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Aerobiology in South Africa: A new hope!

Pollen and fungal spores (aerospora) are the major atmospheric bioaerosols. Aerospora occurrence and concentration vary by geographical region and blossoming period, and with meteorological factors. Allergic respiratory diseases affect about 20 million South Africans, with pollen and fungal allergens amongst the leading triggers. Asthma triggered by aerospora can be life threatening; allergic rhinitis causes considerable morbidity and carries financial implications for individuals and health systems. Thus, knowledge about geographical variation, seasonal timing and intensity, as well as annual aerospora fluctuations in South Africa, where climate and vegetation are exceptionally diverse, is essential for effective diagnosis and treatment of allergies. Unfortunately, there is a lack of continuous aeropalynological data from South Africa. The longest annual monitoring exists for Cape Town (~20 years), with almost no data out of the Cape since the 1990s, and many parts of South Africa have never been monitored. In this brief review, we highlight the cross-disciplinary need for strengthened and expanded continuous aeropalynological study in South Africa, the history of efforts to date, and the introduction of the interdisciplinary South African Pollen Network (SAPNET). SAPNET was launched in seven major cities in August 2019 in order to monitor weekly variations of aerospora, and provide online data for allergy sufferers and health-care providers (www.pollencount.co.za) with the aim to establish regional pollen calendars.

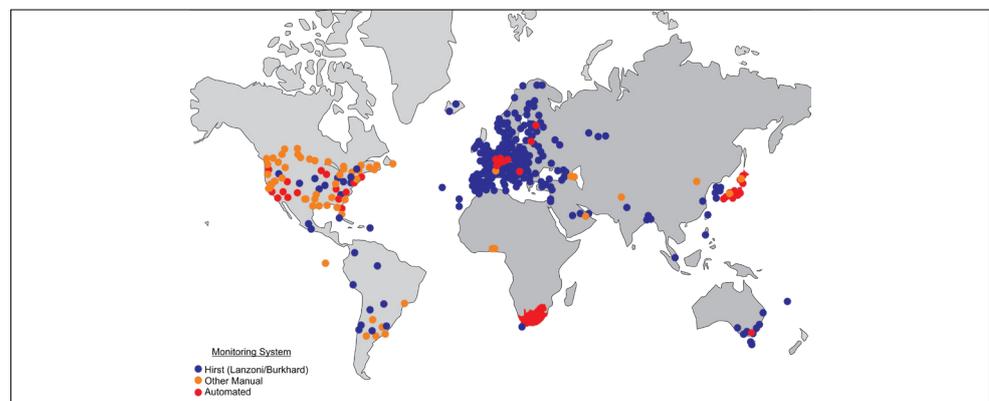
Significance:

- The significance of aerobiology as the study of airborne organic particles which include pollen, spores of fungi and cryptogams, plant hair, insect remains etc. especially as agents of allergic rhinitis (commonly known as hay fever) is outlined. Cases of allergic rhinitis are globally increasing due to current climate change.
- Very limited pollen monitoring data are available for South Africa; such data are a prerequisite for establishing pollen calendars to help medical practitioners and allergy sufferers. SAPNET (South African Pollen Network) addresses this lack of data. Since August 2019, seven 7-day volumetric spore traps have been operating in South Africa in major cities, and are continuously gathering data about the pollen and spore contents in a country which is highly affected by allergic rhinitis.

The problem

Allergic rhinitis affects 20–30% of South Africans, with co-morbid asthma in 20% of cases. Pollen and house dust mite allergens are the commonest triggers of allergic rhinitis and asthma. Most of the common global aeroallergens are found in South Africa, due to a variety of climates and biomes.¹ Non-native trees have been planted in South Africa to produce timber, for example eucalypt (*Eucalyptus* spp.) and pine (*Pinus* spp.) trees, or because of their ornamental value, for example London plane tree (*Platanus acerifolia*). Many non-native trees have undesired effects, such as fire proneness or pollen allergenicity.² Global warming is responsible for alarming changes, including increased total pollen amount, earlier shifts of pollen seasons with levels expected to be four times higher by 2050, invasion of allergenic plants with resultant increases in allergic sensitisation, and increased amounts of allergenic protein in pollen.³ The changing environment, the major health ramifications and the biodiversity of South Africa underline a need for widespread pollen monitoring. In this paper, we follow Galán et al.⁴ in regard to aerobiological terminology.

