

### Allergologia et immunopathologia

Sociedad Española de Inmunología Clínica, Alergología y Asma Pediátrica

www.all-imm.com



### REVIEW ARTICLE



### A review of aeropalynology research in Nigeria: implication on public health and environmental research collaboration

Linus Bashie Ajikah<sup>a,b\*</sup>, Olugbenga Shadrak Alebiosu<sup>c</sup>, Emuobosa Akpo Orijemie<sup>d</sup>, Dough Onahb

- <sup>a</sup>Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa
- Department of Plants and Ecological Studies, University of Calabar, Calabar, Nigeria
- Department of Botany, University of Ibadan, Ibadan, Oyo, Nigeria

Received 22 February 2021; Accepted 1 June 2021 Available online 1 November 2021

### **KEYWORDS**

aerospora; allergic; epidemiological; pollinosis; susceptible

Background: Aeropalynology is a branch of palynology that studies the content of atmospheric pollen grains and spores. The amount, concentration, and distribution of these aerospora are influenced by the seasonal flowering of parent plants and variations in climatic conditions as well as local and regional variabilities. Atmospheric pollen grains and spores are diverse and have been identified as major biological particles that trigger immune cells to release inflammatory chemical mediators, inducing respiratory-linked and allergic conditions, such as pollinosis, among susceptible individuals.

Objective: The burden of these allergic conditions on patients, families, healthcare systems, and governments has risen globally, thereby affecting developing countries, including Nigeria, wherein the financial and infrastructural institutions are not effective enough to mitigate these challenges. Avoidance of allergenic aerospora is an effective mode of addressing pollinosis with its associated conditions. However, there is a need to ascertain the atmospheric quantity, diversity, and pattern of occurrence of allergenic pollen/spores.

Results: In this paper, we reviewed published articles on aeropalynology in Nigeria with attention to the design and duration of the study and the used equipment. We further investigated whether identification and quantification of allergy-causing palynomorphs was part of published articles' foci.

Conclusion: The availability of such data/information is crucial for reducing epidemiological uncertainties, enhancing the diagnosis of allergic conditions, and securing a robust set of mitigation strategies and/or effective treatment of these conditions in Nigeria.

© 2021 Codon Publications. Published by Codon Publications.

\*Corresponding author: Linus Bashie Ajikah, Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa. Email address: linus.ajikah@wits.ac.za

https://doi.org/10.15586/aei.v49i6.241

Copyright: Ajikah LB, et al.

License: This open access article is licensed under Creative Commons Attribution 4.0 International (CC BY 4.0). http://creativecommons.org/

<sup>&</sup>lt;sup>a</sup>Department of Archaeology and Anthropology, University of Ibadan, Ibadan, Nigeria

### Introduction

The Anthropocene Epoch describes the present era of globally pervasive and steeply increasing human influence on planet Earth, including the land surface, biosphere, and atmosphere.<sup>1,2</sup> Human activities have become a driving force that have changed many characteristics of our environment such as climate, biodiversity, vegetation, and air quality on local, regional, and global levels. Some of these anthropogenic impacts occur through changes in land use, agriculture, fossil fuel burning, vehicle emissions, and release of industrial emissions.<sup>3,4</sup> Consequently, the atmosphere of the present Anthropocene Epoch is laden with many kinds of suspended particles of organic and inorganic origins; they have a great diversity in size, shape, and density, and are from diverse sources.<sup>5</sup> These atmospheric substances are inhalable and can trigger various allergic conditions, including allergic rhinitis, conjunctivitis, asthma, hay fever (pollinosis), and atopic dermatitis. Some aeropalynological investigations have revealed that pollen and fungal spores (aerospora) are the most dominant, pervasive, respirable, and potent sources of allergens present in the atmosphere, resulting in morbidity among hypersensitive individuals.6 They are the major atmospheric bioaerosols and vary with geographic region, blossom period, and meteorological factors. In addition, climate change and air pollution influence the bioavailability and potency of allergenic aerospora and adjuvants in multiple ways. In addition, changes in vegetation cover, pollination, and sporulation periods, as well as chemical modifications, also affect aerospora. Moreover, climatic conditions, air pollutants, and human-induced changes in climate may skew physiological processes and the immune system toward the development of allergies. These changes impact the human health and environment by influencing the spread of allergenic pollen grains, fungal spores, and other biological aerosols, 8,9

The dispersal of atmospheric particles of biological origin has been reported to cause public health impacts among teeming urban human population, giving rise to the elicitation of allergenic conditions, including allergic rhinitis, conjunctivitis, itching of the eyes and skin, and exacerbation of asthma and related conditions, among others. This subsequently burdens the individual, particularly those in the working group and subsequently on global healthcare systems with more socioeconomic expenditures. Hence, there is a need for collaboration among scientists, including palynologists, geographers, climatologists, health practitioners, and clinicians.

A large amount of pollen grains and spores are found in the atmosphere. In the temperate regions, a large percentage of such pollen comes from flowers of anemophilous plants from gymnosperms and angiosperms. When pollen grains and spores (palynomorphs) are released, they usually form hazy dust or clouds that are carried in the wind.<sup>6</sup> In the tropical regions, especially in rainforest ecological zones, such phenomenon is hardly noticeable. Consequently, determining the types and amount of airborne palynomorphs is crucial and helpful for patients suffering from allergic diseases.<sup>10</sup> One such common allergic disease is pollinosis, commonly referred to as hay fever. It has been established that this pollen-induced allergy

is caused mostly by wind-transported pollen grains.<sup>11</sup> Therefore, the prediction of aeropollen or specifically those with allergenic properties (aeroallergen) is important. One can identify the "culprit" palynomorphs by providing data about the diversity and amount of atmospheric pollen and spores during specific periods and environmental (weather) factors that influence their occurrence. It is for this primary reason that pollen calendars are prepared, and this sub-discipline is called aeropalynology.

