Pact 33 - IV.3 : Paolo Mandrioli, Andrea Malossini and Cristina Sabbioni

The Monitoring of Allergenic Pollen, Phytopathogenic Fungal Spores and Pollutant Atmospheric Particles

Abstract

The following communication deals briefly with the range of activities carried out in the field of aerobiological monitoring in Italy. The presence of allergenic pollen and phytopathogenic fungal spores in the atmosphere gives rise to major fields of application such as that related to allergic diseases and that concerning crop diseases. Aerobiological monitoring could be extended to other particles recognizable on the basis of their morphology, and, in particular, to those affecting our cultural heritage.

Introduction

Since the beginning of 1980's, the Institute for the study of physical and chemical phenomena in the lower atmosphere - National Research Council (FISBAT-CNR) in Italy has devoted part of its scientific research to investigating atmospheric particles of various origin and their impact on human health, agricultural crops and the cultural heritage. In particular, research on the sources and distribution of allergenic pollen has been carried out and, as a consequence, the instruments and methods necessary for setting up a National Network to monitor the concentration of these particles have been established. A similar programme has been implemented to check the presence and concentration of certain fungal spores responsible for agricultural crop damages directly in the field. These data have been employed to optimize control strategies for plant protection. With respect to the damaging effect of particles of natural or anthropogenic origin on the cultural heritage, investigations have particularly concentrated on techniques for monitoring the sources of the various sort of particles and/or chemical compounds.

TABLE 1. — LIST OF THE AEROALLERGEN MONITORING STATIONS

ITALY - LIST OF STATIONS (1985-89)

