

Origin and SEM analysis of aerosols in the high mountain of Tenerife (Canary Islands)

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ABSTRACT

Focusing on aerosolized matter of relevance to respiratory health, a major public health issue worldwide, we studied mineral and biological aerosol (bioaerosol) composition (TSP and PM_{2.5}) and geographical origins during dust intrusions in the Canary Islands. Seven days' backward trajectories were assessed daily during March 2004 with the ends of back trajectories being the sampling station of Izaña (high mountain, 2360 m a.s.l. at the Cañadas del Teide National Park, Tenerife island), a free troposphere site allowing characterization of dust with low influence of other pollutant sources. Scanning electron microscopy (SEM) was used to survey major types of airborne particles in the dust plumes. Control, non-intrusion conditions correspond to Atlantic oceanic middle troposphere (OMT) air masses. Of the 14 samples taken, 1 corresponded to a control (clear atmosphere conditions), and the remaining 13 to dust intrusions, with the following sources: African Dust; EAM: mixture of Europe, Africa and Oceanic; MaA: maritime aerosols. Of the air masses, 79% were directly transported to the islands from Africa, and an increase of African dust events was detected when comparing with a 52-year previous data sequence. Quartz microcrystals and aggregates of quartz and platy clay were the dominant minerals identified, with marine salt and gypsum also present. Freshwater diatom tests (from two *Aulacoseira* species) represented the most important biogenic aerosols, although fungi and pollen were also detected. The diverse and complex mixture of respirable particles in large

quantities in airborne dust, especially from nearby Sahara and from the Sahelian region, is of maximum interest for airway pathology in the Canaries, including the highly visited highlands in Tenerife.

Keywords: Allergens; Bioaerosols; Diatoms; High altitude; Desert dust intrusion; Public health; Scanning electron microscopy

1. INTRODUCTION

The dispersal of abiotic and biological aerosols (bioaerosols), has a growing interest in interdisciplinary research comprising epidemiology, public health and atmospheric physics. This is due to the great capacity of air masses to transport both viable organisms and inorganic dust to remote areas, where they transform local tropospheric conditions [1] and may affect human health [2]. The cell-carrying capacity of wind, long-range and high frequency transport of dust masses, aggravate the effects of seasonal peaks in local allergens through additive and synergic effects. The transport of dust might involve carrying up to 10.000 bacterial cells per gram of soil from some desert areas [3]. For example, diatoms are a large fraction of dust carried from fresh waters of the Saharo-Sahelian areas and Eurasia to remote areas such as the Caribbean [4]. Charles Darwin, on his 1845 voyage aboard the surveying ship H.M.S. Beagle, collected African dust in the Atlantic and microscopically detected the occurrence of diatoms in the dust. This same historic dust has been recently analyzed to find at least 16 different viable bacterial lineages and 2 fungal isolates [5].

Although the global amount of species of airborne pathogens is not so far clearly defined, several hundreds

of bacterial lineages, fungi and viruses can be involved in allergy, asthma and pulmonary affections, and airborne dust is a vehicle for them [6-10]. Inhaled atmospheric aerosols of any origin can be associated with a number of diseases and disorders, namely allergic airways disease (or asthma), rhinitis and rhinosinusitis, alveolitis or allergic parenchymal disease, airways or parenchymal infections, atypical thoracic pain, anxiety disorders, cardiopathy, and meningitis, among others [11-14].

The Canary Islands lay 96 km off the west of the largest dust source on Earth, the Sahara desert (> 9 million square kilometres), being comprised within the “dust-belt”, where the atmospheric dust concentration is inherently very high [15]. Dust transport to the Canaries causes several-fold increase over the standard levels of particulate matter over the islands [1,16-20]. Although studies relating desert dust to “airborne” diseases in the Canary Islands are scant, dust events reach the archipelago with a high frequency, being associated with augmented prevalence, morbidity and mortality [12]. There are precedents in other regions, such as the Caribbean Sea where increase of frequency in African dust episodes reaching Barbados were associated to a seventeen-fold increase in asthma between 1973 and 1996 [21-23]. In Gran Canaria and Tenerife, type and frequency of asthma symptoms have been analyzed in a large population sample, and climatic conditions have been invoked to explain high prevalences [24].

In this paper we study aerosols from African dust intrusions at a high altitude ecosystem in Tenerife, Canarian archipelago. Specific health effects of mineral dust and bioaerosols have not been studied so far in the Canary Islands, and this task is difficult to approach without recognizing the type of particles involved. We thus aimed to identify and survey, through scanning electronic microscopy (SEM) analysis, the biological and mineral aerosol particles transported with dust during intrusions of African air masses and from other origins to the Canary Islands. Imaging characterization of dust particles could give us explicit information on aerosol types in relation with complementary data on origin and travelling time of air masses. We related the dust events with the air-mass origin, tracing back the dust trajectories to assess source areas. Our primary concern was on aerosolized particles with a potential interest in public health that are transported with dust plumes from Africa to the Canary Islands.

