Postscript

The analyses detailed above were completed during July 1993, but the anticipated widespread rainfall has not eventuated. The same analytical method was subsequently used to determine whether or not the cyclicity was apparent in the annual rainfall in the Vaal Dam catchment, and the annual Southern Oscillation Index. Surprisingly, the cyclicity is not apparent in either of the two records, nor is there a close visual relationship between the cumulative departures from the mean of the three data sets. However, subsequent analyses of the river flow data have confirmed the cyclicity, which can now be modelled.

The following conclusions can be made with confidence.

- There is clear evidence of cyclicity in river flow data for most of the large river catchments in South Africa.
- This cyclicity is closely associated with sunspot activity.
- The cyclicity is much more apparent in annual river flow than in annual rainfall, or the annual Southern Oscillation Index.
- Time series analyses cannot be used with confidence where the data are lower bounded, highly skewed, not identically distributed, and with appreciable cyclicity or non-random grouping as is the case with annual river flows in most South African rivers.
- Consequently, it will not be possible to detect changes in the statistical properties of climatological data sets within a period of several decades after the postulated changes have occurred.

The following deduction is somewhat speculative.

- If there is a stronger linkage between solar activity and river flow than between solar activity and annual rainfall, or between solar activity and annual Southern Oscillation Index, the conclusion is that the solar activity is affecting the phenomenon that controls the extreme events (runoff-producing river flow, floods and droughts) rather than the mean conditions.

More studies will be required to determine the validity of this deduction.

Availability of data used in this study

The data sets used in this study as well as the executable computer programs that were used to carry out the analyses are available on disk from the author at no charge.

The assistance provided by the Directorate of Hydrology of the Department of Water Affairs and Forestry in updating the hydrological data sets used in this study is gratefully acknowledged.

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Research Letters

Airspora concentrations in the Vaal Triangle: monitoring and potential health effects. 2, Fungal spores

Atmospheric fungal spores were monitored in Vanderbijlpark for the period 1991–92 as part of the Vaal Triangle Air Pollution Health Study of the Medical Research Council and the CSIR. Cladosporium, Aspergillus / Penicillium, Alternaria *and* Epicoccum *were among the most prevalent fungi, and have potential consequences for the health of the population in the area. Higher spore counts were recorded in 1991 than in 1992. Rainfall may have accounted for this variability.*

Fungal growth is sustained wherever there is moisture, oxygen and a suitable substrate. Some species may require more specific conditions for growth. Generally, temperatures between 18°C and 32°C with relatively high humidity allow for optimal fungal growth. Fungi are able to occupy suitable outdoor and indoor environments over relatively short periods, and to produce and disperse large masses of spores. The majority of fungi disperse their spores by means of air currents. The air is therefore never free of fungal spores.[1]

Fungal hosts in the outdoor environment include all forms of organic material. Fungi can attack agricultural crops and can constitute high concentrations in a geographical area.[1] Fungi in the indoor environment are able to grow on virtually any substrate including glass, paint, rubber, textiles and even electrical equipment.[2] Kitchens, refrigerators, garbage containers, perishable food stuffs, damp areas such as bathrooms, showers and basements, lofts, window-sills, mattresses, upholstery, pillows or any other place where moisture and organic material are present, will promote fungal growth.[3] In poorly ventilated homes and unventilated rooms, high concentrations of fungal spores can build up. Humidifiers and air-conditioners in homes and the work-place also support their growth.[4,5]

The direct relationship between the prevalence of respiratory disease symptoms and fungal concentrations is well

