

Aerobiological monitoring applications in the Etnean volcanic plume evaluation (Mt. Etna, Sicily) and correlation with allergopathies

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Abstract This paper describes the study of the application of a Hirst-type impact volumetric sampler (IVS) in the sampling of volcanic ash continuously emitted by Mt. Etna. This methodology is commonly used for measuring the atmospheric concentration of airborne pollen grains and fungal spores. This study was undertaken between April 2003 and January 2005, when a series of ash emissions occurred; moreover, during this period, namely on 7 September 2004, there was an eruption from various fractures located in the higher eastern flank of the volcano. The airborne volcanic ashes involving the lower south-eastern flank of Mt. Etna were monitored by means of an IVS stationed in the town of Acireale. In some people volcanic ash can trigger predisposing factors linked with allergens, and an allergic response may occur. After exposure,

immunoglobulin E (IgE) antibodies are produced and released into the bloodstream and they can, therefore, be identified by haematological analysis. In this study we compared the number of ash events recorded by our IVS and the number of total immunoglobulin E (IgE) values found in the population living on or near this volcano sector. A correlation was established between air pollution from volcanic ash and IgE values over a period of 22 months.

Keywords Aerobiology · IgE values · Impact volumetric sampler · Mt. Etna volcano · Volcanic ash

1 Introduction

Several studies on the effects of indoor and outdoor environmental pollution on public health have been carried out in various countries in the past 20 years. Environmental pollution is clearly considered to be one of the most important causes of allergic reactions such as asthma and rhinitis; it can also be responsible for serious pathological conditions such as lung cancer, and it can increase mortality (Baxter et al., 1999; Custovic, Murray, Gore, & Woodcock, 2002; Dockery et al., 1993; Durand and Grattan, 1999; McConnell et al., 1999). It is known that prolonged exposure and the nature of the pollutant are key factors

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affecting human health. In fact, short periods of exposure can only provoke mechanical transitory effects, generally if the metal content of the particles is very low; it is also known that the presence of metal in the particles can favour an increase in particle toxicity (Hatch et al., 1985). Various studies have reported an increase in pulmonary response to volcanic ash (Vallyathan, Mentnech, Tucker, & Green, 1983; Yano, Yokoyama, & Nishii, 1986).

Rojas-Ramos et al. (2001), after a 7-month prospective study of the respiratory, nasal and ocular effects of exposure to ash from Popocatepetl volcano (Mexico), found that the health impact of exposure in 35 non-smoking farmers was present only during acute episodes of ash emission. The effects found were both a reversible decrease in pulmonary function and an increase in respiratory symptoms, probably due to an inflammatory response of the respiratory epithelium after inhalation of particles containing less than 3.5% of free silica, considered to be of relatively inert nature. The violent nature of Mt. Etna's 2001 and 2002–2003 eruptions produced an exceptional amount of ash in the atmosphere, and a large number of inhabitants tested positive for allergies at a time when the airborne allergen count was relatively low (see Sect. 4). We noticed that the amount of volcanic ash in the atmosphere had been recorded by the Hirst-type impact volumetric sampler routinely used to monitor pollens and spores over a period when more or less abundant ash episodes occurred from the summit eruptive vent of Mt. Etna. In this study we report the correlation found between the recorded immunoglobulin E (IgE) values and the number of volcanic ash episodes and their duration in the time span from April 2003 to January 2005.

2 The site

Mt. Etna is a volcano located on the eastern coast of Sicily, with a basal diameter of approximately 40 km and a height today of 3,314 m above sea level (Fig. 1). Its eruptive behaviour has evolved in the past 500,000 years from prevalently fissure-type eruptive activity to a central type one

(Chester, Duncan, Guest, & Kilburn, 1985; Kieffer, 1985; Tanguy, Condomines, & Kieffer, 1997). Its activity actually consists of prevalently strombolian and laval fountains from all four summit craters (La Delfa, Patanè, Clocchiatti, Joron, Tanguy, 2001; La Delfa, Innocente, Patanè, & Tanguy, 2003) and flank eruptions through long fissures extending from medium [1,900 m above sea level (a.s.l.)] to high (2,800 m a.s.l.) altitude (Behncke and Neri, 2003; Neri, Acocella, & Behncke, 2003; Tanguy, Clocchiatti, La Delfa, & Patanè, 2001; Tanguy, Aubert, Clocchiatti, La Delfa, & Patanè, 2002).