### What we know (a brief history of aeropalynology in Nigeria)

Aeropalynology as a sub-discipline was initiated at the University of Ibadan in the 1980s. The bulk of data came in the form of students' undergraduate and postgraduate dissertations. Aeropalynology research was also initiated by Prof COC Agwu, Dr Njokoucha, and their students at the University of Nigeria, Nsukka. Profs Olowokudejo and Ogundipe and Associate Profs OH Adekanmbi and PA Adeonipekun, and their students started aeropalynology research at the University of Lagos. The major findings were that aeropollen were anemophilous in nature, accompanied by a few entomophilous pollen types. A high diversity of fungal spores existed; and high aeropollen abundance and diversity correlated with weather conditions such that high amounts of aeropollen are observed at the end and beginning of wet and dry seasons, respectively. Other factors that influence aeropollen include vegetation, topography and altitude of study sites, and demographic variables. Following are the three areas of aeropalynological research crucial for its success and/or validity: (i) efficient pollen trap, (ii) robust counting and identification methods; these are aimed at reducing any errors, and (iii) application of aeropollen data in the medical field of allergy and respiratory diseases and environmental monitoring, which has remained underdeveloped till now.

Three main pollen type straps have been employed for pollen sampling in Nigeria, namely (i) any type of container, plastic or metal, with an opening to trap palynomorphs; (ii) a Tauber or modified Tauber pollen trap, which more or less functions as the above-mentioned container trap, except that it is fitted with a ≥250-µm mesh at the top or opening or mid-way into the container; and (iii) Agwu M6-5;12 and Gbenga-213 samplersboth are modified forms of above-mentioned Tauber trap. The first pollen trap is set up as follows: A plastic or metallic container of 10-30 cm in height and 10-20 cm in diameter is selected. Glycerol and either glacial acetic acid (GAA) or a mixture of formaldehyde and phenol are added in this container. Glycerol is used to prevent the drying up of the container and its contents, while any one of the latter compounds, that is GAA or formaldehyde and phenol, prevents decaying of organic matter and ensures minimal or no insect attack on organic material. The Tauber pollen trap was designed as a gravity sampler to sample particles in air-flow, that is to say, for pollen deposition.14 In 1965, it was used to trap pollen.15 Subsequently, it was adopted for aeropalynology research. The Agwu M6-5 and Gbenga-2 samplers are modified Tauber traps. For a long time, the Tauber

**Table 1** History of aeropalynological research, duration of sampling, and purpose of each research (only published sources) in chronological order.

Investigator(s)	Region in Nigeria	Mode/duration of sampling	Purpose and results of research
Agwu et al. (2004) <sup>21</sup>	Southeast	November 1991- February 1992 (4 months)	Survey; pollen and other palynomorphs were recovered in high quantity.
Njokuocha & Osayi (2005) <sup>22</sup>	Southeast	September 1999- February 2000 (6 months)	Survey; recovered pollen grains of plants around the study location.
Njokuocha (2006) <sup>12</sup>	Southeast	February 1993-January 1994 (12 months)	Survey; recorded the highest pollen in the late rainy season early dry season.
Adekanmbi & Ogundipe (2010) <sup>23</sup>	Southwest	February-May 2007 (4 months)	Survey; total aeropollen abundance was highest in the rainy season.
Adeonipekun & John (2011) <sup>24</sup>	Southwest	March 2010	Survey; study revealed the presence of savanna and derived savanna pollen grains.
Adeonipekun (2012) <sup>13</sup>	Southwest	March 2011	Survey; dominance of Poaceae and Amaranthaceae was observed.
Essien & Agwu (2013) <sup>25</sup>	North-Central	March-December 2012	Their study provided a template used to monitor the frequency and intensity of fungal allergies and various disease conditions of plants, animals, and man in the surrounding Savanna environment, and provide adequate restoration and conservation measures for safety and health and environmental sustainability.
Adeniyi et al. (2014) <sup>26</sup>	Southwest	January-December 2013	Survey; pollen counts were highest in dry season (October) and lowest in rainy season (June).
Ajikah et al. (2015) <sup>5</sup>	Southwest	April-June 2014 (3 months)	Survey; recovered pollen types showed a correlation with the surrounding vegetation.
Adekanmbi et al. (2018) <sup>27</sup>	Southwest	July 2015-June 2016 (1 year)	Pollen allergy studies: differences were observed between the levels of certain hematological and serological parameters elicited by each test group and sensitization periods. Hair loss (alopecia) was observed on the skin of a Mus musculus in the Alchornea cordifolia test group.
Alebiosu et al. (2018) <sup>28</sup>	North-Central	July 2015-June 2016 (1 year)	Survey; Findings revealed seasonal distribution patterns of various airborne pollen types at the study locations.
Ezike et al. (2016) <sup>29</sup>	North-Central	June 2011-May 2012 (1 year)	Survey; they provided insight about the relationship between the prevalence of aerospora and meteorological parameters.
Orijemie & Israel (2019) <sup>30</sup>	Some parts of Nigeria	December 2015-April 2016 (5 months)	Environmental monitoring; the study provided data of travel history and routes of vehicles; the dominant palynomorphs were those of Poaceae, secondary forest, and herbaceous taxa.

trap was used for aeropalynology research. However, there were concerns about the accuracy of pollen data so derived as well as the effect of contamination of the trap itself. Peck<sup>16</sup> observed that Tauber pollen sampler trapped smaller size pollen less efficiently compared to larger ones. Krzywinski<sup>17</sup> challenged accuracy of the results obtained from Tauber sampler during the rainy season, because it was observed that rain splash transferred pollen from the ground onto the traps, thereby compromising integrity of the results.