01	1	ACIREALE CT	37.37 N 15.10 E	50	3	MATERA	40.40 N 16.36 E
02	5	ANCONA	43.38 N 13.30 E	51	2	MESSINA	38.11 N 15.34 E
03	5	AOSTA	45.44 N 07.20 E	52	1	MESSINA	38.11 N 15.34 E
04	4	ARCO TN	45.55 N 10.53 E	53	1	MESSINA	38.11 N 15.34 E
05	0	ARIENZO CE	41.01 N 14.30 E	54	4	MILANO	45.28 N 09.12 E
06	5	ASCOLI PICENO	42.51 N 13.34 E	55	5	MILANO NIGUARDA	45.31 N 09.12 E
07	4	AVELLINO	40.54 N 14.47 E	56	5	MILANO SUD	45.25 N 09.05 E
08	5	BARI	41.08 N 16.51 E	57	5	MODENA	44.40 N 10.55 E
09	0	BELLUNO	46.09 N 12.13 E	58	0	MODENA	44.40 N 10.55 E
10	0	BOLLATE	45.33 N 09.07 E	59	5	MONTESCANO PV	45.02 N 09.17 E
11	5	BOLOGNA	44.29 N 11.20 E	60	2	NAPOLI	40.50 N 14.15 E
12	4	BRESCIA	45.33 N 10.15 E	61	4	NAPOLI NORD EST	40.50 N 14.15 E
13	3	BRISIGHELLA RA	44.13 N 11.46 E	62	2	NUORO	40.19 N 09.20 E
14	1	BUSTO ARSIZIO VA	45.37 N 08.51 E	63	4	ORBASSANO TO	45.03 N 07.32 E
15	5	CAGLIARI	39.13 N 09.07 E	64	0	ORISTANO	39.54 N 08.36 E
16	4	CAMPOLI BN	41.08 N 14.39 E	65	0	OZIERI SS	40.35 N 09.00 E
17	3	CARRARA MS	44.05 N 10.06 E	66	5	PADOVA	45.25 N 11.53 E
18	5	CASATENOVO CO	45.41 N 09.19 E	67	0	PALERMO	38.07 N 13.22 E
19	4	CASERTA	41.04 N 14.20 E	68	5	PARMA	44.43 N 10.20 E
20	5	CASSANO MURGE BA	40.53 N 16.46 E	69	4	PARMA OVEST	44.43 N 10.20 E
21	5	CATANIA	37.30 N 15.06 E	70	5	PAVIA	45.10 N 09.10 E
22	3	CATANZARO	38.54 N 16.35 E	71	1	PERGINE VALSUGANA TN	46.04 N 11.14 E
23	4	COMO	45.47 N 09.05 E	72	5	PERUGIA	43.08 N 12.22 E
24	5	CONSELICE RA	44.31 N 11.49 E	73	0	PERUGIA	43.08 N 12.22 E
25	3	COSENZA	39.18 N 16.15 E	74	0	PERUGIA	43.08 N 12.22 E
26	0	CRAVANZANA CN	44.34 N 08.08 E	75	2	PESCARA	42.28 N 14.13 E
27	3	CREMONA	45.07 N 10.02 E	76	3	PIACENZA	45.01 N 09.40 E
28	2	CROTONE CZ	39.05 N 17.08 E	77	4	PIETRA LIGURE SV	44.09 N 08.17 E
29	1	CUNEO	44.23 N 07.32 E	78	3	REGGIO CALABRIA	38.06 N 15.39 E
30	3	DARFO BOARIO TERME ES	45.53 N 10.11 E	79	1	REGGIO EMILIA	44.43 N 10.36 E
31	1	ERCOLANO NA	40.48 N 14.21 E	80	4	ROMA	41.54 N 12.29 E
32	5	FERRARA	44.50 N 11.35 E	81	1	ROMA	41.54 N 12.29 E
33	5	FIRENZE NORD OVEST	43.48 N 11.15 E	82	0	ROVIGO	45.04 N 11.47 E
34	5	FIRENZE SUD OVEST	43.45 N 11.13 E	83	1	SAN MICHELE ADIGE TN	46.11 N 11.08 E
35	5	FOGGIA	41.27 N 15.34 E	84	5	SANREMO IM	43.49 N 07.46 E
36	4	GALLARATE VA	45.40 N 08.47 E	85	5	SASSARI	40.43 N 08.34 E
37	5	GENOVA	44.25 N 08.57 E	86	3	SAVONA	44.17 N 08.30 E
38	4	GROSSETO	42.26 N 11.08 E	87	0	SIENA	43.19 N 11.21 E
39	5	IMOLA BO	44.21 N 11.42 E	88	0	SONDALO SO	46.20 N 10.19 E
40	1	L'AQUILA	42.22 N 13.22 E	89	3	TARANTO	40.28 N 17.14 E
41	1	L'AQUILA OVEST	42.22 N 13.22 E	90	4	TORINO	45.03 N 07.40 E
42	5	LANCIANO CH	42.14 N 14.23 E	91	1	TORINO	45.03 N 07.40 E
43	5	LECCE	40.23 N 18.11 E	92	3	TRIESTE	45.40 N 13.46 E
44	1	LECCO CO	45.51 N 09.23 E	93	5	VARESE	45.48 N 08.50 E
45	5	LIVORNO	43.33 N 10.19 E	94	2	VERCELLI	45.19 N 08.25 E
46	1	LOZZO DI CADORE BL	46.29 N 12.17 E	95	4	VERONA	45.27 N 11.00 E
47	3	MASSA MARITTIMA GR	43.03 N 10.53 E	96	2	VERONA SUD	45.27 N 11.00 E
48	0	MATERA	40.40 N 16.36 E	97	5	VERUNO NO	45.42 N 08.32 E
49	5	MATERA	40.40 N 16.36 E	98	1	ROMA	41.54 N 12.29 E

Legend : a) station item ; b) number of years in operation ; c) site name (city) ; d) latitude/longitude.

Allergenic pollen

Some years ago a network was set up in Italy, for monitoring pollen of allergenic interest and this is now operating throughout the whole country (Mandrioli, 1988). The wide interest in such a network is due chiefly to an increase in allergies which now affect 15 % of the population, 5 % of whom show symptoms of pollinosis. The main airborne pollen types in Italy which cause an allergic reaction are reported in Fig. 1. Another reason for the increase in interest results from the great variation of bioclimatic features throughout Italy, the country stretching over 1200 km from North to South. Such climatic and vegetational variation requires a denser network for monitoring pollen concentration as shown in Fig. 2 and Tab. I.