There are more than 879 active pollen monitoring stations globally.⁵ Pollen monitoring coverage is biased towards the northern hemisphere; Europe has more than 500 spore traps. Pollen monitoring in Africa was, until August 2019, restricted to four spore traps in northern Africa (Morocco, Algeria, Tunisia), four spore traps in western Africa (Nigeria, Benin) and one spore trap in southern Africa (Cape Town, South Africa) (Figure 1⁵) – the only location of continuous monitoring in South Africa.⁶ Monitoring in the Cape has shown large seasonal variability and increasing pollen productivity; changes in other parts of the country were until recently unknown.⁶



Source: after Buters et al.⁵, updated in accordance with <https://www.eaaci.org/19-activities/task-forces/4342-pollen-monitoring-stations-of-the-world.html>, 2020 May 13

Figure 1: Global map of aerospora monitoring stations. Area in red represents South Africa and Lesotho.

Aerospora are globally increasingly inducing allergic respiratory disorders such as asthma, rhinitis, allergic conjunctivitis and atopic dermatitis, especially in arid to semi-arid regions in the world.⁷ Atopic individuals have a genetic predisposition to produce IgE antibodies against usually harmless environmental proteins (allergens). Several factors influence the development of new allergic sensitisations, including: (1) allergen exposure (large geographical pattern in aeroallergen profiles); (2) nature of the allergenic proteins, e.g. certain aeroallergens are considerably more allergenic; and, increasingly, (3) the co-factor of air pollutants such as particulate matters NO₂, ozone, CO and SO₂.⁸

A major challenge for aerobiologists in South Africa is the diverse vegetation and climate across its nine biomes (Figure 2) – ranging from the arid Karoo to the humid coast of KwaZulu-Natal in the East and from the cool Drakensberg grasslands to the wet, windy Cape.^{9,10} The Cape Floristic Region, which consists of the Fynbos and Succulent Karoo Biomes, illustrates this diversity, with its approximately 9000 flowering plants¹¹ (Figure 2) compared to Europe which harbours about 10 600 flowering plants¹². Other South African biomes are the tropical Indian Ocean Coastal Belt, the temperate Grassland, and the hot Savanna Biome which represents the southern extension of the largest biome of Africa (Figure 2).¹⁰ These different environments have distinct flora and include, next to indigenous vegetation, alien plants from Europe, North and South America and Australasia (548 taxa).¹³ Aerospora diversity is associated with distinct allergy patterns, and it is inaccurate to apply aerospora data from one biome to another; multiple monitoring stations are the only option for understanding regional aerospora diversity.

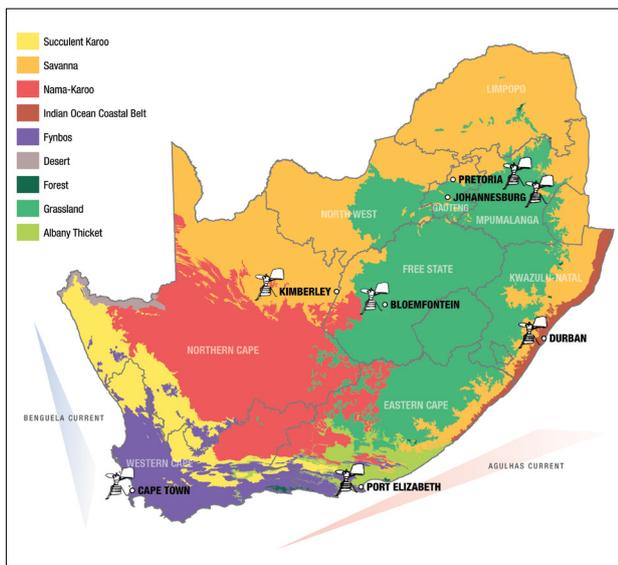


Figure 2: Biomes of South Africa, Lesotho and Swaziland after Mucina and Rutherford¹⁰, with oceanic currents which trigger climate (blue arrow: Benguela Current; red arrow: Agulhas Current). Dots show cities covered by SAPNET since August 2019.