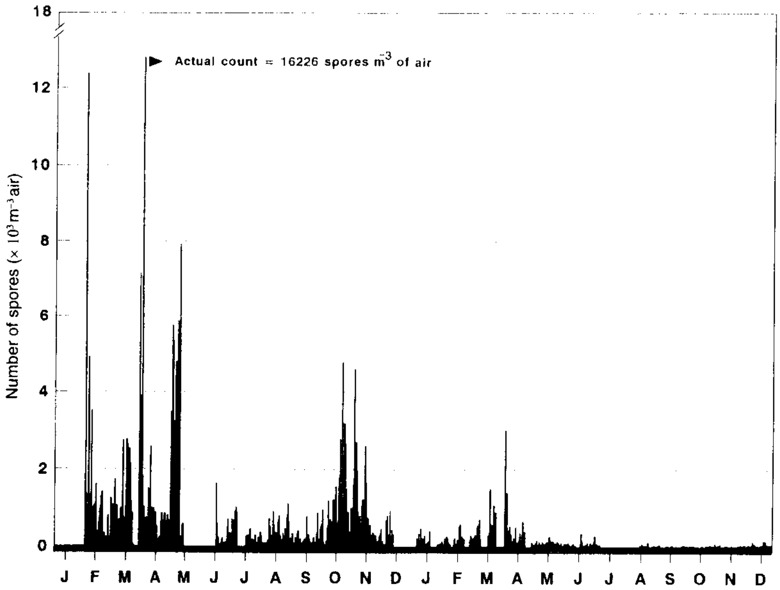

Fig. 1. Total daily spore counts in Vanderbijlpark (January 1991 to December 1992).

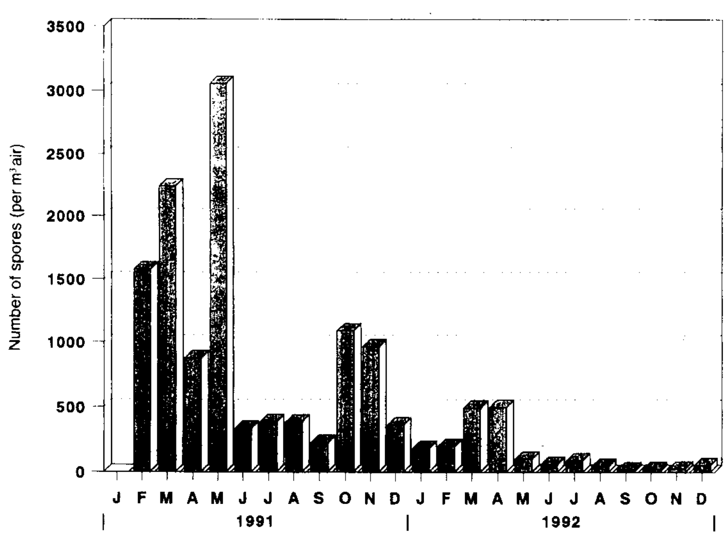

Fig. 2. Mean daily counts for each month for total spore counts in Vanderbijlpark (January 1991 to December 1992).

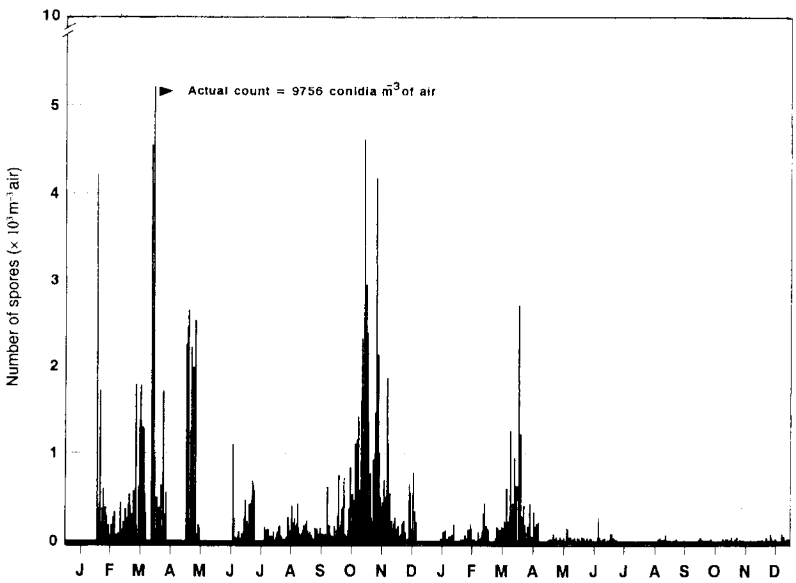

Fig. 3. Daily *Cladosporium* spore counts in Vanderbijlpark (January 1991 to December 1992).