The main purpose of the Aeroallergen Monitoring Network is to measure the concentration atmospheric pollen which is allergologically interesting. The Sampling Network is co-ordinated by the Italian Association of Aerobiology (AIA), which has standardized both sampling and data processing methods. The dissemination of these methods has been achieved by means of preparatory and specialization courses held all over Italy and aimed at training all the station operators.

The AIA has set up a National Data Bank which collects the pollen data sent in by all the stations, arranges for the delivery of information to the mass media, gives its consent to those centres wishing to join the network and maintains the connection between the domestic network and the European Aeroallergen Network (EAN).

The Sampling Network began its activities in 1985. During 1989, namely from March to October, 70 stations operated regularly. The sampling stations

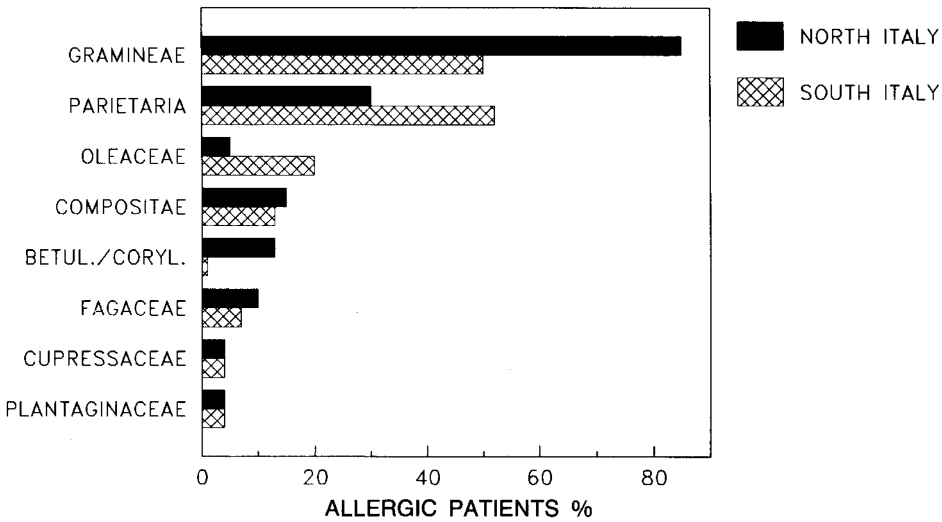


Fig. 1. Positivity to main airborne pollen grains in Italy.

are located in University Institutes (i.e. University Clinics and Institutes of Botany) and their activities are carried out on a self-financing basis.

The stations located in the Institutes of Botany, which include the following cities : Turin, Genoa, Modena, Perugia and Cagliari, identify a greater number of taxa. Each team consists on average of 1 allergologist and 1 biologist, the latter having the task of carrying out the pollen count and the

Fig. 2. Italian aeroallergen monitoring network ; the numeric codes represent the sampling stations (see Tab. I).

data transmission. Each sampling station has to identify the following taxa : Betulaceae, Compositae, Corylaceae, Fagaceae, Gramineae, Oleaceae, Plantaginaceae, Urticaceae.

Since 1987 some sampling stations also identify : Cupressaceae/Taxaceae, Cheno-Amaranthaceae, Polygonaceae, Euphorbiaceae, Myrtaceae, Ulmaceae, Platanaceae and Aceraceae.

There are some Regional Nodes which are responsible for collecting the data of several groups of stations. Subsequently these regional collectors send the data to the Computer Centre at Bologna. All stations which do not have a regional node as a reference point, send their data to the National Collecting Centre at Montescano. This procedure takes place every Thursday. Each Operative Centre transmits weekly the pollen data concerning the previous week. Two different kinds of station are operative namely, those technically equipped for the transmission of data by telephone and those equipped for the transmission of data by personal computer (Fig. 3).

