Abstract. The bioallergens occurring naturally in the atmospheric air are microorganisms, pollen grains, plant seeds, leaf and stem scrap, or their protein molecules. The presence of various airborne fungal spores determines a high allergenic potential for public health. This effect is due to the high number of produced spores, which under favourable meteorological conditions (dry weather and wind) reach the surrounding air. This paper traces the dynamics of two types of fungi, Alternaria sp and Cladosporium sp, fungi which can be found outdoors, in the surrounding air, as well as indoors, inside houses (especially the conidia of Cladosporium sp). The effects of these fungal spores on human health are varies, ranging from seasonal allergies (hay fever, rhinitis, sinusitis etc.) to sever afflictions of the respiratory system, onset of asthma, disfunctionalities of the nervous systems, of the immune system, zymoses etc. The monitoring of the dynamics of the aerospores Alternaria sp and Cladosporium sp was carried out between 2010 and 2013, over a period of 42 weeks during one calendar year, from February to the end of September, in the surrounding air in the French capital, Paris. The regional and global climate and meteorological conditions are directly involved in the occurrence and development of fungi colonies, the transportation and dispersion of fungal spores in the atmospheric air, as well as in the creation of the environment required for the interaction of chemical and biological components in the air. Knowledge of the dynamics of the studied fungal aerospores, coupled with climate and meteorological changes, offers a series of information on the magnitude of the allergenic potential these airborne spores can determine. Legal regulations in this domain set the allergen risk threshold for the Alternaria sp aerospores at 3500÷7000 spores/m³ air/week, and for the Cladosporium sp aerospores at 56,000 spores/m³ air/week. Besides these regulations there exist a series of health, social and individual recommendations meant to considerably reduce or even prevent exposure to aerobiological pollution.

1. Introduction
The spores of various types of fungi are present as aeroparticles in huge quantities in the surrounding air.

In the outdoors, fungi grow on the ground, on vegetation, on domestic waste, and indoors one can find both the spores specific for the outdoors (which infiltrate the houses through the ventilation system or through open windows), and spores of fungi specific for the indoors, developed in humid environments (walls, basement, wallpaper, bathrooms etc.).
Their occurrence in high concentration may seriously affect human health (respiratory allergies) or may cause toxic effects linked to the release of toxins by certain strains (Stachybotrys). The Stachybotrys fungus (also called the black toxic) produces trichothecene mycotoxins (some of the most toxic and stable mycotoxins) with a live span of several years, sometimes being almost impossible to eliminate from households [1].

In our country, the dominant fungus is Cladosporium sp., followed by Penicillium sp. and Alternaria sp., which can cause respiratory sensitivity, while Aspergillus sp. is considered to be the fungus most frequently involved in the occurrence of respiratory allergic accidents [2].

The most common indoor fungi (moulds) are Cladosporium, Aspergillus and Penicillium. The species Alternaria, Stachybotrys, Rhizopus, Mucor, Wallemia, Trichoderma, lees,Botrytis, Epicoccum and Fusarium are often found indoors as well.

Exposure to indoor mould and to the inhaled mycotoxins can be a major source of harm for human health through all three known mechanisms: infections, allergies and toxicity [3].

2. Monitoring the dynamics of fungi aerospores
When monitoring aerobiological particles in the Parisian air, supervision is based on tracing the dynamics of two types of fungal spores, Alternaria sp. and Cladosporium sp, while also monitoring the pollen from trees and vegetation [4].

The devices used in collecting conidia (aerospores) are type VPPS (Volumetric Pollen & Particles Sampler) Lanzomi (Figure 1). One VPPS is located on the roof of the Pasteur Institute in Paris, at a height of 30 m above the ground, which allows it to cover a geographical area with a diameter of 100 km.

The other device is located in the proximity of the Lyon railway station. Samples are analyzed by the Laboratory of Hygiene in the city of Paris (IHVP).

![Figure 1. Volumetric Pollen & Particles Sampler](image)

These devices absorb the atmospheric air in doses equivalent to the amount a human inhales, namely 10 liters of air/minute (14.4 m³/24 h), than the particles of absorbed air fall over a resin-covered strip.

The mould pores are counted under an optical microscope, and results are expressed in number of mould spores/m³ of absorbed air /day [5].

