implicated in bio-deterioration of equipment, house paints and storage materials.

Since sporulation and release of spores depend on the weather, their concentration in the atmosphere therefore fluctuates according to the prevailing meteorological conditions. The presence and dominance of these aerospora in the atmosphere affirms the influence of anthropogenic activities on the local vegetation.

The highest period of fungal spore abundance was recorded in the month of July and was significantly different from those of other months. Seasonal variation showed that the highest mean fungal spore abundance was 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. Avoidance of exposure to fungal allergens during their season of abundance and prevalence in the atmosphere is highly recommended.

Compliance with ethical standards

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The author declares that there is no conflict of interest.

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