Since the second half of the twentieth century Mt. Etna has been considered to be one of the most active volcanoes in the world, due to its exceptional activity (Patanè, La Delfa, & Tanguy, 2004). This activity consists of abundant emissions from the four summit craters and from open eruptive fractures at various altitudes on its flanks. These manifestations, often of high intensity, evolve first in lava fountains and, afterwards, in copious emissions of lava flows (Patanè et al., 2004). Between 1971 and 1996, 19 of these eruptions involved the flanks of the volcano; this frequency of occurrence is approximately five-times greater than that of the three previous centuries. At the same time, the effusion rate of $0.8 \text{ m}^3/\text{s}$ was three-times higher than the rate

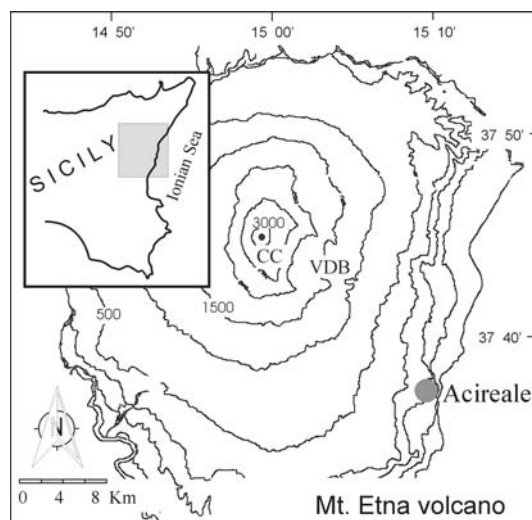


Fig. 1 Map of Mt. Etna volcano (Sicily). CC central craters, VDB Valle del Bove

recorded in the period between 1868 and 1970 (Murray, 1990). These effusion rates are inferior only to the Hawaiian Kilauea volcano, which expels a lesser amount of gases. Since the 1971 eruption, Mt. Etna has been producing an average of 2×10^5 tons/day of watery vapours and 7×10^4 tons per day of sulphuric gases (Allard et al., 1991). Despite the highly concentrated emissions, Mt. Etna is not a dangerous volcano; the casualties of its long history have not, in fact, been due to eruptive phenomena, but to incautious behaviour. The dimensions of the volcano (40 km from north to south and 38 km from east to west and the present-day 3,314 m altitude) attenuate the effects of highly explosive eruptions, since the city belt is located more than 12 km from the summit craters. Such distance is, however, not sufficient to protect the urbanised areas from cineritic and vaporous emissions, even during periods of relative quiescence; in fact, a certain activity of micro-particulates (solid particles with micrometric dimensions) from the summit craters remains. The upward currents concur to direct such emissions towards the advanced layers of the atmosphere. The meteorological conditions can, however, push the volcanic plume downwards, forcing it into a sinusoidal trajectory, thus involving also the distant inhabited areas, as recorded during the 2002 eruption (Fig. 2; modified from Andronico et al., 2005).

The visual observation of the volcanic plume during the past 3 years has shown that the prevailing wind directions pushed the volcanic plume towards the east and south-east; moreover, this has allowed us to hypothesise that the Valle del Bove (VDB), the large caldera on the eastern flank of the volcano, could contribute to push the plume to considerable height, possibly because it consists of lava flows without vegetation (known as sciare) which, when heated by the sun, generate upward thermals that confer new energy to the system.

In our study we consider all the cineritic events recorded by our impact volumetric sampler (IVS) and involving the low south-eastern flank of the volcano during a 22-month period. The results obtained were compared with the acquired airborne pollen concentrations and with total IgE antibody data acquired from patients residing