In recent times, Behling, Oldfield, and Burkard pollen traps have been used for daily pollen records because they provide more accurate and error-free data. The most common and effective of such traps is the Burkard pollen trap. The Burkard raps record pollen types, reflecting the local anemophilous vegetation of their study sites; hence, these both are effective in trapping pollen. However, no contamination challenge has been associated with the Burkard trap. The Burkard pollen trap was designed in 1952 by Dr James Hirst. The Burkard trap is a suction slit impactor, wherein air is drawn into a 14  $\times$  2-mm orifice at a rate of 10 L/min; the head rotates into the oncoming wind by means of fins and the 10-mm  $\times$  3.7- $\mu$ m pollen-trapping orifice traps the smallest spores efficiently. (see Table 1 for an overview of historical aeropalynological research). The surkard pollen traps is the smallest spores efficiently.

# Challenges/limitations to the study of aeropalynology in Nigeria

As stated above, some success has been recorded in the field of aeropalynology in Nigeria. However, following are the constraints to the study in different parts of Nigeria.

- 1. One of the major problems associated with the study of aerospora in Nigeria is the considerably vast diversity of species. Oftentimes, one finds that plant distribution within the same genus and family occurs across a wide geographical region. Therefore, vegetation is a major contributor to the array of pollen types recovered in the atmosphere of any location. 12,13,28 Owing to its variable geographic and climatic attributes, Nigeria has a rich plant diversity, in which almost 7895 plant species have been documented.31 Basically, the Nigerian vegetation is controlled by climate, with special reference to the mean annual rainfall and extent of dryness in a season, suitably determined by minimum relative humidity and the period of no rainfall.<sup>32</sup> The climax vegetation in the southern part of the country is a wetter rainforest, while that in the northern part is a woodland-type sandwiched by grasses, implying a primary composition of forest and savanna zones.<sup>32</sup> In view of this immense plant diversity, collaborative efforts by Nigerian taxonomists assist in acquiring a sufficient understanding of the flora in different parts of the country. This consequently aid palynologists in collecting and analyzing polleniferous material from different identifiable plants. This provides more taxonomic information about pollen types and their distinct features for easy identification in aeropalynological studies. Once this is achieved, there would emerge more pollen libraries (print and electronic) comprising reliable pollen albums, atlases, and type slides as well as other reference material for the future use.
- 2. Another drawback in the practice of aeropalynology in Nigeria is the lack of accessibility to advanced microscopy for achieving an elucidated pollen ultrastructure. The modern trend in technology has undoubtedly helped in the advancement of microscopy that is greatly relevant in the process of capturing, identifying, characterizing, and interpreting the recovery of palynomorphs, considering their well-detailed morphological features of diagnostic value. Presently, one major problem faced by scientists in Nigeria and several other parts of Africa is the short supply and access to scanning electron microscopes. These are found and operational at very few places within the continent and elsewhere in the world. This may be due to their relatively expensive cost and difficulty in maintaining them. This has greatly affected research outputs in the continent, as there is likely to be a dearth of alternatives if the palynomorphs become obscure under the light microscope.

However, few pollen morphological studies have been done in Nigeria using both light and scanning electron microscopes; this has contributed to the knowledge of various morphological properties exhibited by palynomorphs. These include the study conducted by Sowunmi,<sup>33</sup> involving the use of scanning electron microscope in studying pollen grains of about 40 plant

- species; this has aided tremendously in further examining pollen types with undetectable characters under light microscope. In addition, Adekanmbi et al.<sup>34</sup> provided additional characters as a guide to plant taxonomy as well as reference material for routine-based analytical studies in palynology.
- 3. There is also a problem of pollen polymorphism that occurs when the pollen of a plant species exhibit more than one morphological feature, particularly shape and apertural status. Consequently, in some cases this has caused pollen identification cumbersome, leading to a few uncertainties in palynological inferences. Instances include *Elaeis guineensis* and some other members of the same family Arecaceae, which produce morphologically dissimilar monosulcate pollen;<sup>35</sup> members of different plant families of Cucurbitaceae and Rutaceae also produce morphologically similar colporate and prolate pollen types.<sup>36,37</sup>

More so, setbacks in allergenicity studies of potential pollen allergens in Nigeria include (i) inadequate understanding of phenological shifts among plant species<sup>28</sup> during collection of pollen samples; (ii) difficulty in accessing human subjects; and (iii) its accompanying complexities of ethical issues. Adekanmbi et al.<sup>27</sup> cited the work of Conejero et al.,<sup>38</sup> and stated that an important limitation in their study of allergenicity was the subcutaneous route of *Mus musculus* sensitization. This phenomenon varied from that of human sensitization and accompanied by probably differential immune responses and disease manifestation.