All data are stored and processed through a special software package. Some stations, which best represent the Italian situation, have been selected to join the European Aeroallergen Network.

The routes employed for spreading pollen information depend primarily on the target group to which it is directed. If the information is directed towards allergic patients, then the routes chosen are pharmacies and TELETEXT. If it is the doctors and technicians who are the target group,

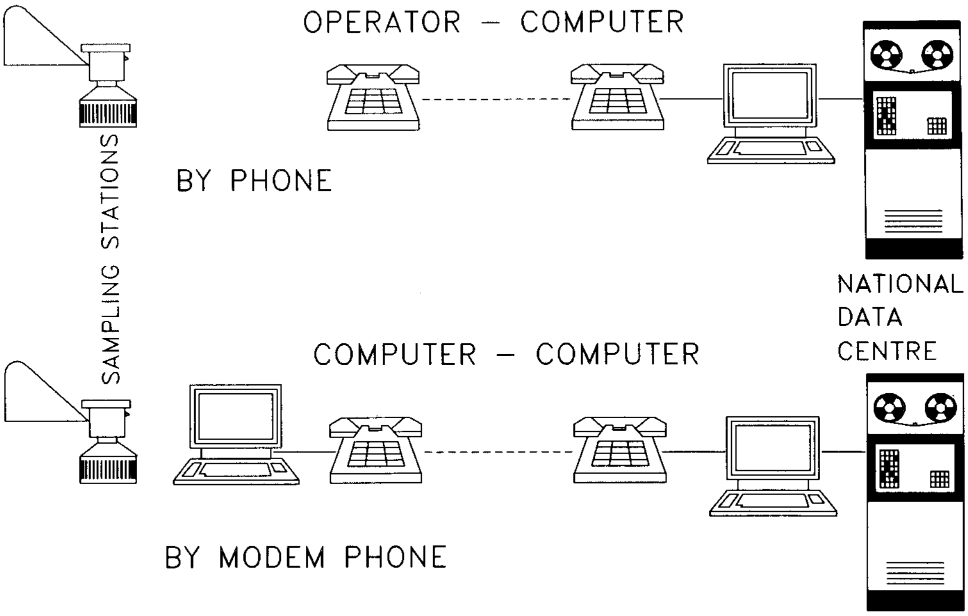


Fig. 3. Data transfer system performed by Italian Aeroallergen Network.

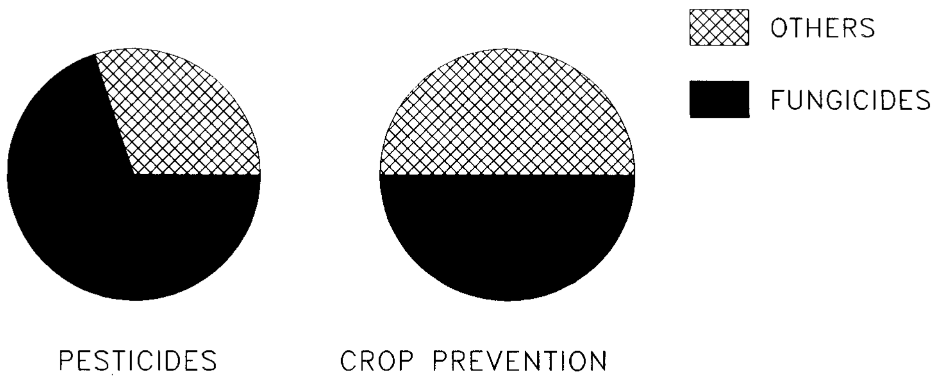
then the medical press is the preferred route. Teletext pages may be consulted on the national television channels, on page 635 under the heading « Health ». Several pharmacies display a regional Pollen Bulletin issued weekly by AIA. The utilization of VIDEOTEX (phone cable connection) may be considered as a future route aimed specifically at the medical sector.

The details outlined so far clearly indicate the clinical and social importance of pollinosis. As a matter of fact, the age classes which are primarily affected are those under forty basically from school age to that of higher individual productivity. When medical expenses (health examinations, diagnostic tests, medical treatment) are added to both the absence from school or work and the lower working efficiency and productivity of the patients, the social costs of this disease are clearly recognizable.