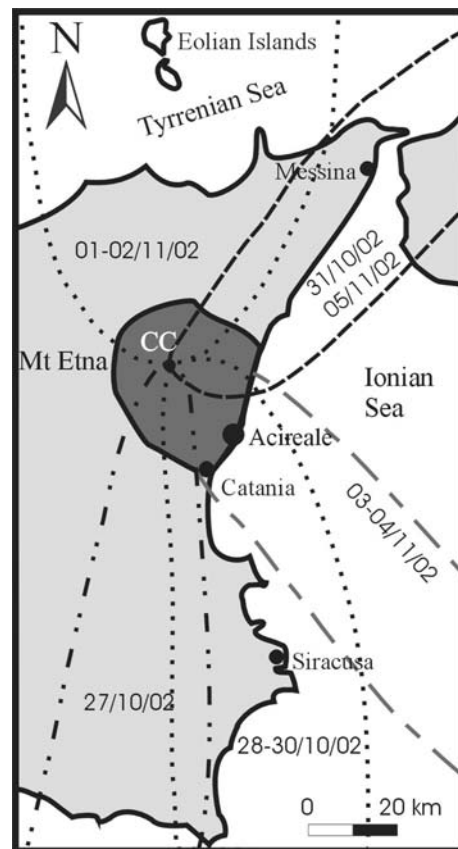


Fig. 2 Map of the areas covered by lapilli and ash deposit fallen between 27 October and 5 November 2002 (modified from Andronico et al., 2005). CC central craters

within an area a maximum of 4 km away from our IVS instrument.

3 Material and methods

3.1 Volcanic ash and meteorological parameters

A Hirst-type impact volumetric sampler (Hirst, 1952), installed 16 m above the ground on the terrace of the Istituto di Ricerca Medica ed Ambientale (I.R.M.A.) (Medical and Environmental Research Institute), in Acireale (20 km south-east of the central craters) (Fig. 3a, b), was the instrument used to acquire the data for airborne cineritic particles in the atmosphere. The sampler has a pump that ensures a constant

flow. The flow rate, corresponding to a human mean breath rate of approximately 10 l/min, ensures intake and delivery of particles on a sampling surface. The air passes through an intake orifice measuring 2 mm × 14 mm, impacting on a plastic tape attached to a rotating drum covered with adhesive silicone paste and positioned at the opening. The drum has a clock mechanism that allows rotation for 7 days at a speed of 2 mm/h. The particles in the air (with a diameter below 200 µm) are trapped on the tape, which is subsequently separated into sections (Fig. 4), one for every day of sampling, and thereafter analysed by optical microscopy. The relationship between the rotation time of the drum and the length of the tape allows one to determine the time, in hours and minutes, at which the particles were trapped (Fig. 4a). Apart from pollen and spores, we noted areas of varying degrees of opacity, depending on the abundance of the trapped particles. The optical microscope (highest magnification 20×) allowed us to identify accurately the boundaries of those black areas representing cineritic ash. The number of these dark areas for each section constituted the number of daily cineritic events (NCE), whereas their duration (DCE) was obtained from each dark area's width (an example inside the rectangle in Fig. 4b). Counting the number of particles was not possible because they accumulated in large amounts on small portions of the sampling area. This work is, however, aimed at establishing the number and duration of periods during which volcanic ash is recorded, disregarding the absolute count of airborne ash contents.

Concurrently with the recording of the airborne particles, the meteorological parameters were recorded by a Davis Vantage Pro weather station located on the terrace of the Institute, 5 m from the IVS. The meteorological data were



Fig. 3 (a) Sketch of Mt. Etna volcano, indicating the investigation site (ACR) and the four active summit craters: north-east crater (NEC), central crater (CC), Bocca Nuova crater (BN) and south-east crater (SEC). (b) The aerobiological sampler operating in Acireale. (c) Vertical degassing from the summit craters in the absence of wind. (d) Strong emission of gases and ash involving the eastern flank of the volcano. (e) Linear plume directed towards the west

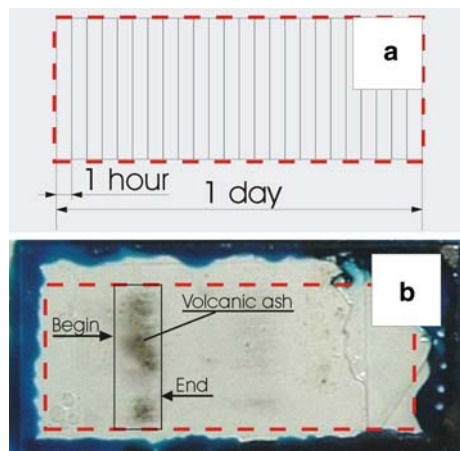


Fig. 4 Sampling area and time division in hours (a); cineritic band on adhesive silicone paste (b)