documented.[6–10] Clinical characteristics vary widely and illnesses associated with airborne fungi include allergic asthma, hypersensitivity pneumonitis, hayfever, allergic rhinitis and inva-sive disease, for example cryptococcosis, histoplasmosis and aspergillosis.[4,5,11–14]

We report on the monitoring of fungal spore concentrations in Vanderbijlpark, south of Johannesburg, for which no data on airspora are available and where air pollution levels are exceptionally high.[15]

Materials and methods

Fungal monitoring was conducted in Vanderbijlpark simultaneously with pollen analysis, using the Burkard 7-day recording volumetric spore trap.[31]

Sample strips were read at a magnification of 1000 ×. A total of 31 fungal taxa were identified. Identification was aided by inoculating culture-plates of potato-dextrose agar medium with material derived from atmospheric samples, producing identifiable fungal colonies. We did not attempt identification below the level of genus.

For the purpose of this study, the collective term 'spores' will be used to include asexually produced spores, for example conidia and sporangiospores, as well as sexually produced spores, such as ascospores and basidiospores. Fungal spores were distinguished on the basis of their morphological characteristics, such as size, shape, septation and colour. The presence of attachment scars separated spores of the deuteromycetous fungi (fungi imperfecti) from ascospores. The absence or presence of apical pores, and asymmetrical appendages, identified basidiospores. Neither ascospores nor basidiospores were classified in genera. Spores between 3 μm and 5 μm in size were grouped as *Aspergillus / Penicillium*. Spores which we were unable to culture or positively identify were categorized as 'unidentified'. Data were analysed using a Lotus data-base.

As part of the larger Vaal Triangle Air Pollution Health Study (VAPS) conducted by the Medical Research Council (MRC) and the CSIR,[15] 11 916 questionnaires (both in English and Afrikaans) were distributed over a period of three weeks to the parents of white primary schoolchildren between the ages of 8 and 12 years. Forty-six schools in Vanderbijlpark, Vereeniging, Sasolburg, Meyerton and Randvaal took part.[15] Of these questionnaires, 85.5% (n = 10 187) were returned and 70% of the questions answered.[15] The questionnaire formed the basis of assessing health effects and were adopted from similar questionnaires used by the American Thoracic Society, the Harvard Six City Air Pollution Health Study and Canadian Health and Welfare.[15] The survey collected data on the general health status of the child, respiratory diseases, including upper respiratory (URI) and lower respiratory illnesses (LRI), as well as information on home characteristics, socioeconomic status, sources of indoor air pollution and perceptions of air pollution.[15] URI were documented for the previous year as well as the previous two weeks. Although the health effects were not medically validated, apart from stating 'as

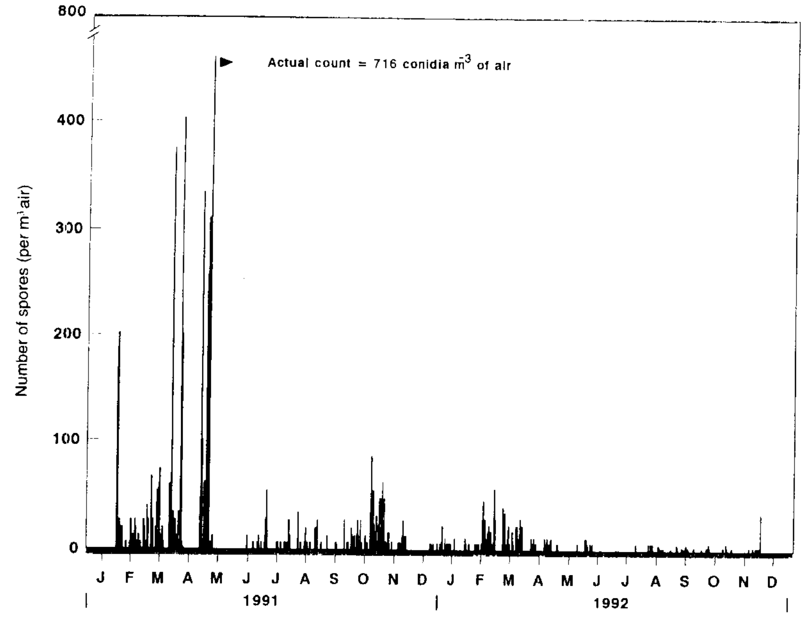

Fig. 4. Daily *Penicillium/Aspergillus* spore counts in Vanderbijlpark (January 1991 to December 1992).