With the use of human subjects, pollen allergenicity tests have been conducted in other parts of the world. In India, previous researcher, including Acharya<sup>39</sup> and Agashe and Anand,40 have rendered credence to Albizia lebbeck, Artemisia scoparia, Ricinus sp., and Salvadora sp. as important pollen allergens. Singh et al.41 recorded positive skin reactions to Pinus roxburghii obtained from the foothills of Himalayas in 16.9% of patients administered with it. High sensitivity to Cocos nucifera has been reported by Karmakar et al.<sup>42</sup> In France, Caillaud et al.<sup>43</sup> conducted a panel study in 10 towns and observed that ocular and respiratory symptoms were less frequent than nasal symptoms. In the United States, Galant et al.44 detected during sensitization of aeroallergens in California patients with respiratory allergy that asymptomatic control subjects responded to only 4% of all allergens tested. In Bratislava, Ščevkova et al.45 examined relationship between pollen exposure of selected allergenic plants and concentration of allergen-specific Immunoglobulin E (IgE) in the sera of patients with seasonal allergy. They observed in their findings that the patients were most frequently sensitized to Poaceae and Ambrosia sp., and commented that pollen allergens affecting the immune system for a more extended period may induce some tolerance, characterized by a lower specific IgE level. Bastl et al.46 investigated relationship between measured allergen content of birch and grass pollen types, pollinosis symptom load in allergy sufferers and airborne pollen concentrations in Australia, Germany, France, and Finland. Their investigations noted that allergens of these plants vary with seasons and regions of study but increased with an increase in symptom load.

# Efficient pollen trapping: drawbacks in the use of volumetric pollen traps in Nigeria

The Burkard Hirst-type volumetric spore trap<sup>47</sup> has been recommended and employed to achieve local and regional aerobiological sampling in many parts of the world.<sup>48</sup> It has been used extensively to conduct continuous airborne pollen monitoring in Europe, compared to other discontinuous or nonvolumetric samplers, such as Rotorod, Cour, and Durham.<sup>49-52</sup> In Nigeria, most aerobiological research studies are completely dependent on the use of nonvolumetric, modified Tauber samplers,<sup>14</sup> inarguably providing a view of pollen and spore depositional rates at selected study sites. Previously, workers in Nigeria employed these samplers, thereby drawing inferences based on dominant pollen types.

Faegri and Iversen<sup>53</sup> affirmed that the use of Tauber trap could provide an insight into pollen distribution and deposition but also opined that the depositional processes are inaccurate and not natural. However, the Burkard volumetric spore traps possess a higher advantage of providing absolute pollen concentrations (in cubic meters), unlike the use of Tauber trap, wherein pollen levels are estimated based on a more tedious analysis of microscopic counts.

Difficulties in the successful use of volumetric spore traps for continuous and standardized monitoring of pollen levels in Nigeria and indeed most of the Third World countries include high cost of procurement, insecurity of equipment, unavailability of constant power supply, and limited technical know-how.

# Way forward to successful pollen monitoring in Nigeria

A deep understanding of the cyclicity of annual, diurnal, and seasonal fluctuations in fungal spores and pollen types in any geographical area is mandatory for the effective diagnosis and treatment of pollen allergies. A national network of pollen and spore traps in Nigeria as a collaborative exercise between allergists and botany or palynology departments of Nigerian universities has become a necessity. A

#### Aeropalynology research and health practitioners

The majority of aeropalynology research in Nigeria, as part of their goals, has the following: (i) construction of a pollen calendar, and (ii) identification of possible allergen pollen and/or spores for pollinosis. The first goal is significant because pollinosis has an "annual periodicity, with symptoms usually occurring at the same time of the year, during pollination."<sup>55</sup> Pollen data collected from different localities from a few months to 1 year in Nigeria, <sup>12,13,20,21,24,26-28,49-52,56</sup> suggest that some pollen and/or spore types, based on their abundance or otherwise, could be responsible for allergenic reactions among patients of hay fever. For instance, it has been reported that Poaceae grains have a high possibility of stimulating pollinosis reaction in patients, <sup>26</sup> but neither this has been tested nor there are any proofs of such relationships in Nigeria. The idea

seems to have been borrowed from Europe,<sup>55</sup> Australia,<sup>57</sup> and Asia,<sup>58</sup> where several grass pollen types have been identified clinically to possess allergenic properties. In other words, there is no clinical basis for claiming that certain pollen and spore types could be allergenic. In other cases, pollen contents of the atmosphere have been identified from unusual media,<sup>59</sup> and a few have been suspected as allergens. Njokuocha et al.<sup>22</sup> and Ezike et al.<sup>29</sup> suspected that some fungi could be implicated in allergic diseases, yet these suggestions were not subjected to clinical trials.

