ORIGINAL ARTICLE

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Effect of ambient air temperature and solar radiation on changes in bacterial and fungal aerosols concentration in the urban environment

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Abstract

Bioaerosols are particularly sensitive to sterilization processes due to their biological characteristics. Phenomena occurring in the atmosphere have major influence on airborne bacteria and fungi concentration levels. The presented study evaluates the sterilization properties of ambient air temperature and solar radiation on viable bioaerosols concentration levels in outdoor air in Gliwice, Poland. Assigned were the breakpoints indicating limited stimulation properties of the air temperature, which amounted 7.5 °C for bacterial aerosol and 16.5 °C for fungal aerosol. Also revealed was the influence of solar radiation properties on decreasing the bioaerosols concentration levels. Both bacterial and fungal viable aerosol were sensitive to this radiation, although the phenomenon was more effective for airborne bacteria.

Key words

Bioaerosol, solar radiation, sterilization, airborne microorganisms, temperature breakpoint

INTRODUCTION

Bioaerosol concentration in ambient air is strongly dependent on meteorological parameters, reflecting seasonal variability. Atmospheric air is only a temporary place of residence for biological aerosols, not their natural habitat. Microorganisms cannot grow in colonies in the atmosphere, but can undergo the influence of different meteorological factors and sterilization phenomena. The spectrum of microorganisms present in the air depends largely on their ability to colonize the environment, life and transport processes and transformations [1]. The level of concentration of bioaerosols is largely determined by parameters such as temperature and relative humidity, ensuring appropriate conditions providing the ability of microorganisms to grow colonies. In the case of biological aerosols, their sensitivity to sterilization processes is also essential. Biological aerosol particles are particularly vulnerable to adverse thermal conditions. In studies concerning the analysis of seasonal variations, a significant reduction in the concentration levels of bacterial and fungal aerosols measured during winter, compared to the levels obtained in other seasons, are usually noted [2]. The level of concentration in winter is several times lower than in summer. Despite a relatively good description of the seasonal variation of bioaerosols concentration levels in ambient air, there is still no sufficient analysis concerning quantitative assessment of temperature and solar radiation impact on the concentration of viable bacterial and fungal aerosol present in ambient air. The solar radiation contains in its spectrum waves in the range of UV radiation, and thus it can have a significant impact on the reduction of bioaerosols concentration levels. It is well known that ultraviolet radiation has disinfectant properties, widely used in various fields of industry and laboratory practice. Sensitivity coefficients for a number of microorganisms present in the air were determined, but only on a laboratory scale [3]. However, in relation to the outdoor environment, knowledge of the sterilizing properties of solar radiation is still incomplete. General trends are known, but there are no comprehensive quantitative assessment of the impact of solar radiation on decreasing concentration levels of bioaerosols in ambient air.

The aim of this study was to assess the sterilization phenomena in ambient air, focusing on the influence of the ambient air temperature and solar radiation.

MATERIALS AND METHOD

Sampling and culturing. Sampling was performed in the ambient air of an urban environment on the Silesian University of Technology campus in Gliwice, Poland. To determine the annual characteristics of viable bioaerosols concentration level, samples were taken weekly, from April 2015 – September 2016. Concentration measurement was performed using the six-stage Andersen cascade impactor (Tisch Environmental, Ohio, USA); during the measurements the air flow was 28.3 dm^3/min and the sampling time was 10 minutes. Microorganisms were collected on nutrient media in Petri dishes located on all impactor stages. Trypcasein soy agar (TSA) was used for bacteria, with cycloheximide added to inhibit fungal growth. Malt extract agar (MEA) was applied for fungi, with chloramphenicol added to inhibit bacterial growth. Samples were incubated for 3–4 days at room temperature (bacteria 20 °C, fungi 22 °C). Concentrations

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were calculated by counting the number of grown colonies and the results were expressed as colony forming units per cubic meter (CFU/m^3), using positive hole corrections.

Meteorological conditions. Simultaneously with the bioaerosol sampling, on the testing site were also measured the basic meteorological parameters using portable Weather Station WMR 200 (Oregon Scientific, Portland, USA) and distant (< 300 meters from sampling site) Davis Weather Station Vantage Pro2 (Davis Instruments Corporation, California, USA). Additional information concerning level of solar radiation was obtained from the Regional Inspectorate for Environmental Protection in Katowice, Poland. Aerosanitary parameters in particular seasons are presented in Table 1.

Statistical analysis. Statistical analysis was performed using Statistica 12 software (StatSoft, Tulsa, USA). Significance level for the analysis was assumed at $p<0.05$. Due to non-normal distribution of variables describing concentration, the non-linear regression model was assumed and the values logarithmized. To assess the influence of the ambient air temperature on bacterial and fungal concentration levels, regression analysis was performed fitted to the coordinate data according to the distance-weighted least squares smoothing procedure. As a result of segment regression analysis, the break points were designated and the corresponding linear regression models were fitted. 3D surface plots were prepared to visualize the co-influence of the ambient temperature and solar radiation on the concentration levels of bacterial and fungal aerosols.