3. Effects of the aerospores Alternaria sp and Cladosporium sp. on the human body
The fungus Alternaria sp. (Figure 2) – has approximately 40-50 species: A. alternata, A.solani, A.alliiariae officinalis, A.asphodeli, A.brassicae var. minor, A.brassicae var. dianthi, A.brassicae var. nigrescens, A.brassicae var. tabaci, A.brassicae var.sonniferi, A.capsici annui, A.celosiae, A.crassa, A.nucis, A.porri, A.rugosa, A.tabacimun, A.tenuis, A.triticina, A.zinniae, A.humicola, A.linicola, A.longipes, A.dianthi, A.dianthicola etc. As regards the production of potential toxins, Alternaria alternata sp produces an antifungal substance called alternariol.
This type of mould is not a natural component of the indoor air of human habitat, yet clinical research has indicated that the Alternaria sp spores are powerful aeroallergens. The Alternaria sp aerospores can live on dead plants (cereals and grass), as well as on live plants, the soil, textiles, decomposing plants etc. It acts upon human health, often causing sinusitis, hay fever and asthma, as well as osteomyelitis, zymoses, keratomycoses, lung diseases, and infections of the nasal septum [6]. Skin sensitivity to Alternaria sp mould spores has been linked to a high risk of respiratory arrest in people suffering of asthma [7]. The various epidemiological studies associated skin sensitivity to indoor fungi with the higher occurrence or severity of asthma, as well as higher rates of sinusitis. Certain species of Alternaria sp. which are parasites of living plants and cause the early blight in tomatoes and potatoes.

The Cladosporium sp. mould (Figure 3) – has approximately 28 - 40 species, of which we mention: C.cucumerinum, C.herbarum, C.aecidiicolum, C.bacilligerum, C.banaticum, C.bellynckii, C.dendriticum, C.depressum, C.epiphyllum, C.fasciculare, C.fuligineum, C.fulvum, C.fumago, C.georginae, C.graminum etc. It is one of the most common and frequent mould aerospores found in the air samples. These can often be found in the indoor air, on humid walls or old carpets, in the bathroom, or even on the ceiling. Certain species of Cladosporium contaminate food, my colonize textiles, rotten wood, even cultivated or wild grass. As regards the production of potential toxins, Cladosporium sp produces cladosporium and emodin (none of them is very toxic). Frequent exposure to mould spores in the indoors air has negative effects on the human health, which lead to numerous lesions and dysfunctions of the internal organs and systems of the human body: the respiratory system, the immune system, the nervous system, hematological systems and the skin. Certain species are saprophytes and have no negative implications on the human health; other
cause systematic lung infections, profound skin infections which can invade the central nervous system, sinusitis respiratory diseases, keratomycoses, and allergies.

In the air samples it is impossible to microscopically separate the Cladosporium sp. spores in potentially pathogenic species and non-pathogenic species, yet considering their huge numbers, their occurrence must be considered a potential infection source.

Aerospores are found in concentrations 5 times higher than aero-pollen, allergies being caused by over 80 types of fungi. In temperate regions, the number of airborne fungi is at its maximum during summer, and decreases in the cold season [9].

The analysis and monitoring of mould aerospores in Paris is carried out through the National Aerobiological Monitoring Network in partnership with the Hospital Centre Aix-en-Provence, the Hygiene Laboratory of the City of Paris, and the Mycology Service of the Toulouse Hospital. The monitoring of the mould spores is carried out over 42 weeks during one calendar year, from the end of January to the end of September.

The regional and global climate and meteorological conditions are directly involved in the occurrence and development of fungi colonies, the transportation and dispersion of fungal spores in the atmospheric air, as well as in the creation of the environment required for the interaction of chemical and biological components in the air.

In the professional literature it is mentioned that the Cladosporium genus is well represented throughout the year, with a daily average concentration in the air never below 40 spores/m³ around January and February. The peak of the Cladosporium period is during the months of August and July, with an annual average spore concentration exceeding even 5,000/m³. Alternaria reaches its peak in August, with about a daily average between 160 and 320/m³ [10].

4. Outcomes and discussions
French legal regulations have set the allergen risk threshold for the Alternaria sp aerospores between 3,500÷7,000 spores/m³ air/week, and for Cladosporium sp the allergen risk threshold value is 56,000 spores/m³ air/week.

4.1. The dynamics of the Cladosporium sp. aerospores
As regards the annual dynamics of the Cladosporium sp fungal aerospores, for the years taken into account (2010-2013), one can notice (Figure 4) a slow start during the first months of the year (January-May), followed by a surge in their occurrence in June, and continuing the same trend until the end of August.

In September, once climate conditions changes (abundant rainfall, lower temperatures etc.), the concentration in fungal spores in the atmospheric air decreases dramatically.

One can notice important variations of the concentration of Cladosporium sp fungal aerospores in 2013, with an extreme maximum point on June 29, when the recorded concentration of Cladosporium sp fungal aerospores was 57,722 spores/m³ air/day.

This value exceeds the regulated threshold value for allergen risk set at 56,000 spores/m³ air/week. For the same year, a more dramatic situation than the aforementioned is the situation recorded on August 9, when a concentration of Cladosporium sp spores of 67,392 spores/m³ air/day was recorded in the atmospheric air.

For the year 2012 there were no serious variations of fungal spores recorded in the air, and their dynamic is tightly linked to the recorded meteorological conditions. February began with unexpectedly low minimal temperatures for that period (-5 °C to -10°C), then March, in contrast with February, brought exceptionally high temperatures (+25°C).
These meteorological conditions are not favorable for the dispersion of pollutants into the environment.