2. METHODS

2.1. Study Area

We studied air samples searching for biogenic particles (bioaerosols) during a non-intrusion episode (“clean atmosphere”) and during dust invasions to Tenerife, the largest and more densely populated and visited island of this group (**Table 1**). Our sampling was focused on the

Table 1. Characteristics of air samples from filters taken at the high mountain station of Izaña in Tenerife.

Particle sampler type	Hour (GMT) and initial sampling date		Hour (GMT) and final sampling date		Cycle volume (m ³)	African dust outbreaks	Back Trajectory	
							Initial sampling	Final sampling
PM2.5	14:44	03/03/04	14:50	04/03/04	731	+	EAM	EAM
PM2.5	14:58	04/03/04	15:40	05/03/04	506	+	EAM	EAM
PM2.5	12:22	17/03/04	12:26	18/03/04	731	+	AfD	AfD
PM2.5	11:05	22/03/04	11:40	23/03/04	733	+	AfD	AfD
PM2.5	10:12	04/04/04	15:35	05/04/04	732	+	MaA	MaA
TSP	15:48	03/03/04	15:55	04/03/04	732	+	EAM	EAM
TSP	16:10	04/03/04	16:20	05/03/04	731	+	EAM	EAM
TSP	16:30	05/03/04	16:45	06/03/04	731	+	EAM	EAM
TSP	12:26	11/03/04	15:10	12/03/04	731	– (control)	OMT	OMT
TSP	12:13	17/03/04	12:17	18/03/04	731	+	AfD	AfD
TSP	12:23	18/03/04	13:30	19/03/04	732	+	AfD	EAM
TSP	11:00	22/03/04	11:35	23/03/04	731	+	AfD	AfD
TSP	11:45	23/03/04	12:20	24/03/04	731	+	AfD	AfD
TSP	10:05	04/04/04	13:40	05/04/04	732	+	MaA	MaA

Trajectory codes: OMT: Atlantic Oceanic Middle Troposphere; AfD: African Dust; EAM: mixture of Europe, Africa and Oceanic origins; MaA: maritime aerosols.

high mountain scrub, at the Teide National Park (free troposphere, over the stable inversion layer, which is found between 1000-1500 m), at the facilities of the Instituto Nacional de Meteorología (Izaña Observatory, 16°29'58" W; 28°18'32" N; 2360 m a.s.l.) (**Figure 1**).

The Izaña site is located above a sharp temperature inversion between 500 and 1500 m, thus remaining relatively apart from the contamination foci of the low areas and human settlements [25]. At Izaña, the characterization of African dust is possible with low interference of other pollutant sources [26]. The dust transport is strongly seasonal, occurring near the surface in the cold season (October to March) and above two kilometres altitude in the warm season (April to September) [27,28]. We centred the sampling effort in March-April 2004. Annual distribution of particulate matter at low areas in the Canary Islands peaks in winter and shows a minimum in summer, whereas in the Tenerife high mountain, the maximum dust incomes occur in summer. Nevertheless dust episodes are also commonly detected in spring-time in both levels [19,27,28].

2.2. Dust Trajectories and Origins

To assess the origin of the aerosols, seven days backward trajectories were calculated daily at 00 and 12 UTC during March 2004 with HYSPLIT-4 model (Draxler and Hess, 1997 in [27]). The end point of the back trajectories was the Izaña station. Physical-chemical aero-

sol properties can be related with the origin and trajectory of the aerosol-laden air masses. Díaz [27] and Díaz *et al.* [28] developed a methodology to characterize the source-transport paths of the aerosol over this region using multivariate clustering analysis. The back trajectories classification is based on the contribution of the main aerosol sources, considering the geographical regions, the residence time in these sectors and the altitude of the air mass during the evolution towards the island. With this technique, clusters of back trajectories can be found for different levels of transport and origins of the air masses [28].

2.3. Dust SEM Analysis

TSP (Total Suspended Particles) and PM_{2.5} (Particulate Matter with 2.5 micrometers diameter or smaller) were sampled simultaneously on quartz glass filters (Schleicher and Schuell, QF20), with high volume samplers MCV CAV-A / M (30 m³/h). Samplers operated for 24 h periods from 03 / 03 / 04 until 05 / 04 / 04, and completed 14 samples (**Table 1**). We separated part of the filters for scanning electron microscope (SEM) analysis. A small section (< 1 cm²) of each filter was cut and glued onto an aluminium stub and processed for SEM. Complementarily, another section of the filter was gently pressed on an adhesive carbon conductive tab to transfer the filter content to the preparation, then the tab was glued to the stub and processed for SEM. Preparations