diagnosed by a doctor', repeat items in the questionnaire were used to validate the answers given, and statistically analysed before conclusions were made. Full details of the preliminary results obtained by the VAPS have been published by Terblanche *et al.*[15]

Results

Total statistics of the VAPS questionnaires indicated that 5.5% of households used humidifiers and 11.2% reported fungal growth on walls of houses, especially in bathrooms. Allergies, as diagnosed by a doctor, were reported in 17.9% (or 18%) of these children. Upper respiratory illnesses, defined to include sinusitis, rhinitis and earache, were documented in 74% of the total study population. A borderline significant relationship between the reported presence of fungal growth in the homes and URI/LRI was obtained on a univariate level for the Vanderbijlpark children.

Total daily spore counts were less than 3000 per m^3 air for most of the two-year monitoring period (Fig. 1). However, particularly high spore counts were recorded on 1 February 1991 (12 377 spores per m^3 air) and on 28 and 31 March 1991 (7154 and 16 226 spores per m^3, respectively). The spore counts were overall much lower during 1992 than 1991. An exception was 7 April 1992, when the total spore count exceeded 3000 per m^3 (Fig. 1). High counts were also noted on occasional days in March and April 1992, but these were all lower than 3000 per m^3 (Fig. 1). Daily averages for each month (total monthly count divided by the number of days monitored for that month) indicated that during March and May 1991 counts of 2000 and 3000 per m^3, respectively, were recorded (Fig. 2). In February, April, October and November 1991, the daily average counts varied from 500 to 1600 per m^3. At all other times daily averages were below 500 per m^3 (Fig. 2).

Spores of *Cladosporium* occurred most often and made up 53.7% of the total counts, followed by ascospores (14.1%), basidiospores (9.6%), hyphal filaments (6.0%), *Periconia* (4.2%), unidentified spores (3.2%), *Aspergillus/Penicillium* (2.3%), *Alternaria* (2.1%), smuts (1.6%), *Epicoccum* (0.7%), *Helminthosporium* (0.7%) and rusts (0.4%). The remaining 19 taxa occurred at daily levels less than 500 per m^3. These fungi constituted 1.6% of the total count, and included taxa such as *Curvularia, Torula, Stemphylium, Fusarium, Erysiphe, Ganoderma* and *Nigrospora.*

Analysis of data for the more prevalent fungi revealed that the counts for *Cladosporium* were especially high on 28 and 31 March 1991, reaching 4550 and 9760 spores per m^3, respectively. High counts were also recorded in November 1991 and April 1992, accounting for more than 68% and 73%, respectively, of the total count for those months (Fig. 3). Peaks of higher counts on days from March to May 1991 were noted for *Aspergillus/Penicillium* (Fig. 4). These counts were, however, lower than 1000 spores per m^3 air on any given day. In the case of *Alternaria,* the spore count exceeded 100 per m^3 only on days in February, March and on several days in May 1991 (Fig. 5).