Damage to agricultural crops

In recent years plant pathologists have focussed their interest on the aerobiological field in terms of monitoring the dispersal of fungal spores of sexual and asexual origin. This is in order to forecast the spread of cryptogamic diseases.

In agricultural production and, in particular, in vine and fruit cultivation fungal diseases certainly supercede other problems, from both the economic and the technical point of view. It is pertinent to remember that, in Italy, fungicides are applied in amounts in excess of 100 Gg per year (2-4 kg/ha S.A.U. Utilized Agricultural Surface) which corresponds to about 70 % of the total amount of pesticides and 50 % of the chemicals used globally for the prevention of crop damage (Fig. 4).



* 100 Gg per year of fungicides in Italy.
2 - 4 Kg per Ha of Utilized Agricultural Surface.

* 100.000 tons.

Fig. 4. Chemicals in agriculture : prevention of crop damage.

These values are supplied by ISTAT (Italian Institute for Statistics) and also include data on production and distribution which however, do not differ appreciably from those of application. Considerably more detailed analyses, carried out on experimental crop areas have produced similar average data, whereas single analyses have given rise to extremely different data ; as a matter of fact, the utilization of fungicides for the control of downy mildew, mildew and bunch rot in vine cultivation ranged from 1,7 kg/ha/year to 27,9 kg/ha/year, the average being 4-5 kg/ha/year (Giannico, 1988).

The chemical treatments are particularly costly (15-20 % of global production costs) being exceeded only by harvesting costs. Despite the introduction of integrated plant protection (at present the decrease in cryptogamic diseases is 7 % in apple trees and 27 % in peach trees) the number of chemical treatments during particularly unfavourable seasons is still very high (8-10 year, up to a maximum of 20 in apple trees, 25 in pear trees, 12 in peach trees, 12 in vine and 3 in other plants of the same species (Rossi and Randi, 1985).

To give fuller details, some examples must be presented using average values and taking into account the different requirements of the various crops, otherwise it is only too easy to make gross errors. On the basis of a survey carried out in 1983 on more than 100 farms all over Emilia Romagna, it was concluded that the costs of fungicides used in apple orchards which cover an area of about 88,000 ha in Italy, was 390,000 It.Lire/ha (300 USD) in the case of traditional plant protection and 357,000 It.Lire/ha (274 USD) in the case of integrated plant protection ; the cost for peach orchards, covering an area of 82,000 ha amounted to 180,000 It.Lire/ha (138 USD) (traditional plant protection) and 100,000 It.Lire/ha (77 USD) (integrated

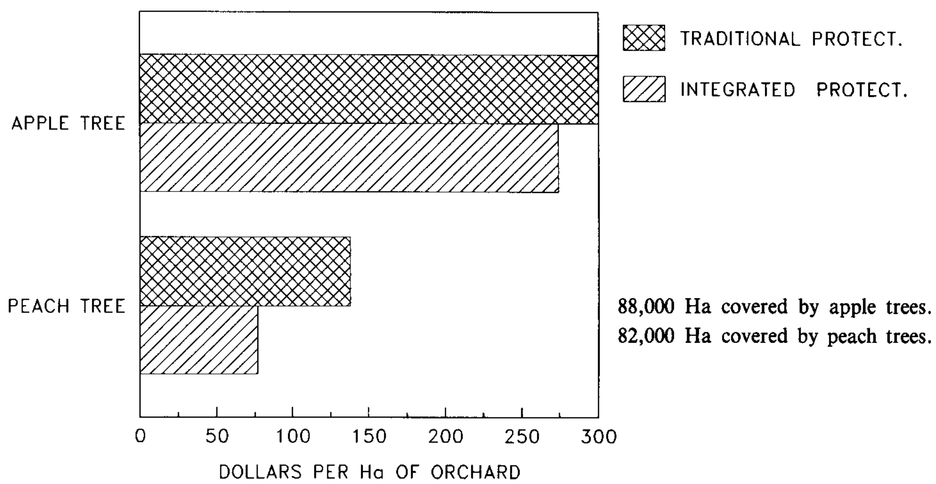


Fig. 5. Chemicals in agriculture : costs of fungicides.

plan protection) (Fig. 5). In addition, it should be noted that the costs involved in using specially designed equipment and skilled manpower have to be added to the above.