Probably, Adeniyi et al.26 were the first to compare aeropollen data with hospital records regarding the incidences of pollinosis (hay fever). In their study, they used pollen data to identify pollen types with allergenic potential and indicated that in Shomolu, Lagos, Ludwigia and Cyperaceae had positive correlation with the occurrence of asthma/rhinitis, 25 and went a step further by collecting records of 3826 patients who were diagnosed with allergy-related diseases. Maximum incidences occurred in October and July, as both months yielded the highest amount of aeropollen. However, no skin prick or provocation test was conducted in case of both months. Therefore, in Nigeria, huge lacuna is detected between the generated aeropollen data and the incidence of pollinosis. This could be connected to the lack of hospital and/or clinical pollinosis data, or cooperation of medical staff as well as the bureaucratic process required to secure such medical data for aeropalynology research. This challenge could be taken care of by having appropriate hospital or clinic department and staff, especially otolaryngologists, at the planning stage of aeropalynology research, active participation in the field work and collection of data, and joint presentation at conferences and in publications. Adeniyi et al. 56,60 were the first to report allergenic proteins and their impact on the health of allergen-susceptible individuals in Nigeria. Allergenic proteins were isolated from Alchornea cordifolia, Amaranthus hybridus, Casuarina equisetifolia, and Terminalia catappa, the pollen types of which were previously recovered in abundance from aeropollen data in the study location of Lagos State. A major result of the above-mentioned research was that "the allergenicity ranking of pollen grains is dependent on the type of allergenic proteins in the pollen and the nature of the susceptibility of the individuals selected for the study."60 Hence, Adeniyi et al. 60 suggested that in Nigeria, the isolated allergenic proteins could be explored to develop immunotherapy drugs to treat allergies.

#### Aeropalynology and environmental monitoring

A few of aeropalynology studies have focused on environmental monitoring, climate change, and generation of data for making other palynological implications. <sup>61,62</sup> These studies suggested that routine aeropalynological monitoring could provide early signals of vegetation response to climate change. Therefore, a synergy of all aspects of aeropalynology research is required with clearly defined goals in the form of a national pollen monitoring program. The main goals of such a program could be to: (i) understand the aeropollen of certain regions with a view to producing a national or regional pollen calendar, (ii) understand

pollen rain of local vegetation and their dependence on meteorological effects data, (iii) conduct an evaluation of the effect of aeropollen impact on allergic individuals, and (iv) decipher the effect of climate change on flowering seasons, diversification of vegetation, and biogeography of a particular region. In Nigeria, aeropalynology research has included climate change as part of its goal. 13,24,30 Adeonipekun and John<sup>24</sup> studied an unusual dust that swept across Nigeria in March 2010; they found that the dust was from a late Harmattan period. This late occurrence of the Harmattan dust indicated a delayed inter-tropical continental zone whose position should have moved further north but maintained it until the month of March 2010. This study suggested a climate change experience resulting in a longer and/or highly seasonal dry period in southern Nigeria.13 Adeonipekun<sup>13</sup> further confirmed the inferences made by Adeonipekun and John<sup>24</sup> Similarly, Orijemie and Israel<sup>30</sup> sampled the air filters of 20 vehicles that travelled to several parts of Nigeria with the aim of using the associated palynomorphs to reconstruct their routes. Reconstruction of the routes was successful in 75% of vehicles. A significant aspect of the study was the occurrence of pollen type of a Mediterranean plant (Alnus cf. glutinosa) in the northwestern areas of the country. Alnus glutinosa does not grow in Nigeria; hence, its occurrence indicated the significance of wind activities prevalent in that region. It was also a reflection of changing climate<sup>63</sup> reporting the transport of pollen type of the Guinea savanna mosaic ecological region from localities distant from their study sites in Ondo State, which is in the forest zone of southern Nigeria.

A major part of Goal 3, that is, "Good Health and Wellbeing," a critical part of the United Nations Sustainable Development Goals (SDG), is air quality. Employing environmental monitoring as a tool in assessing environmental conditions and trends is not very popular in Africa, although it is guite common in Europe and Asia. Aeropalynology offers an exciting opportunity to contribute to the emerging data on air quality, necessary to support policy development and implementation at national and regional levels. Air pollutants have adverse effects on human health and ecosystems. The key is to use aeropollen data as air pollutant indicators, and employing the same to provide or advocate for national environmental policy. In cases where these are already available, they could be adjusted or improved based on aeropollen and pollutant and/or environmental degradation indicators. A new direction in which pollen identification and counts are heading is automatic pollen sampling.64 It has been shown that the Swisens digital pollen monitoring technology identifies particles within seconds and allows for the calculation of actual local pollen-taxa concentration with a time resolution of minutes. Preliminary results revealed that "more than 87% of 15 different pollen species were correctly classified."64 It is, however, not clear as to how this would work in a tropical setting where palynomorph diversity often ranges from 30 to 65 pollen grains, excluding (pteridophyte and fungal) spores and other cells! In a similar vein, several aeropalynology studies have wrong identification of pollen and spore types. This is a serious issue that must be tackled because of the dangers of wrong identification in any aeropalynology research.

The International Association for Aerobiology (IAA) is a global body that coordinates all national aerobiological programs. Founded on September 11, 1974 in The Hague. The Netherlands, today IAA has about 800 members. It publishes the biannual International Aerobiology Newsletter and organizes training and short basic- and advance-level courses in aerobiology. These courses are predominantly conducted in Europe and seldom in the United States. The palynology community of Nigeria must take advantage of these opportunities for a better understanding of the subject and collaborations with countries having advanced knowledge of aerobiology (adapted from https://sites.google.com/site/aerobiologyinternational/). In 2019, the first worldwide network of automatic pollen monitoring station (Electronic Pollen Information Network [ePIN]), which could recognize different pollen species, was launched online in Bavaria, Germany. 65 ePIN is a hybrid system comprising eight automatic and four manual Burkardttype pollen traps. According to Buters et al.,65 the project was sponsored by the Bavarian Ministry of Health and Care and the Ministry of Environment and Consumer Products, and established by the Bavarian Health and Food Safety. The ePIN recorded birch pollen at the end of May 2019, an occurrence that had hitherto not been recorded.