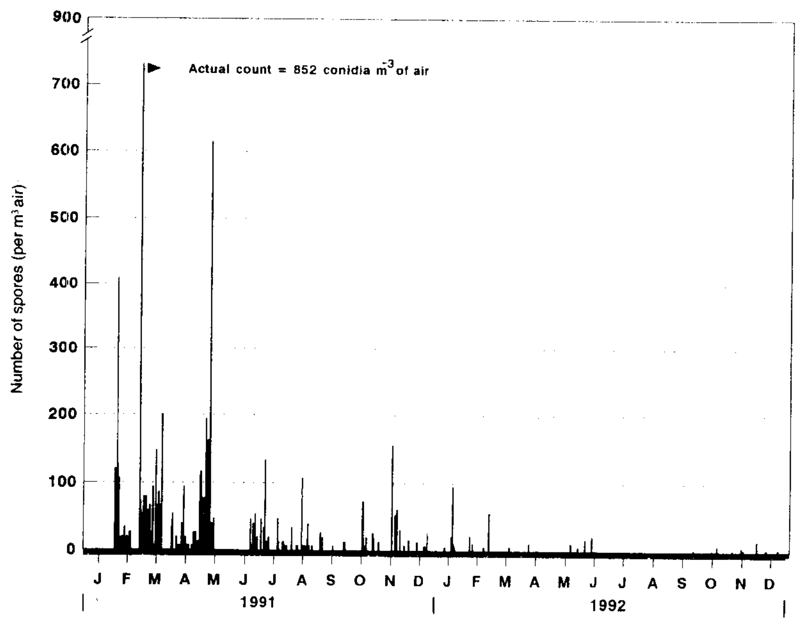

Fig. 5. Daily *Alternaria* spore counts in Vanderbijlpark (January 1991 to December 1992).

Discussion

Results of this study are in good agreement with those conducted in other parts of southern Africa, with some differences occurring in the areas with obviously different climatic conditions.[1,16–24] A two-month monitoring period in winter in the south-western Cape showed that basidiospores were most common and represented 40% of total spores.[25] Basidiospores and ascospores as well as the spores of *Cladosporium, Aspergillus/Penicillium, Alternaria* and *Epicoccum* gave the highest counts in our study. Although ascospores and basidiospores occurred at higher frequencies than some other fungi in the current study, they appear to be of less importance in causing fungal allergies.[4,8]

Spore counts peaked during late summer and autumn in our study, but were much more pronounced in the first year of the enquiry. Although total rainfall for 1991 and 1992 in Vanderbijlpark was similar, i.e. 587 mm and 552 mm respectively, monthly averages varied markedly, and this may account for the lower counts experienced during 1992. A longer monitoring period is necessary to elucidate the effects of precipitation and other climatic conditions, including relative humidity, sun hours, temperature, wind speed and direction. Past studies have shown sunshine and wind to cause an increase in the atmospheric distribution of spores.[4,25] Rain is reported to affect airborne concentrations both positively and negatively and may have a more direct effect on spore production than on spore liberation and dispersal.[26] The diurnal pattern of spore production may also influence the presence of fungi in the air.[4] The influence of such factors may account for *Cladosporium* being found consistently in Gauteng compared with *Alternaria* in the Western Cape.[20]

Allergy sensitivity levels in the literature are reported only for *Cladosporium* and *Alternaria*. Bagni[27] quoted 3000 spores per m^3 as the threshold value for the clinical significance of *Cladosporium*, while the threshold value for *Alternaria* was given as 100 per m^3. Thus, some species have stronger allergenic properties than others.[8,27] Differentiation of fungal species therefore seems necessary and additional monitoring methods to identify the species currently grouped in the unidentified category in this study appear needed.

High spore counts and the prevalence of respiratory symptoms have been positively correlated, while exposure to aeroallergens in damp houses has been identified as a risk factor for asthma in the Netherlands and elsewhere.[7,28] In our study, spore counts were significantly higher than the threshold values on some days and could be a potential health hazard. Both *Cladosporium* and *Alternaria* as well as other fungal allergens, including *Aspergillus/Penicillium* and *Epicoccum* occurred in the Vanderbijlpark district. In the USA, 10–15% of the general population is allergic to fungi as reported from delayed hypersensitivity skin tests and/or RAST tests,[5,11] whereas the prevalence of fungal allergy within the allergic population has been estimated to be 2–30%.[12] Allergic asthma in children occurs more frequently owing to fungi than pollen in some geographic areas.[4] Fungal spores as an additional factor can therefore play a significant role in a group of children where pollution levels are high, as is the case in Vanderbijlpark.[15]

Although allergies were reported in 17% of the total study population, a confounding variable was the presence of humidifiers and fungal growth in some houses. A marginal correlation between damp houses, where fungal growth was present, and URI in the Vanderbijlpark children was documented. Children in these homes would be exposed to both the outdoor and indoor fungal load. It will therefore be necessary specifically to monitor these homes in order to draw direct correlations between URI and the overall role that fungi play. Hypersensitivity skin tests and the RAST test on these children are also being considered and will further aid in establishing the role that fungal allergens play. The relationship of other air pollutants to respiratory illnesses in these children is also significant. The presence of such pollutants can have a synergistic effect when associated with the airspora.[29–31]

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