The summer months (June and July) brought significant amounts of precipitation, and August recorded canicular temperatures (+40°C). The end of the year was marked by rainy periods, with alternations between mild periods and very cold.

Year 2011 is remarkable due to two exceptions with regard to the concentration of Cladosporium sp in the air, namely on June 8 (47,853 spores/m³ air/day) and June 15 (55,926 spores/m³ air/day).

The meteorological review drawn up by Meteo France specifies the fact that 2011 was one of the hottest years recorded after 1900, coupled with an extreme deficit in rainfall during the spring and the autumn. During the spring, from March to May, extremely high temperatures were recorded for this period, i.e. 30°C. Yet during the summer, temperatures were seriously inferior, coupled with heavy rainfall, and the winter was mild and without snowfall.

The meteorological conditions in 2011 were favorable for the dispersion of pollutants into the environment [12].

Year 2010 is the year when the dynamics of the Cladosporium sp fungal aerospores in the atmospheric air is relatively slow: there were no high concentrations of aerospores recorded during the spring months, yet once the climate changes characteristic for the summer months kicked in, there were days when the allergen risk threshold was dramatically exceeded (on August 8 the aerospore concentration was 26,988 spores/m³ air/day, and on August 9 it was 26,910 spores/m³ air/day).

The annual variation in the concentration Cladosporium sp mold spores in the air of Paris, between the years 2010-2013, can be viewed in Figure 5.
4.2. *The dynamics of the Alternaria sp. aerospores*

High concentrations of the Alternaria sp fungal spores in the atmospheric air had been recorded since in June, and their concentration gradually decreased after the second half of August (Figure 6).

Year 2010 is remarkable due to two peaks in the concentrations of Alternaria sp spores in the atmospheric air: on July 8 with a concentration of 1,248 spores/m$^3$/day and July 20 with a concentration of 1,599 spores/m$^3$/day.

For 2011, summertime brought high levels of Alternaria: on June 29 1,799 spores/m$^3$/day. Year 2011 was considered a very hot year, with an annual average temperature by 1.5°C higher than the normal temperature. The spring and the autumn were extremely hot and with very limited rainfall,
contrast with a cold and rainy month of July. Another remarkable aspect of the year was the unexpectedly high temperature at the end of September – beginning of October [13].

Year 2012 is a relatively calm year, most days recording concentrations within the legally established limits. Year 2012 was considered a year with temperatures, rainfall, sunny weather close to the normal values. The exceptions were February, April and June, when the temperature was lower [14].

The year 2013 was characterised by conditions favourable for the dispersion of atmospheric pollutants. The first trimester of the year was marked by episodes of pollution with particles in suspension, yet less intense than the pollution recorded in the previous year, i.e. 2012. The quantity of precipitation came close to the normal annual value, despite the fact that the beginning of the year was characterised by snowfall with limited quantities of rain; May was by compensation a very rainy month.

The average annual temperatures were those specific to the area, with some exceptions in April (28°C) and May: 24th of May was declared the coldest day of the year, with maximum recorded temperature of 8÷10°C. During the summer, temperatures were normal, the highest being recorded in Paris 35.5°C. There were not heat-waves as during the previous year [15].

Nevertheless 2013 was a year during which the highest concentrations of Alternaria sp aerospores were recorded in the atmospheric air over the past four consecutive years; these concentrations were recorded at the end of July and especially in August: July 30 – 1,287 spores/m³/day; August 1 – a concentration of 2,028 spores/m³/day; August 2 – a concentration of 2,106 spores/m³/day and August 5 – a concentration of 1,872 spores/m³/day.

The annual variation in the concentration Alternaria sp mold spores in the air of Paris, between the years 2010-2013, can be viewed in Figure 7.

![Figure 7](image-url)

**Figure 7.** The annual variation in the concentration Alternaria sp mold spores in the air of Paris, between the years 2010-2013

You can observe high concentrations of Alternaria mold spores in the air in Paris, especially in 2011 and 2013, because of to favorable meteo conditions.

5. **Conclusions**

Over the four years (2010-2013) of monitoring there was no improvement in air quality in terms of reduction of the aforementioned fungal aerospores. Moreover, during summer months (June-August), the allergen risk threshold was exceeded almost daily (Cladosporim sp 8,000 spores/m³/day and Alternaria sp. 750 spores/m³/day).
The dynamics of the fungal aerospores is directly influenced by climate and meteorological conditions; thus, high temperatures and low rainfall lead to the discharge into the air of quantities of fungal spores higher than those specific for the type of climate characterized by low temperatures and abundant rainfall.

Moreover, during periods with strong wind, these bioallergenic aerospores are carried over long distances and dispersed over wide areas.

It is recommended that special attention be given to the proper maintenance of green areas, to the daily information on the occurrence of allergens in the surrounding air (pollen and fungal spores), to issuing specific recommendations during episodes of pollution, and to preparing sensitive individuals for these periods.

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