### Future goals and recommendations for Nigeria

- Expansion of pollen monitoring in the northwestern parts of Nigeria as well as in the neighboring countries of Cameroon, Benin Republic, Togo, and Ghana in West and West-Central Africa. This would assist to produce a database of aeropalynological and health- and/ or environment-related issues in Nigeria and West and West-Central Africa.
- Rural areas of Nigeria also need to be covered. The cities and towns also need to be monitored, particularly in the oil-rich Niger Delta where gas flaring has been going on for years. Other areas where air pollution and risk of asthma are high should not be left out.
- There is a need for collaboration and synergy within African nations in all the four regions—north, west, east, and south.<sup>55</sup>
- 4. Collaboration with hospitals and other healthcare facilities is essential. The training and knowledge exchange of students and researchers should be conducted in countries where pollen monitoring has been established firmly. This would aid the improvement of methods, including automated counting.

### Acknowledgments

We are grateful to the Wits School of Governance for sponsoring the "Life in the City" project and providing funds to Linus Bashie Ajikah for postdoctoral research at the University of the Witwatersrand, South Africa. We also acknowledge the Evolutionary Studies Institute, University of Witwatersrand, for providing a platform to accomplish this study.

### References

- Poüschl U, Shiraiwa M. Multiphase chemistry at the atmosphere-biosphere interface influencing climate and public health in the anthropocene. Chem Rev. 2015;115(10):4440–75. https://doi.org/10.1021/cr500487s
- Steffen W, Crutzen PJ, Mc.Neill JR. The anthropocene: Are humans now overwhelming the great forces of nature? Ambio. 2007;36(8):614-21. https://doi.org/10.1579/0044-7447(2007)36[ 614:TAAHNO]2.0.CO;2
- Foley SF, Gronenborn D, Andreae MO, et al. The palaeoanthropocene—The beginnings of anthropogenic environmental change. Anthropocene. 2013;3:83-88. https://doi. org/10.1016/j.ancene.2013.11.002
- Lewis SL, Maslin MA. Defining the anthropocene. Nature. 2015;519(7542):171-80. https://doi.org/10.1038/nature14258
- Ajikah L, Ogundipe OT, Bamgboye O. Palynological survey of airborne pollen and spores in the University of Lagos, Akoka campus, southwestern Nigeria. IFE J Sci. 2015;17(3):643-55.
- Singh AB, Dahiya P. Aerobiological research on pollen and fungi in India during last fifty years: An overview. J Allergy Clin Immunol. 2008;22:27-38.
- Reid CE, Gamble JL. Aeroallergens, allergic disease, and climate change: Impacts and adaptation. Eco Health. 2009;6(3):458-70. https://doi.org/10.1007/s10393-009-0261-x
- D'Amato G, Baena-Cagnani CE, Cecchi L, et al. Climate change, air pollution and extreme events leading to increasing prevalence of allergic respiratory diseases. Multidscip Respir Med. 2013;8(1):12. https://doi.org/10.1186/2049-6958-8-12
- Ziska LH, Beggs PJ. Anthropogenic climate change and allergen exposure: The role of plant biology. J Allergy Clin Immunol. 2012;129(1):27-32. https://doi.org/10.1016/j.jaci.2011.10.032
- Kaplan A. Airborne pollen grains in Zonguldak, Turkey, 2001-2002. Acta Botanica Sinica. 2004;46:668-74.
- 11. Ezikanyi DN, Ogundipe OT, Adeiga AA. Allergenic potential of two species of Poaceae: *Panicum maximum* Jacq and *Sacciolepis africana* CE. Hub pollen protein in albino mice. Int J Environ Sci. 2017;6(10):1-5.
- Njokuocha RC. Airborne pollen grains in Nsukka, Nigeria. Grana. 2006;45(1):73-80. https://doi.org/10.1080/00173130600555797
- Adeonipekun PA. Comparative aeropalynology of Ota, Nigeria.
  J Ecol Nat Environ (JENE). 2012;4(12):314-20. https://doi.org/10.5897/JENE12.031
- Tauber R. A static non-over load pollen collector. New Phytol. 1974;73:359-69. https://doi.org/10.1111/j.1469-8137.1974. tb04770.x
- Giesecke T, Fontana SL, Van der Knaap W, Pardoe HS, Pidek IA. From early pollen trapping experiments to the pollen monitoring programme. Veg Hist Archaeobot. 2010;19:247-58. https://doi.org/10.1007/s00334-010-0261-3
- Peck RM. Efficiency test on the Tauber trap used as a pollen sampler in turbulent water flow. New Phytol. 1972;71:187-98. https://doi.org/10.1111/j.1469-8137.1972.tb04827.x
- Krzywinski K. The Tauber pollen trap, a discussion of its usefulness in pollen deposition studies. Grana. 1977;16(3):147-8. https://doi.org/10.1080/00173134.1977.11864651
- Levetin S, Rogers CA, Hall A. Comparison of pollen sampling with a Burkard spore trap and a Tauber trap in a warm temperate climate. Grana. 2000;39(6):294-302. https://doi.org/10.1080/00173130052504333
- 19. Levetin E. Use of the Burkard spore trap. Tulsa, OK: The University of Tulsa; NA.
- 20. Agwu COC, Osibe EE. Airborne palynomorphs of Nsukka during the months of February-April, 1990. Nigerian J Bot. 1992;5:177-85.
- 21. Agwu COC, Njokuocha RC, Mezue O. The study of airborne pollen and spores circulating at "head level" in Nsukka environ-