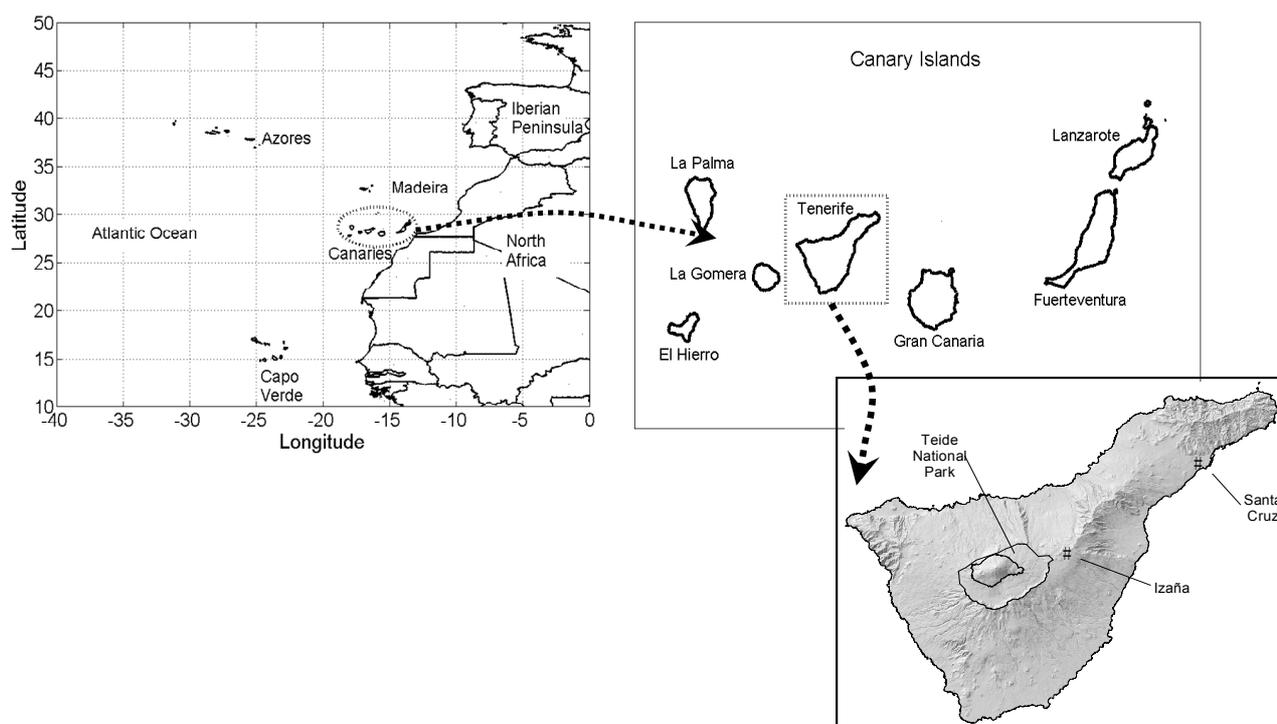


Figure 1. Study area and sampling stations.

were observed and photographed in a JEOL JSM 6300 electron microscope. We resolved the elemental composition of some particles with X-ray electron probe microanalysis (EDX) (OXFORD 6699) of selected SEM samples. The system operated at 20 kV (operation range: 0.2-30 kV) with a maximum resolution of 3.5 nm.

3. RESULTS

3.1. Dust Trajectories and Origins

Clusters of back trajectories found were: 1) representative of Atlantic oceanic middle troposphere (OMT); 2) air masses originated in the African continent (AfD); 3) mixture of aerosols from at least two of these sources: Europe, Africa and Ocean (EAM); 4) air masses with high load of maritime aerosols (MaA). The average frequencies of occurrence of these clusters on March over a 52 year period (1948-2004) were 17% AfD, 24% EAM, 40% OMT and 19% MaA.

Mean altitude for trajectories ending at Izaña was 2970.85 m (range: 0-8119.5 m) in March 2004. The back trajectories analysis for Tenerife for that month showed that air masses were 30% AfD, 24% EAM, 24% OMT and 22% MaA. These values revealed an increase in frequency of African dust events (cluster AfD) of 13% at the high mountain site compared with the average value of the 52-year period. In particular, of the 14 samples obtained at Izaña (**Table 1**), 13 corresponded to mineral dust conditions, where the 79% of the air masses were directly transported from the African continent (43% AfD and 36% EAM), whereas the remaining two represent maritime air masses with presence of dust particles. This last situation is observed most likely during the spring-summer period at Izaña [28], where the air masses cross areas with a high concentration of dust due to a Sahara-Sahel outbreak occurred in previous days. As exemplified in **Figure 2** (upper panel), the air mass in cluster AfD progressed at low altitudes while crossing the eastern Sahara desert (particularly between 0 and 15° E) and then gained altitude approaching the Atlas range, finally reaching the end point in the Tenerife high mountain at 2360 m. Furthermore, given that a 24 h sampling schedule was applied, the possibility of ascending air masses transporting coastal material up to the summit at Izaña station can not be disregarded [26].