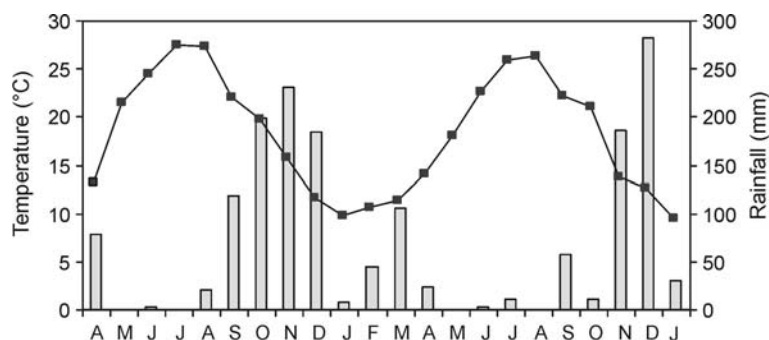
acquired every 30 min and were analysed monthly. For this study, we only considered parameters regarding temperature (degrees Celsius) and rainfall (millimetres) (Fig. 5). Wind speed and directions were not considered, because our recording station is too far from the centres of ash emission and both speed and directions change depending on altitude. So, when the volcanic plume moves from the central craters altitude (more than 3 km), towards Acireale, it is possible to have several different flow directions which do not provide any link with the volcanic ash sources.

3.2 Immunoglobulin E

In some people, volcanic ash can trigger predisposing factors linked with allergens, and an allergic response may occur. After exposure,

IgE antibodies are produced and released into the bloodstream and they can, therefore, be identified by haematological analysis. It has been widely demonstrated that serum concentration of IgE isotype antibodies is more elevated in allergic patients, both children and adults, than in same-age non-allergic patients. Total IgE serum concentration varies greatly amongst healthy individuals, from minimum levels at birth to progressively higher values, to peak values in the second decade of life. While the arithmetic average is relatively low, a confidence interval of 95% is particularly widespread in all age brackets (Klink, Cline, Halonen, & Burrows, 1990). IgE can, in fact, be in the bloodstream without binding to mastocytes, or it can bind to the surface of basophils thus sensitising them even in the presence of low-level serum IgE. It is, therefore, possible to have high IgE levels without any symptoms but also low IgE levels and presence of symptoms. Considering that there is some overlapping between allergic and non-allergic patients, since it is necessary to differentiate between atopic, asymptomatic state and allergic disease, and excluding non-allergic pathologies caused by hyper-IgE (IgE myeloma, Job's syndrome or intestinal parasitosis), it is reasonable to suppose that high IgE levels argue in favour of the atopic state. On the basis of this premise a selection was made of 925 patients who had come to the Institute to have an IgE total count test performed (Yunginger, 1988) between April 2003 and January 2005. All the cases we studied concerned patients residing in the immediate Acireale area. All patients with rhino-conjunctival symptoms due to various aeroallergens were included. No patient with

Fig. 5 Meteorological parameters: temperature (line) and rainfall (histograms)



IgE higher than 100 IU/ml suffered from intestinal parasitosis, Job's syndrome or IgE myeloma. The IgE total count was obtained through the Diagnostic Products Corporation (DPC) immunometric method, on an Immulite 2000 automatic AutoAnalyser which works on the principle of chemiluminescence in solid phase.