- ment. Bio-Research. 2004;2(2):7-14. https://doi.org/10.4314/br.v2i2.28552
- Njokuocha RC, Osayi EE. Airborne pollen and spore survey in relation to allergy and plant pathogens in Nsukka, Nigeria. Bio-Research. 2005;3(1):77-84. https://doi.org/10.4314/br.v3i1. 28575
- 23. Adekanmbi OH, Ogundipe OT. Aeropalynological studies of the University of Lagos campus, Nigeria. Notulae Scientia Biol. 2010;2(4):34-9. https://doi.org/10.15835/nsb245393
- Adeonipekun PA, John M. Palynological investigation of haze dust in Ayetoro-Itele Ota, Southwest Nigeria. J Ecol Nat Environ. 2011;3(14):455-60. https://doi.org/10.5897/JENE11. 082
- Essien BC, Agwu COC. Aeropalynological study of Anyigba, Kogi State, Nigeria. Stand Scient Res Essays. 2013;1(13):347-51.
- Adeniyi TA, Adeonipekun PA, Olowokudejo JD, Akande IS. Airborne pollen records of Shomolu local government area in Lagos State. Notulae Scientia Biologicae. 2014;6(4):428-32. https://doi.org/10.15835/nsb649355; https://doi.org/10.15835/nsb.6.4.9355
- Adekanmbi OH, Alebiosu OS, Adeiga AA. Aerofloral investigation and allergenic potentials of two dominant airborne pollen types at selected sites in south-western Nigeria. Aerobiologia. 2019 Mar;35(1):doi:10.1007/s10453-018-9533-7. https://doi.org/10.1007/s10453-018-9533-7
- Alebiosu OS, Adekanmbi OH, Nodza GI, Ogundipe OT. Aeropalynological study of two selected locations in north-central Nigeria. Aerobiologia. 2018;34:187-202. https:// doi.org/10.1007/s10453-017-9506-2
- Ezike DN, Nnamani CV, Ogundipe OT, Adekanmbi OH. Airborne pollen and fungal spores in Garki, Abuja (north-central Nigeria). Aerobiologia. 2016;32(4):697-707. https://doi.org/10.1007/s10453-016-9443-5
- Orijemie EA, Israel I. Using palynomorphs to trace the travel history of vehicles. Aerobiologia. 2019;35:497-510. https://doi. org/10.1007/s10453-019-09577-z
- 31. Ajao A. Harnessing Nigeria's biological diversity in an integrated approach to national development. JORIND. 2012;10(2):40-5.
- 32. Keay RWJ. An outline of Nigerian vegetation. 2nd ed. Lagos, Nigeria: Government Printer; 1959; pp. 1-46.
- Sowunmi MA. Pollen of Nigerian plants II. Grana. 1995;34(2):120-41. https://doi.org/10.1080/00173139509430002
- 34. Adekanmbi OH, Ogundipe OT. Pollen grains of Lagos lagoon swamp and hinter-land vegetation-1. Intern J Bot. 2009;5:270-8. https://doi.org/10.3923/ijb.2009.270.278
- 35. Sowunmi MA. Pollen morphology of the Palmae and its bearing on taxonomy. Rev Palaeobot Palynol. 1972;13(1):1-80. https://doi.org/10.1016/0034-6667(72)90044-9
- Jeffrey C. A note on pollen morphology in *Cucurbitaceae*. Kew Bull. 1964;17(3):473-7. https://doi.org/10.2307/4113823
- Al-Anbari AK, Barusrux S, Pornpongrungrueng P, Theerakulpisut P. Pollen grain morphology of citrus (*Rutaceae*) in Iraq. In: International conference on plant, marine and environmental sciences. 2015. https://doi.org/10.15242/IICBE. C0115048.
- Conejero L, Hagaki Y, Baeza MC, Varela-Nieto I, Zubeldia JM. Pollen-induced airway inflammation, hyper-responsiveness and apoptosis in a murine model of allergy. Clin Exp Allergy. 2007;37:331-8. https://doi.org/10.1111/j.1365-2222.2007.02660.x
- Acharya PJ. Skin test response to some inhalant allergens in patients of nasobronchial allergy from Andhra Pradesh. Asp Allergy Appl Immunol. 1980;15:49-52.
- Agashe SN, Anand P. Immediate type hypersensitivity to common pollen and molds in Bangalore city. Asp Allergy Appl Immunol. 1982;15:49-52.

41. Singh BP, Singh AB, Nair PKK, Gangal SV. Survey of airborne pollen and fungal spores at Dehradun, India. Ann Allergy. 1987;59:229-34.