3.2. SEM Survey of Dust Particulate Matter

In our SEM samples, most abiotic and biological or biogenic particles are within the respirable size range. Aerosols presenting a wide size range (including PM_{2.5} and PM₁₀) were quartz and clay grains, gypsum rods and halite. Crustal aerosols appeared clustered, which increased average lateral dimension of particles. The main bio-

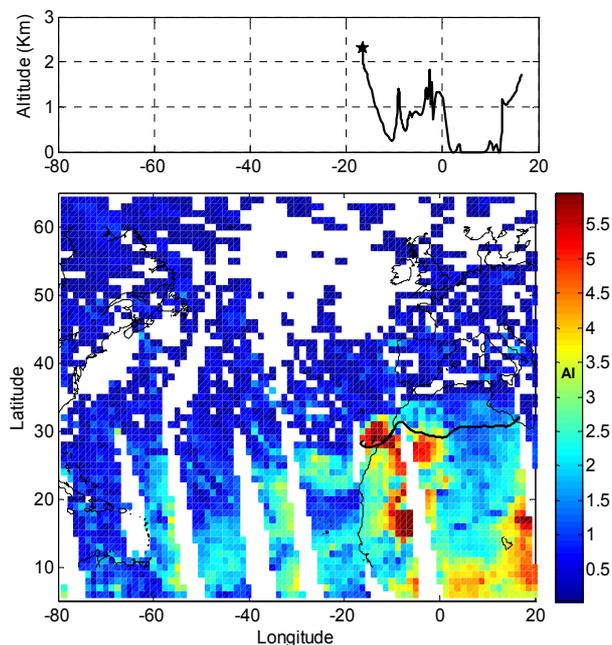


Figure 2. Values of the TOMS AI (Total Ozone Mapping Spectrometer Aerosol Index) for a back trajectory of 24 / 03 / 2004 (black line, below graphic) of African mineral dust estimated for Izaña (Tenerife, Canary Islands). The TOMS aerosol index is a relative measure of the amount of aerosol particles absorbing radiation in the atmosphere. The vertical altitude- longitude cross section of the trajectory is shown in the upper panel (maximum at ca. 2400 m a.s.l.). The white arrow points the geographic evolution of the air mass from left to right. The colour scale is adimensional and depicts the TOMS AI.

aerosols found here (diatoms) belong to the PM₁₀ fraction, although a large amount of fragmented thecae were within the PM_{2.5} class; pollen grains and one fungal conidium were within PM₁₀.

3.3. Aerosols of Biotic Origin

We made only an overview of major aerosol types transported with dust to the Canaries, and we did not quantify the concentration of airborne species. The most abundant biological remains identified in our SEM samples for African dust episodes were diatom siliceous tests (**Figure 3**). Two species of the genus *Aulacoseira* Thwaites (1848) (formerly *Melosira*), were identified: *A. granulata* (Ehrenb.) Simonsen 1979 and *A. islandica* (O. Müller) Simonsen (Bacillariophyta). Apart from diatom remains, other biogenic material was difficult to observe in SEM preparations, where the mineral fraction dominated. We identified only one fungal taxon, most probably *Alternaria* sp., as determined from a clavate conidium, showing the loculi under an irregular surface (**Figure 3 (A)**).