The traditional method, which is a calendar-based protection, is the most widespread at present. Treatments are carried out on fixed dates irrespective of the real risk of infection. Unfortunately, few alternative choices are offered and these concern only some of the cryptogamic diseases. For those with a lower incidence the concept of a « symptomatological threshold » has been introduced (Ponti and Laffi, 1988) consisting basically of a clear definition of the limits beyond which the infection caused by the fungus becomes critical for the plant and, at the same time, can be still kept under control by means of a specific treatment. Otherwise, agrometeorological data and, in particular, such parameters as temperature, relative humidity, precipitation and leaf wetness could be used. These, properly applied on known forecasting models, enable the identification of the right moment at which fungicides should be used.

The technical gap to be filled is therefore the detection of the actual presence of the fungal spores, which are the actual cause of the infection. It is not possible to spot the presence of the fungal spores in all cases, only in diseases where the spore spreading carrier is the air, namely : *Armillariella mellea*, mushroom root rot ; *Fusicoccum amygdali*, cherry canker ; *Gymnosporangium sabinae*, pear rust ; *Mycosphaerella sentina*, ashy leaf spot of pear ; *Nectria galligena*, apple canker ; *Oidium crataegi*, apricot mildew ; *Plasmopara viticola*, grape downy mildew ; *Puccina cerasi*, cherry rust ; *Stereum purpureum*, silver leaf disease ; *Tanzschelia pruni-spinosae*, plum rust and *Venturia inaequalis*, apple scab. Certainly such information would represent a quality jump in the implementation of and the search for new forecasting models.

In recent years in Italy, spore traps for the monitoring of airborne fungal spores of phytopathological interest are being utilized to attain this goal. The activities carried out in this sector have so far been developing within the framework of various research programmes (5-year Project for Integrated Plant Protection, supported by the Region Emilia Romagna - Research Project for the Increased Production of Agricultural Resources IPRA, supported by the National Research Council CNR) and concern the monitoring of ascospores of *Venturia inaequalis*, which is the pathogenic agent of apple scab. Among the great number of spores causing severe cryptogamic diseases more than 70 affect cherry trees, apple trees and vine ; thanks to the aerobiological monitoring some of these are easily detected, allowing a substantial contribution to the improvement of mathematical forecasting models, a slight decrease in the number of chemical treatments and a fall in cropping costs.

Damage to the cultural heritage

The main damage mechanisms operative on the cultural heritage have been ascribed in the literature to pollutant atmospheric gas, particularly SO_2, which is considered responsible for sulphation, that is the transformation of calcium carbonate (the main component of carbonate stones, such as limestone and marble) into gypsum (dehydrated calcium sulfate). In addition to atmospheric gas, aerosol, both natural and anthropogenic, plays an important role in damaging the cultural heritage. The aim of this paragraph is to synthesize those measurements made with regard to the effect of atmospheric aerosols on the surfaces of monuments and historical buildings.

A number of physical, chemical and biological processes can occur on the surface of a momument, such as erosion, dissolution, sulphation etc. Within the different damage typologies, the areas affected by the formation of a patina or crust can be considered as accumulation surfaces for the deposition of both atmospheric gas and aerosol, as well as the products of chemical reactions taking place on the stone surface (Fig. 6). During the formation of a crust, the atmospheric aerosol deposited on the surface is found to be progressively embedded within the weathering layer (Camuffo *et al.*, 1982). A wide series of analyses have been performed to confirm the presence of atmospheric aerosol within these layers.