- Karmakar PR, Das A, Chatterjee BP. Placebo-controlled immunotherapy with *Cocos nucifera* pollen extract. Intern Arch Allergy Appl Immunol. 1994;103:194-201. https://doi. org/10.1159/000236627
- 43. Caillaud D, Thibaudon M, Martin S, Segala C, Besancenot JP, Clot B, et al. J Invest Allergol Clin Immunol. 2014;24(4):177-83.
- 44. Galant S, Berger W, Gillman S, Goldsobel A. Prevalence of sensitization to aeroallergens in California patients with respiratory allergy. Ann Allergy Asthma Immunol. 2010;81:203-10. https://doi.org/10.1016/S1081-1206(10)62813-X
- 45. Ščevkova J, Dušička J, Hrubiško M, Mičieta K. Influence of airborne pollen counts and length of pollen season length of selected allergenic plants on the concentration of slgE antibodies on the population of Bratislava, Slovakia. Annals of Agricul Environ Med. 2015;22(3):451-5. https://doi. org/10.5604/12321966.1167712
- 46. Bastl K, Kmenta M, Pessi A, Prank M, Saarto A, Sofiev M, et al. First comparison of symptom data with allergen content (Bet v1 and Phl p5 measurements) and pollen data from four European regions during 2009-2011. Sci Total Environ. 2016;548:229-35. https://doi.org/10.1016/j.scitotenv. 2016.01.014
- Hirst JM. An automatic volumetric spore trap. Ann Appl Biol. 1952;39:257-65. https://doi.org/10.1111/j.1744-7348.1952. tb00904.x
- Buters J. Pollen allergens and geographical factors. In: Akdis C., Agashe I, editors. Global atlas of allergy. Zurich, Switzerland: European Academy of Allergy and Clinical Immunology; 2014, pp. 36-7.
- Belmonte J, Canela M, Guardia RA. Comparison between categorical pollen data obtained by Hirst and Cour sampling methods. Aerobiologia. 2000;16:177-85. https://doi. org/10.1023/A:1007649427549; https://doi.org/10.1023/A: 1007628214350
- 50. Frenz DA. The effect of wind speed on pollen and spore counts collected with the Rotorod sampler and Burkard spore trap. Ann Allergy Asthma Immunol. 2000;85:392-4. https://doi.org/10.1016/S1081-1206(10)62553-7
- 51. Okamoto Y, Horiguchi S, Yamamoto H, Yonekura S, Hanazawa T. Present situation of cedar pollinosis in Japan and its immune responses. Allergol Intern. 2009;58:155-62. https://doi.org/10.2332/allergolint.08-RAI-0074
- 52. Orlandi F, Oteros J, Aguilera F, Ben-Dhiab A, Msallem M, Fornaciari M. Design of a down-scaling method to estimate

- continuous data from discrete pollen monitoring in Tunisia. Environ Scient Proc Impacts. 2014;16:1716-25. https://doi.org/10.1039/C4EM00153B
- 53. Faegri K, Iversen J. Textbook of pollen analysis. Faegri K, Kaland PE, and Krzywinski K, editors. New York, NY: John Wiley; 1989, 328 pp.
- 54. Berman D. Pollen monitoring in South Africa. Curr Allergy Clin Immunol. 2007;20(4):184-7.
- 55. Taketomi EA, Sopelete MC, Moreira PFS, Vieira FAM. Pollen allergic disease: Pollens and its major allergens. Revista Brasileira Otorrinolaringol. 2006;72(4):562-7. https://doi.org/10.1590/S0034-72992006000400020
- Adeniyi TA, Adeonipekun PA, Olowokudejo JD, Akande IS. Allergenicity of dominant aeropollen in Nigeria: Part I. Curr Allergy Clin Immunol. 2017;30(4):264-9.
- 57. Schäppi GF, Taylor PE, Pain MC, Cameron PA, Dent AW, Staff IA, et al. Concentrations of major grass group 5 allergens in pollen grains and atmospheric particles: Implications for hay fever and allergic asthma sufferers sensitized to grass pollen allergens. Clin Exp. 1999;29(5):633-41. https://doi.org/10.1046/j.1365-2222.1999.00567.x
- Luo W, Huang H, Zheng P, Wei N, Luo J, Sun B, et al. Major grass pollen allergens and components detected in a southern Chinese cohort of patients with allergic rhinitis and/or asthma. Mol Immunol. 2016;78:105-12. https://doi.org/10.1016/j.molimm.2016.08.013
- Walter OJ, Adekanmbi OH, Ajikah LB. Palynological analysis of spider webs from Lagos State, southwestern Nigeria. Intern J Bot Stud. 2019;4(3):82-7.
- Adeniyi TA, Adeonipekun PA, Olowokedujo JD, Akande IS. Allergenicity of dominant aeropollen in Nigeria. (Part 11). Curr Allergy Clin Immunol. 2018;31(3):178-83.
- Rogers CA. Application of aeropalynological principles in palaeoecology. Rev Palaeobot Palynol. 1993;79(1-2):133-40. https://doi.org/10.1016/0034-6667(93)90043-T
- Newnham RM. Monitoring biogeographical response to climate change: The potential role of aeropalynology. Aerobiologia. 1999;15:87-94. https://doi.org/10.1023/A:1007595615115
- Ige EO, Essien BC. The applications of pollen analysis in environmental monitoring in Akoko north-east local government area of Ondo State, Nigeria. GSC Biol Pharm Sci. 2019;8(1):64-77. https://doi.org/10.30574/gscbps.2019.8.1.0113
- 64. Minder P. First results for bioaerosol monitoring by the new Swisens Poleno. Intern Aerobiol Newslet. 2019;85:9.
- Buters J, Oteros J, Weber A, Heinze S, Kutzora S, Herr C. The Bavarian network of automatic pollen monitoring station ePIN went online. Aerobiol Newslet. 2019;85:7-8.