What we do know? History of aerobiology in South Africa

Aerobiological studies in South Africa began with Davidson's studies in 1941 on grasses in Johannesburg. Aerobiological studies in South Africa are summarised in Table 1. Ordman and Etter^{14,15} contributed to the understanding of pollinosis in South Africa. Hawke and Meadows¹⁶ studied seasonal allergens and their morphology by observing, measuring and documenting aeroallergens in 1945–1970 in some areas of South Africa, and unravelling some of the unknown elements of the environmental allergens that trigger allergies. Potato dextrose agar settle plates and Durham (gravity) spore traps were used to collect pollen and to culture fungi by exposing a sticky slide at the top of a three-storey building in Johannesburg. Grasses were identified as the most important pollen allergens in South Africa.¹⁷ The late winter peak pollination period

for Cupressaceae (cypress) pollen in Cape Town and Johannesburg was first documented by Ordman¹⁴. He identified *Prosopis* (mesquite) as an important allergenic pollen in South West Africa (Namibia). Ordman¹⁸ hypothesised a link between climate and respiratory allergy, observing that humidity in coastal areas is a key factor in perennial respiratory allergy. This discovery was remarkable considering that house dust mites had yet to be identified.

Early pioneering contributions were followed by a second wave of allergists and aerobiologists. In 1981, Weinberg et al.¹⁹ successively upgraded and operated a 7-day volumetric spore trap in the Cape. By 1985, the Air Pollution Department in Cape Town added pollen sampling to their Air Quality Monitoring Programme, developing a partnership with the Red Cross Allergy Department. This allowed for pollen monitoring in different suburbs of Cape Town and provision of data to the Allergy Clinic, which treated patients from many areas of the Cape Town metropole.⁶ Cadman and Dames²⁰ added insights and observations on pollen seasonality and profiles of Gauteng and KwaZulu-Natal through pollen monitoring from 1987 to 1991. Potter and colleagues²¹ and Dames and Cadman²² concluded that *Alternaria* was amongst the most prominent fungal spore perennially, both in Cape Town and Durban. In 2008, Berman⁶ set up a 3-year aerobiological survey for an Environmental Impact Assessment commission in Mpumalanga. Here, differences in seasonality of aerospora in the Lowveld were tracked, and differed from those in the Cape. Grass pollen peaked in January, and tree pollen was low and dominated by non-native trees (*Platanus* spp.), oak (*Quercus* spp.) and eucalypt (*Eucalyptus* spp.). High levels of fungal spores were observed, probably due to increased humidity. Berman²³ provided a profile for all aerospora for respiratory diseases at sites close to a residential area. Berman²⁴ continued to conduct research in different parts of South Africa to monitor aerospora for clinical studies.

Aerobiological studies outlined above have provided important insights into the most allergenic aerospora in South Africa. Some of these insights are given below.

- At the Cape, the grass pollen season is September–March, with peaks in October. On the Highveld, the grass pollen season is longer (September–May); grass is regarded as a 'perennial' allergen.¹ In Gauteng, a noticeable variation was reported between the models for both grass pollen and spores for Johannesburg and Pretoria due to meteorological factors.²⁵ Allergenic grass pollens in South Africa are *Eragrostis curvula*, kikuyu (*Pennisetum clandestinum*) and buffalo grass (*Stenotaphrum secundatum*).^{1,23} *Zea mays* is problematic in the Free State Province.
- Unlike in Europe, tree pollen is a relatively uncommon cause of seasonal allergy in South Africa, although further studies are needed as allergenic pollen of non-native trees such as oak (*Quercus* spp.), Italian cypress (*Cupressus sempervirens*), plane trees (*Platanus* spp.), and mulberry (*Morus* spp.) are a 'growing problem', especially in the cities where they are planted as ornamentals or fruit trees.^{1,23} (own unpublished data).
- Weeds are arguably a minor problem, although the invader plantain *Plantago* spp. as well as several, mostly indigenous, members of the daisy family are known to cause allergies.^{1,23}
- Fungal spores are globally the most abundant aerospora. In South Africa, *Cladosporium*, *Alternaria*, *Aspergillus* and *Epicoccum* are the most important.^{1,23}

These insights provided a basic understanding; however, many of these studies were conducted decades ago and environments might have changed. Furthermore, Table 1 and Figure 2 show that aerospora concentrations in many South African provinces and cities have never been monitored (Northern Cape, North West and Limpopo Provinces), and even for well-monitored areas, uninterrupted data are limited. There is an urgent need for up-to-date monitoring data to address knowledge gaps including: (1) the main allergenic aerospora in many areas/regions/biomes; as well as the (2) flowering times and (3) peak concentrations of important allergens.