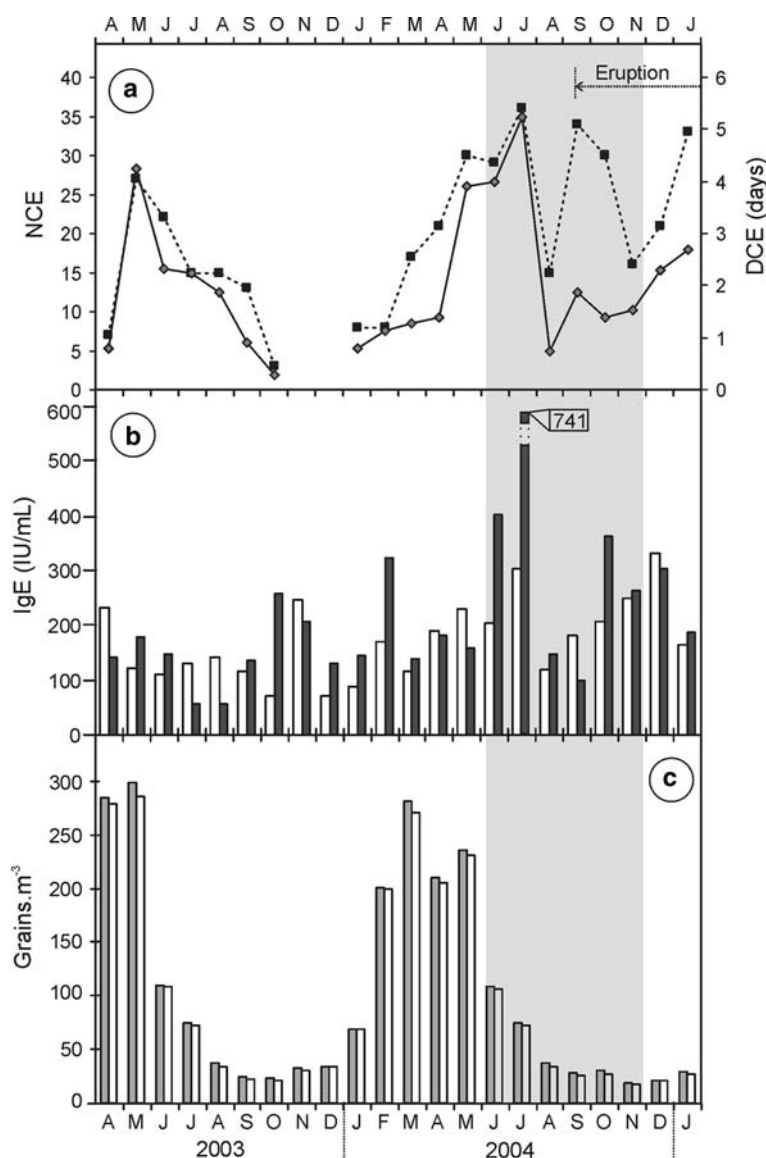
4 Results

The proximity of an active volcano to inhabited areas implies environmental airborne pollution

deriving from volcanic emissions. During the 22 months of data collection, several ash particles had been trapped by our IVS. Results are shown in Fig. 6a. As can be observed, several episodic events of various frequency (NCE) and duration (DCE) have been the object of our investigation. It is also noted that the highest values were recorded in May 2003 and in May, June and July 2004.

The IgE values were extracted from a dataset consisting of more than 1,000 cases. The dataset consists of 925 cases: 413 men and 512 women. The total average IgE values recorded were: 217 IU/ml

Fig. 6 Trends vs time of (a) number (NCE, dotted line) and duration (DCE, continuous line) of cineritic events. (b) Values of total IgE for men (black histograms) and women (white histograms). (c) Concentration of airborne pollen grains: total (grey histograms) and allergenic (white histograms)



and of 174 IU/ml for men and women, respectively. IgE values versus time are shown in Fig. 6b. Increasing and decreasing IgE value trends generally occur for men and women at the same time; however, it is also possible to observe that the highest values are registered in men.

If we look at the recorded meteorological parameters (Fig. 5), we observe a seasonal trend for both temperature and rainfall; in fact, the highest temperature (28°C) was recorded in summer and the lowest (10°C) in winter. The highest rainfall was recorded in winter periods, whereas the lowest precipitation and/or absence thereof were recorded in summer. If we consider the results from all the acquired data, it is possible to observe that, generally, the number of cineritic events and their duration are consistent with the total IgE values recorded for both men and women and show similar trends (Fig. 6b).

The pollen concentration registered in the observation period showed relatively high values in April and May 2003 and from February to May 2004. Such a result, taking into account that the concentration of airborne pollens in the same period was very low, suggests that allergic symptomatology from June to November 2004 was not mainly due to the content of allergenic pollen grains (Fig. 6c). So, this phenomenon must have been due to another factor, and this factor was the Etnean micro-cineritic ashes, as shown in Fig. 6a.