Pollen grains were found by SEM but species could

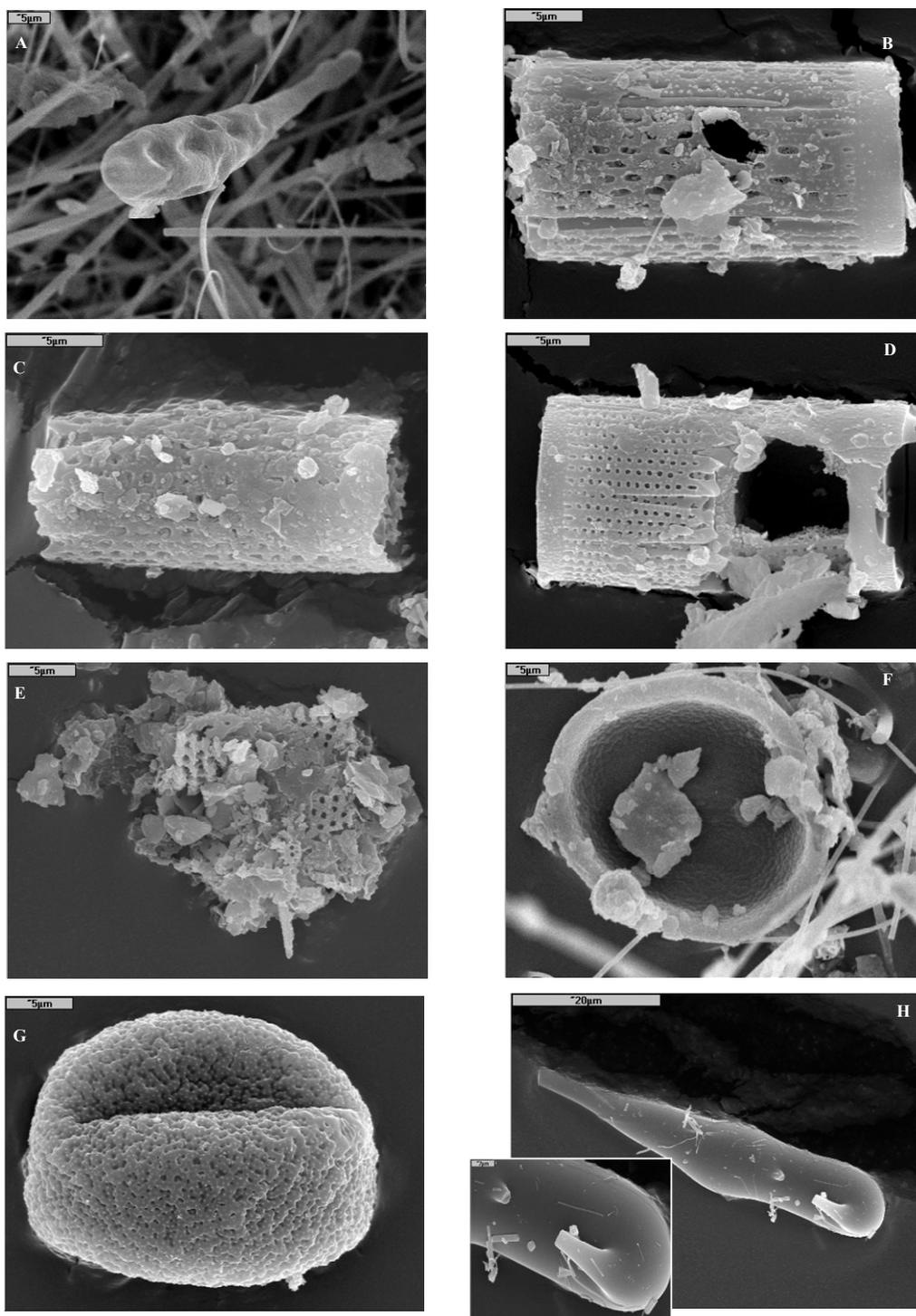


Figure 3. SEM photographs of TSP and PM_{2.5}, biogenic particulate matter or bioaerosols identified in dust filters from Tenerife (Canary Islands) during African dust intrusions. All samples from Las Cañadas (high mountain site), excepting F (Santa Cruz, coastal city). **(A):** Typically club-shaped Conidium of ascomycotan fungi (*Alternaria* sp., a cause of allergic fungal sinusitis). **(B)-(D):** Siliceous tests of freshwater diatoms (**(B)** and **(C):** *Aulacoseira granulata*; **(D):** *A. islandica*), heavily eroded and worn due to the transport process. **(E):** Conglomerate of diatom test remains (presumably *Aulacoseira* spp.) with platy clay particles. **(F):** undetermined pollen grain, cross-section, containing mineral particles (Santa Cruz). **(G):** pollen grain, undetermined species. **(H):** fragmentary spicule-like particle (inset: magnification), origin (either abiotic or biological) and composition uncertain.

not be assigned (**Figure 3(G)**). Pollen was very rare in filters, which operated during the early spring season when flowering period was not at its peak in the Tenerife high mountain. We failed to identify bacterial cells in filter preparations examined with SEM.

3.4. Aerosols of Abiotic Origin

Filters from the control day (“clean troposphere”) showed a very different aspect when compared with filters from dust events (**Figures 4(A),4(B)**), the latter being concealed with a dense mineral-biomineral matrix (**Figure 4(C)**). The abiotic particulate aerosols identified individually included clay grades and quartz microcrystals (isolated or aggregated) of crustal origin (from AfD cluster), and gypsum rods (CaSO_4). Halite, cubic and cube-octahedra crystals of sea salt (NaCl) were obtained from the OMT cluster correspondent to clear atmospheric conditions and incidence of marine aerosol reaching the high mountain area (compare with [26]).

Quartz (SiO_2) microcrystals (particles from $< 10 \mu\text{m}$ to $< 2 \mu\text{m}$) formed the dominant or background material in our filters during dust intrusions (**Figure 4**). Aerosols transported from the Sahara desert are enriched in clay material due to a high residence time in atmosphere caused by a smaller particle size and laminar habit; these clay grade grains are transported as particles of silt size forming aggregates [29,30] (**Figure 4**).

4. DISCUSSION

As suggested by our filter samples from different origins, *Aulacoseira* diatom thecae compound the dominant biogenic aerosol, and quartz is the dominant mineral fraction, which also formed up to 60% of dust material in a study from Gran Canaria [31].