The main analytical techniques used are : (a) Optical and Electron Microscopy, to reveal the morphology, size and distribution of the particles embedded within the weathering layers ; (b) Differential Thermal Analysis (DTA), Thermal Gravimetric Analysis (TGA) and X-ray Diffraction (XRD) to identify and quantify the main salts ; (c) Combustion and IR techniques for carbon and sulphur measurements ; (d) Ionic Chromatography for sulphates and chloride detection ; (e) Plasma Spectroscopy (ICP) to establish the elemental composition ; and (f) Proton Induced X-Ray Emission (PIXE) to evaluate minor elements.

The main components of the atmospheric aerosol identified within the weathering layers present on monuments and historical buildings are both natural and anthropogenic. The mineral dust, which has been found in all the samples analysed, is characterized by high elemental concentrations of silicon, aluminium and iron and by the presence of quartz and feldspars in XRD analyses. The presence of marine aerosol in the weathering layers sampled on limestone and marble monuments situated in maritime localities, such as Venice, Ravenna, Ancona and La Spezia, has been confirmed ; the elemental analyses show high values of sodium, chlorine and magnesium (Zappia *et al.*, 1989). In addition, anthropogenic aerosol has been found embedded within the crusts. Optical and electron microscopy allowed the recognition of particles emitted by combustion processes. Soot particles (Fig. 7), the characteristic spherical, spongy, carbonaceous particles produced by oil fired boilers have been identified in all the analysed samples from monuments and historical buildings situated in urban and industrialized areas in Italy (Del Monte *et al.*, 1981). In contrast, glassy spherical particles characteristic of coal combustion have been preferentially found in specimens sampled in other European countries, such as England (London) and France (Marseille) (Del Monte and Sabbioni, 1987). Recently a comprehensive series of data has been collected analysing the crusts of monuments in the urban areas of Northern and Central Italy (i.e. Milan, Venice, Rome, Bologna, Ravenna, Verona, La Spezia, Trento). These data show that, in addition to sulphur, which is the main element comprising the crusts, other elements are present which are characteristic of atmospheric aerosol emitted by different anthropogenic sources (Bacci *et al.*, 1989). Iron is the heavy metal present at the highest concentration and must be attributed to both the stone constituting the monuments and to atmospheric aerosols, such as mineral dust and particles emitted by different combustion processes. Lead is abundant at all the sites. As this element is the characteristic tracer for motor vehicles, the results obtained confirm the high deposition levels of particles emitted by petrol combustion on all the monument surfaces analysed. Vanadium is present at all the sites analysed. This element is a tracer for the aerosol emitted by fuel oil combustion. In Italy, oil is the main fuel used both for electric energy production and domestic heating. Its concentration in the black crusts gives a quantitative indication of the deposition of carbonaceous particles on the surfaces. Zinc, characterizing refuse incineration, has also been found. Arsenic, which is a tracer for coal combustion, has been detected in the La Spezia samples and must be attributed to the presence of a coal-fuelled electric power plant (one of the few existing in Italy). Although the results of this extended study are still in progress, it can be stated that the concentrations of elemental tracers characteristic of specific pollutant sources provide an indication of the historical atmospheric pollution affecting each site.

Airborne particles deposited on monuments and historical buildings, produce a variety of effects on their surfaces. They contribute to damage through several mechanisms according to their composition. The acid fraction of atmospheric aerosol, particularly nitric acid and sulphuric acid, is responsible for the dissolution of calcareous surfaces. The sulphuric acid reacting with the calcium carbonate, produces thick crusts of gypsum. Metal elements, such as iron, manganese and vanadium, and the carbonaceous fraction act as catalysts in the oxidation of sulphur dioxide, favouring the formation of calcium sulphate. Soluble salts, particularly those in marine aerosol (i.e. sodium chloride, sodium sulphate) produce both an efflorescence on the surface and an inner mechanical stress due to internal recrystallization.