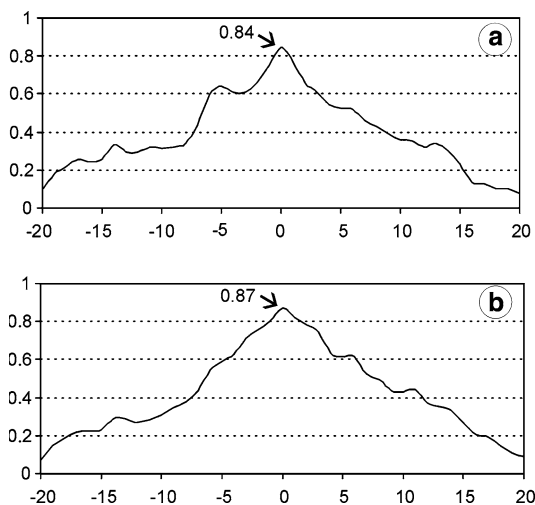


Fig. 7 Cross-correlation of total IgE values (including both men and women) with DCE (a) and with NCE (b), respectively

The effective correlation between the analysed series was confirmed by cross-correlation analysis (Fig. 7). In fact, the statistics result obtained suggests that a correlation of 0.87 and 0.85 exists between total IgE values and NEC and DEC, respectively (Fig. 7a, b). Besides, any significant delay in the occurrence of both trends is observed. These results suggest that an IgE increase and volcanic ash episodes occurred simultaneously.

5 Discussion and conclusions

The input for the compilation of this study derives from an unusual fact: a significant increase in the number of tests prescribed for total IgE specific and IgE for aeroallergens between November 2002 and January 2003. This season is usually characterised by a minimum number of requests for allergological tests, but various large cineritic events took place in 2002. This fact encouraged us to hypothesise that these two phenomena were correlated.

It was hence noted that, for the inhabitants of Acireale and its surrounding area, exposure to Etnean air particulates as a concurrent element to exposure to other more known atmospheric pollutants creates the conditions for alterations of the upper respiratory tract which, in turn, trigger the insurgence of allergopathologies. It is known that allergenic particles in the air, such as pollen grains and fungal spores, can more easily cause an allergenic reaction in the presence of a hypersensitive respiratory mucosa, due to the action of elements with chemical and mechanical aggressiveness. This fact becomes interesting, from the environmental point of view, if it is assumed that volcanic ashes are a natural pollutant, like pollen grains. In fact, they represent, in our opinion, a triggering factor in the dynamics of the insurgence of allergopathies in eastern Sicily, as is demonstrated in the case history of an I.R.M.A. study (Finocchiaro, 2005). What we want to verify is the effective aggressive action on the mucosa of the upper respiratory tract by the Etnean ashes through a mechanical action (a possible chemical action was not analysed

because we consider the particle constituents to be of inert nature). The trends observed for both the monthly number and the duration of cineritic events and the average of IgE total values show a good correlation. The insurgence of allergopathies could, however, occur at the same time or after some months, depending on the frequency of occurrence and/or the duration of the cineritic phenomenon. The high values of IgE recorded late in 2004 could, therefore, have been caused by the cineritic activities recorded since April 2004 and increasing until June 2004. In fact, in the period between October and December 2004, IgE values were relatively higher than those for the same period in 2003.

From the comparison carried out it can be concluded that, in volcanic areas, emissions of micro-cineritic aero-particulates can be recorded by means of a Hirst-type impact volumetric sampler, which can, therefore, be considered to be a good and reliable instrument for this task. It has, moreover, been confirmed that volcanic ash emissions, also in the Etnean areas, can contribute to the insurgence of transitory respiratory pathologies such as allergopathies in a season like autumn, when pollen grains and fungal spores are generally absent in the atmosphere.

This study constitutes a first approach to the problem examined and highlights indications of interest in the relationship between airborne Etnean particulate and allergopathies insurgence. A more focused analysis of the chemical and statistical aspects, carried out for longer periods, would supply clearer indications and could define with greater precision the nature of the relationship between the Etnean aero-particulates and the trigger mechanisms of allergic phenomena or other pathologies. The development of this type of study could contribute to our better understanding of the complex relationship that links human health to volcanic environmental pollution.

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