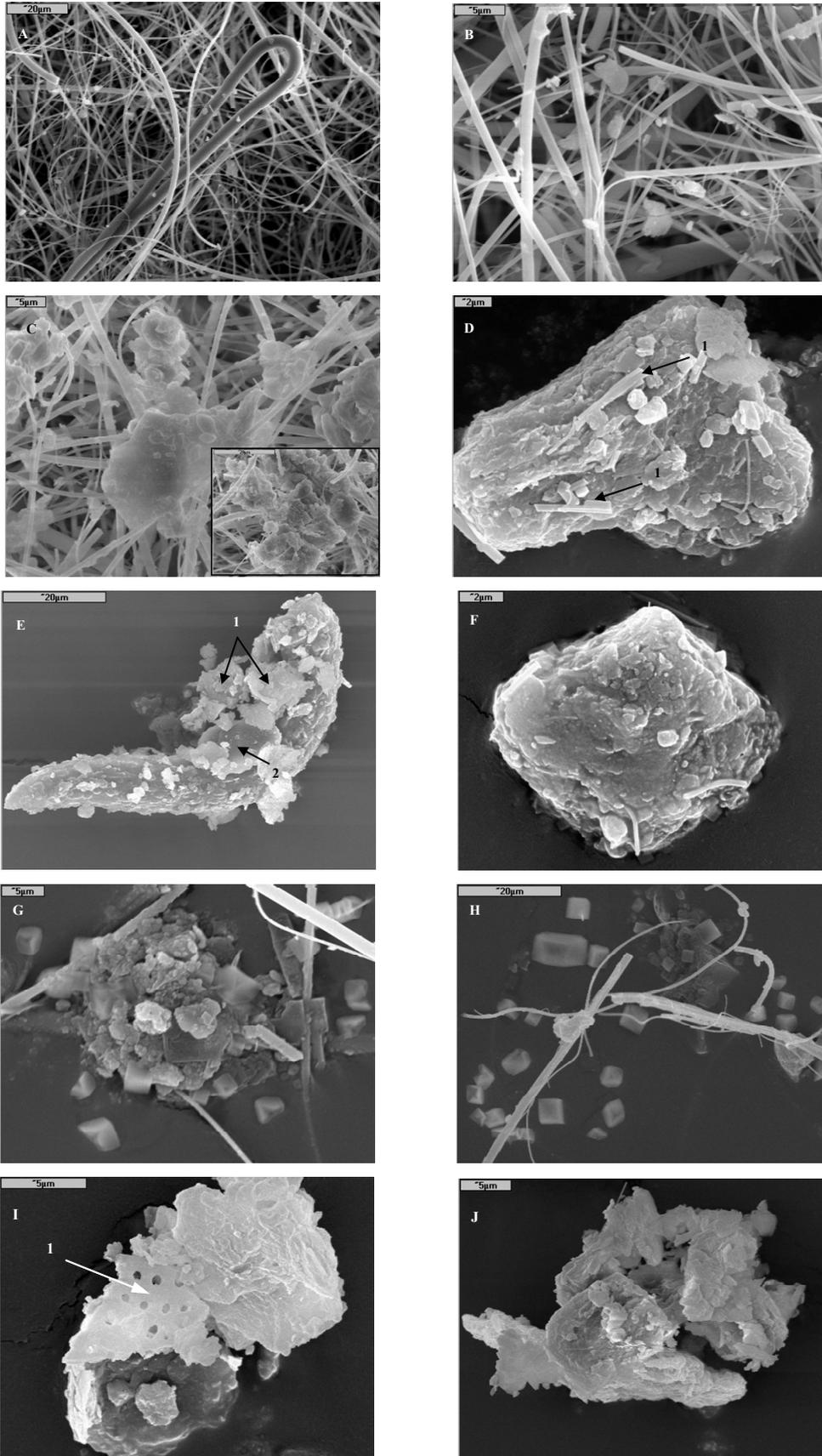
The diatoms identified are dominant taxa in fresh waters from N and NW Africa, and can be found throughout the Palaearctic [32]. *A. granulata* has been recorded in the Arctic probably transported from Siberia [33]. Both *A. islandica* and *A. granulata* are typical of eutrophized and alkaline waters. As far as we know, these species have not been deemed as pathogenic to humans; on the contrary, they are used as bioindicators of freshwater quality in most studies. They can be transported as viable cells through the ocean, and their importance in the windblown diatom fraction decrease with increasing distance from the African continent [4]. The aeolian transport of diatoms and phytoliths from continental fresh water deposits in the Sahara and Sahel [4,34] should be investigated to assess relative contribution to high incidence of environmental airway diseases in the Canaries. We are not aware of detailed clinic studies relating natural (desert) diatom dust with respiratory diseases. Fur-

thermore, concentrations of airborne diatom particles from African deserts and professional exposure to diatom dust are not comparable [35]. Diatoms transported with the dust plumes to the Canaries augment the overall silica content of the aerosols, and silicosis caused by non-crystalline forms of silica have not only occupational but environmental etiology [36]. On the contrary, non-industrial silicosis (known as “desert lung”) has been reported decades ago from autopsy of Bedouine lung tissue, showing high amounts of silica dust of respirable size [37]. More study cases of non-industrial lung or environmental silicosis, have been reported for regions chronically exposed to desert dust (*i.e.* Himalaya [38]).