Finally, specific attention has been given to the study of biological weathering, particularly with regard to the formation of an oxalic patina

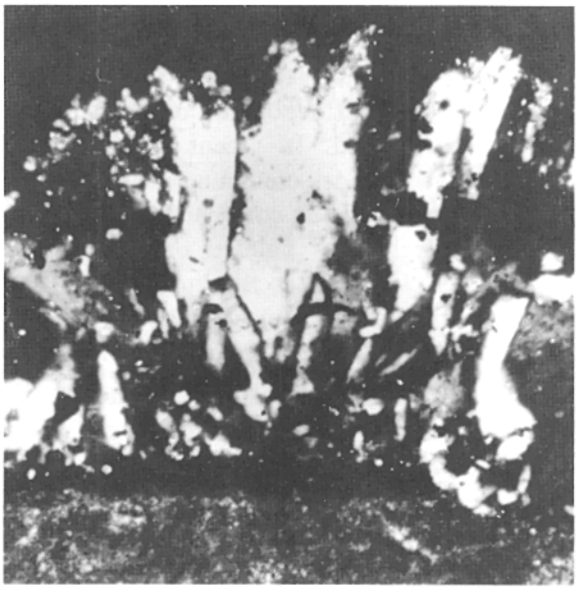


Fig. 6. Thin section of a gypsum crust observed by optical microscopy at crossed nicols.

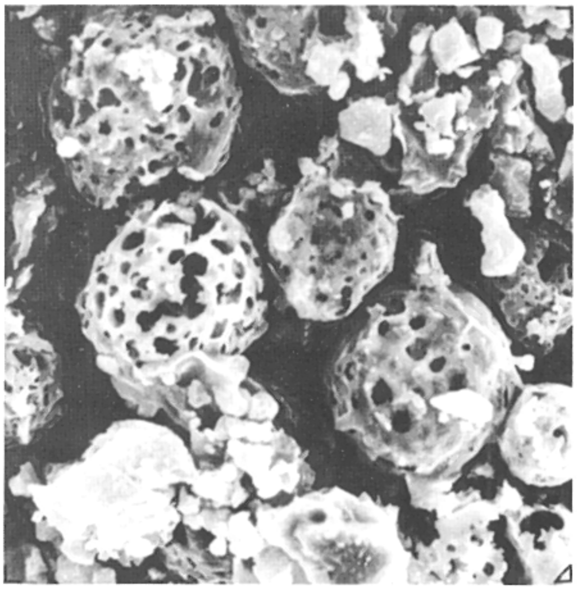


Fig. 7. Scanning electron micrograph of oil-fired carbonaceous particles observed on gypsum crust.

(Del Monte *et al.*, 1987). On a large number of monuments and historical buildings a thin patina composed of calcium oxalates has been found. Chemical and mineralogical analyses of all the samples have shown the presence of whewellite and weddellite, monohydrated and dihydrated calcium oxalate respectively. The formation of these two minerals, first observed on monuments in 1853 by J. von Liebig, has been attributed to the secretion of oxalic acid by microorganisms (endolithic and epilithic lichens), present on limestone surfaces. The oxalic acid reacts with the calcareous substrate to produce a precipitate of calcium oxalate. The possibility of direct deposition of oxalatic particles from the atmosphere must also be considered. In recent works, small quantities of calcium oxalate crystals have been detected in aerosols sampled in the atmosphere. The oxalatic patinas have also been considered in the literature as : (a) the remains of the original polychromes painted on the marble surface, (b) an artificial layer deliberately applied to the marble surface in order to protect it from environmental attack, (c) a secondary transformation product resulting from the oxidation of organic material applied to the marble by way of protection.

Our experimental results indicate that the atmospheric aerosol plays a fundamental role in the processes of damage to the cultural heritage. The aim of this study is to investigate the relationship between the composition of the weathering layers found on monuments and historical buildings in different sites, and that of the local atmospheric aerosol. Our results should provide fundamental indications of the correct methods of conservation and maintenance of the cultural heritage, favouring intervention at an environmental scale rather than on individual monuments.

Conclusions

The study of the deposition of airborne particles and their impact on ecosystems is of great importance both from the scientific point of view, because so little has been published in this field, and from the view of practical applications, owing to the major economic and social problems involved.

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