Table 1: Historical and chronological order of aeropalynology studies and purpose of each study (updated/modified from Buters et al.⁵)

Investigator	Period	Region in South Africa	Purpose	Reference
Davidson	1941	Johannesburg	Pollen research	Ordman ^{14,17,18}
Ordman	1945–1970	Gauteng: Johannesburg KwaZulu-Natal: Durban, Pietermaritzburg Mpumalanga: Nelspruit	Monitoring for clinical practice	Ordman ^{14,15,17,18}
Weinberg	1973–2004	Western Cape: Rondebosch, Table View	Clinical trials monitoring	Weinberg et al. ¹⁹
Dames	1987–1991	Gauteng: Johannesburg, Pretoria KwaZulu-Natal: Durban	Fungal spore research / pollen research	Cadman and Dames ^{20,22,25}
Cadman	1987–1994	Gauteng: Johannesburg, Pretoria KwaZulu-Natal: Durban Western Cape: Kirstenbosch, Parow	Fungal spore research / pollen research	Cadman and Dames ^{20,22,25}
Berman / Potter	1985–1990	Cape Town suburbs	Monitoring for clinical practice	Potter et al. ²¹
	1985–1986	Edgemoed	Monitoring for clinical practice	Berman ⁸
	1986–1986	Bothasig	Monitoring for clinical practice	Berman ⁸
	2000–2001	Somerset West	Monitoring for clinical practice	Berman ²³
	2000–2003	Parow	Monitoring for clinical practice	Berman ²³
	2008–2009	Mowbray Observatory, Parow	Clinical trials monitoring	Berman ²⁴
	2008–present 2010	Mowbray Observatory	Monitoring for clinical practice	Berman ⁶ Potter ¹

The way forward: South African Pollen Network and Monitoring Programme (SAPNET)

The need for a pollen monitoring network in South Africa has been outlined above. Already in 2007, the necessity of a national network of spore traps in South Africa as ‘a collaborative exercise between allergists and the botany or palynology departments of the local universities’ was underlined.²³ A network of this scale requires substantial funding; a strong, dedicated team of collaborators; and widespread public and institutional support. SAPNET was launched in August 2019 at the University of Cape Town Lung Institute and 7-day volumetric Burkard spore traps were placed in seven major South African cities (Bloemfontein, Cape Town, Durban, Johannesburg, Kimberley, Port Elizabeth, Pretoria; Figure 2). This new cycle of monitoring, which covers several biomes and includes major population centres, is a necessity for South Africa, considering the growing and mobile population, climate and environmental changes and the expansion and likely worsening of aeroallergen-triggered allergic diseases. This will provide insight into the high–low risk periods for sensitised individuals through weekly online updates (<http://www.pollencount.co.za/>), as well as the development of updated pollen calendars for major cities and provinces spanning different biomes. Information about allergenic aerospora will assist health-care providers, including general practitioners, in making clinical diagnoses and decisions. It will help pollen allergy sufferers to identify plants which have the tendency to produce allergenic pollen in their environment and adopt prophylactic measures as advised on the website.

Future goals

1. Expansion of SAPNET into northern provinces (Mpumalanga, Limpopo, North West) and neighbouring countries.
2. Coverage of rural areas in South Africa, including townships in the mining belt of Mpumalanga and other, highly industrialised areas or along major transport routes where – due to high air pollution – the risk of asthma, often triggered by pollen allergy^{24–26}, is high.
3. Collaboration with above-mentioned northern and western African nations (see Figure 1), as well as southern hemisphere pollen monitoring networks.
4. Training of aerobiologists and knowledge exchange with other countries, where pollen monitoring is established, with the aim to improve aerobiological methods in South Africa.

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Authors' contributions

L.A.: Conceptualisation, formulation of the overarching research aims, preparation and creation of the published work, specifically writing the initial draft. F.H.N.: Critical review, commentary, extension and revision of text, tables, figures, corresponding author. D.B.: Verification, whether as a part of the activity or separate, of the overall replication/reproducibility of the review and other research outputs, contributions to text. J.P.: Acquisition of the financial support for the project leading to this publication, management and coordination responsibility for the research activity planning and execution, contributions to text.

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