The Tenerife highland ($> 2000 \text{ m a.s.l.}$) is not a populated area, but it receives > 4 million visitors/year, the most visited volcanic area of the world after Mount Fuji, Japan. There is evidence that symptoms of asthma in lowland patients improve with therapy of high-elevation stays [39,40]; however, episodic but severe dust events may imply additional health risks given the extreme conditions at these altitudes for such long permanencies (moderate hypoxia, high aridity of this area and increased sun radiation exposure, among other stressors). Origin and type of air mass and aerosol load can be predicted and used to establish and prevent potential interactions with respiratory disease in susceptible visitors to the island’s National Park.

Particles of different sizes have different ability to penetrate the pulmonary system and reach the lung parenchyma [41]. Modelling of aerosol inhalation schematize the stratification of particle deposition along the human airways depending on their aerodynamic diameter [42]. Particulate matter (PM) $< 10 \mu\text{m}$ (PM_{10}) penetrate the tracheobronchial region; increased deposition in the oropharynx occurs with particles larger than $6 \mu\text{m}$, whereas central airway deposition peaks within the 4-6 μm range. Particles like those in **Figures 4(B), 4(D)** or **4(I)** would be able to reach the central airways. PM between 2-4 μm ($\text{PM}_{2.5}$) reach the alveolar cavities (*i.e.* lung periphery), where their damage is greater due to higher reactivity [42]. Particles like the one depicted in **Figure 4(K)** seem of potential interest in this range.

Although a great proportion of diatom remains are within or above the PM_{10} fraction (particulate matter 10 micrometers in diameter), thereby being potentially retained by the trachea and bronchia, a great amount of test fragments are within the $\text{PM}_{2.5}$ fraction, and thus could reach the lung alveolar system [35]. In addition, the role of diatom thecae as carriers of particles of health interest (e.g. bacteria, viruses, fungal or protozoan spores or cists, pollen) can be important, since: a) these remains co-dominate, along with quartz mineral, in many of the dust events of North African origin, and b)



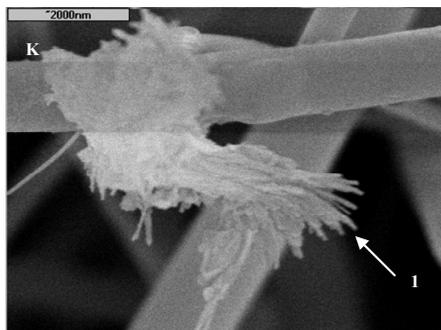


Figure 4. SEM photographs of TSP and PM_{2.5}, mineral aerosols of crustal, marine and anthropogenic origin identified in dust filters from Tenerife (Canary Islands) during an African dust intrusion. **(A)-(B)**: two general views of a relatively clean filter with few mineral particles (without African dust) from Izaña. **(C)**: filters with dense platy clay microcrystals typical of a dust intrusion (Santa Cruz). **(D)**: Agglomeration of clay on carbon adhesive film (EDX: Si, Al, K, Ca, Fe, Na, Mg) (Izaña); 1: elongate rectangles on the aggregate surface are gypsum rods (EDX: Ca, S, O). **(E)-(F)**: clay microcrystals; 1: clay aggregates; 2: flat and rounded quartz particles adhered (Izaña). **(G)-(H)**: halite (EDX: Na, Cl), clusters of cubic crystals from marine aerosol (Santa Cruz). **(I)-(J)**: conglomerates of quartz clay grades with diatom test fragments of laminar habit (1); **(K)**: fibrous particle of unknown origin around the 2 µm size range attached to filter; note the “fringed” end (1).

due to their structural complexity, large adsorption surface and cavities for shelter of diverse particles, and lateral dimension.

We found only a fungal remain in our dust samples. However, fungal species linked to respiratory disease are surprisingly frequent from desert areas [6]. Some deserts next to urban areas behaved as differentiated sources of Basidiomycotan fungi [43]. Kellogg *et al.* [10] detected *Alternaria*, *Cladosporium* and *Aspergillus* in dust samples from Mali. *Cladosporium* was also isolated from African dust in the Virgin Islands (Caribbean) [7]. Prospero *et al.* [44] isolated more than 20 fungal taxa from North African dust in Barbados, finding low percentages of *Alternaria*. With *Cladosporium*, *Alternaria* is one of the most abundant spore-forming fungi in dry and warm regions such as the subtropical Canary Islands [6]. *Alternaria* was also a very frequent bioaerosol in a study at mid elevation on Tenerife [45]. In other dry climates (e.g. Phoenix, Arizona), *A. alternata* and *A. raphani* has been detected in PM₁₀ from desert neighbouring urban areas [43], and Glikson *et al.* [46] found that fungal spores were predominant over other bioaerosols such as pollen in Brisbane (Australia). We failed to find other fungal remains through SEM, a surprising result since we expected a higher importance of this type of particles during dust events, judging from literature. However, we isolated and cultivated other common allergenic fungi (*Aspergillus*, *Penicillium* and *Cladosporium*) which were not detected by SEM from the same filter samples (unpublished data).

Apart from plant pathogen, *Alternaria* is a cosmopolitan, saprophytic soil fungus comprising several species pathogenic for immunocompromised hosts [47,48].

A. alternata causes environmental allergic alveolitis, and for many authors it is the most important fungi in allergy causation, especially in Mediterranean areas [49]. Allergic fungal sinusitis is due to finely dispersed fungal spores in air, and 56-95% percent of patients diagnosed with chronic rhinosinusitis presented fungus in nasal secretions [50,51]. We should investigate frequency and concentration of fungal spores in this insular region and if causes for high prevalence of allergies in areas affected by dust intrusions might be attributed to airborne fungal species.

Around 20% of the human population of the Canaries suffers from allergy or allergy-related diseases [52]. However, prevalence of diseases such as asthma or allergies has not been paid enough attention regarding associations with climatic factors, climate change or influence of atmospheric phenomena such as Saharo-Sahelian dust episodes on the archipelago [24]. The complex mixture of particles of respirable size identified by SEM in this study may play a role in sensitizing and thus preparing the road for other “opportunistic” airway diseases. Processes of aerosol particles deposition and effects in the airways depend on particle size and form, and respiratory conditions [35], but the mechanisms by which both mineral aerosols and bioaerosols act in the airway pathologies are poorly comprised.

In populated areas, mixtures amongst particulate matter of different origins are common during dust intrusions, as revealed by our SEM analysis. In many instances, allergens invade the respiratory tract in or on a different particle, and it is today clear that exposure to an allergen on or within a carrier pollutant can substantially enhance its allergenic potential [53,54]. Many of the

aerosol types overviewed here can incorporate additional pollutants from the atmosphere, and in case of bioaerosols, surface proteins can be altered and then released into the respiratory system. Synergies between anthropogenic aerosols and bioaerosols also deserve attention. Diatom tests, quartz and gypsum fiber-like particles mix to form aggregates, and pollen grains can transport those and other mineral particles (**Figures 4(B)-4(F),4(J)**). Important synergies between bioaerosols (mostly pollen, fungi and soil bacteria, but perhaps also viruses) and other atmospheric pollutants (*i.e.* NO_x, VOCs—volatile organic compounds—ozone, tobacco smoke) have been reported in relation with increasing asthma prevalence in urban areas [46]. Pollen secrete eicosanoid-like molecules (*i.e.* leukotriene-like) which act signaling in immunity and inflammation, and such releasing is favoured by contact of pollen with gases from traffic exhaust and petrol industry [54].

The study of the origin of the air mass through back trajectory would allow knowing the potential of remote subtropical and tropical areas for issuing other disease vectors in dust plumes to the Canary Islands and other places. This tool should be integrated along with quantitative and qualitative aerosol characterization in the creation of prevention nets [12,55]. Attention should be paid to candidate disease vectors that can be predicted, through tracing of backward trajectories, to reach the islands with dust intrusions in the next future. In fact, nearly 80% of the air masses reaching the islands have a direct North African origin. SEM analysis is useful as a complementary tool in the morphological identification of new particle types or combinations of particles of interest in disease causation [56]. Moreover, exploratory biopsy of the respiratory mucosa through SEM analysis would prove useful in identifying PM types and linking them as causal factors with atmospheric dust PM. Nevertheless, molecular and clinical characterization of the active substances associated to aerosols is a critical and unavoidable step for prevention of dust mass impact on human health [54]. In the Caribbean, relationship between asthma attendance peaks and African dust intrusions have previously been revealed [23]. For the Canary Islands, where African dust intrusions exert their effects before reaching the Caribbean, the studies dealing with problems posed by dust intrusions on public health remain anecdotic, whereas effective control of dust effects on human population is a major sanitary goal [12].

5. CONCLUSIONS

Aeolian dust reaching the high altitude areas of the Tenerife island has a larger contribution of North African air masses, and is formed by a structurally complex mixture of biogenic and abiogenic particles, of respirable

size and contrasting morphology; we found that the diatom test fraction is qualitatively relevant (along with the dominant, background quartz fraction), whereas other biogenic fractions such as pollen or fungi are more scarce, or difficult to resolve, at least by means of SEM, and at these elevations within the island. Increasing aridity periods, irregular and torrential rains, changes in vegetation cover and desertification would affect the aerosol load (both biogenic and abiogenic in origin) received by these subtropical islands as dust intrusion events increase in frequency [16,17,57].

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