RESULTS AND DISCUSSION

Analysis of the influence of ambient air temperature. Obtained results showed that, to a limited degree, the ambient air temperature had a stimulating impact on the concentration level of airborne fungal and bacterial concentrations. At low temperatures, increase of the temperature stimulated the microorganisms growth and their emission from soil, water and other sources. Therefore, the bioaerosol concentration increased. Analysis revealed the occurrence of breakpoints where the stimulation effect of the temperature refracted. A specific temperature above the threshold increase of the ambient air temperature did not effect obtaining a higher bioaerosol concentration level. Results for fungal and bacterial aerosol are shown on Figures 1 and 2. The breakpoint for inhibiting the increase of fungal aerosol concentration was 16.5 °C, and in the case of bacterial aerosol 7.5 °C. Although these specific temperature breakpoints can be strongly related with local characteristic of the sampling points, the difference between the breakpoint for the airborne fungi and bacteria (approximately 10 °C) seems to be more universal and should be rather independent from the studied area.

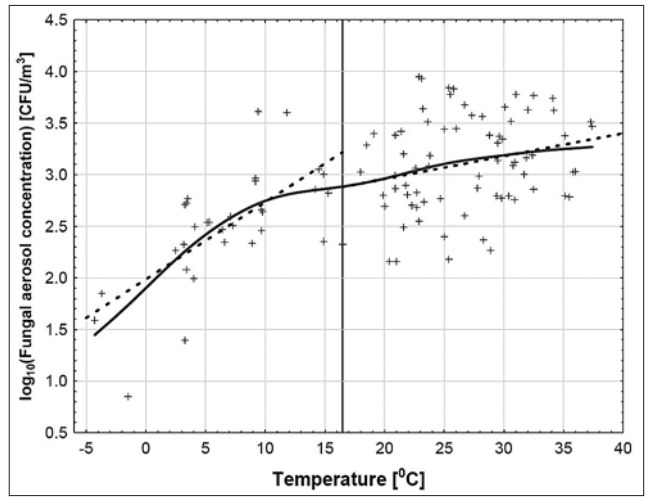

Figure 1. Relationship between ambient air temperature and fungal aerosol concentration

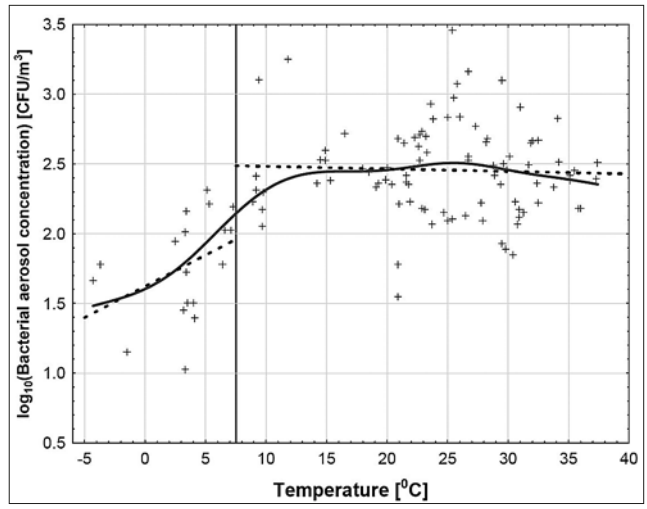

Figure 2. Relationship between ambient air temperature and bacterial aerosol concentration

This fact may be explained by the phenomena causing the lowering of the airborne fungi and bacteria concentration level, and even sterilization in ambient air. Further analysis showed that solar UV radiation is responsible for the obtained results. These results are consistent with the literature data. For example, in the winter periods at low temperatures, the concentration levels of bioaerosols are much lower than in the summer months [4]. On the other hand, higher temperatures contribute to higher levels of airborne microorganisms, providing viability for their growth [5, 6]. It was also evidenced

Table 1. Descriptive statistics of aero-sanitary conditions in Gliwice by particular season of the year

Season	Ambient air temperature [°C]		Relative humidity [%]		Atmospheric pressure [hPa]		Wind speed [m/s]		Total solar radiation [W/m^2]	
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Spring	20.94	6.32	33.15	14.39	991.35	6.43	1.83	1.28	446.50	232.35
Summer	28.84	4.78	36.19	10.75	996.25	4.22	1.24	0.88	502.89	193.12
Autumn	11.48	5.71	52.69	17.59	1000.75	5.12	1.38	0.80	147.19	165.46
Winter	3.71	4.68	61.21	15.22	996.64	13.35	1.31	0.65	144.27	78.80

that temperature has a significant, positive correlation with biological aerosol concentrations [7].

Analysis of the radiation. Sterilization phenomena occurring in the atmosphere are complex processes. Figures 3 and 4 demonstrated the interaction of temperature and total solar radiation causing lowering of the levels of fungal and bacterial aerosols.

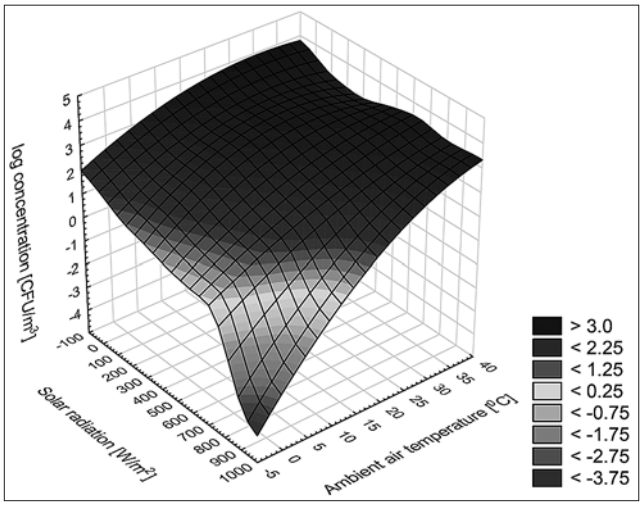

Figure 3. Simultaneous impact of air temperature and solar radiation on fungal aerosol concentration

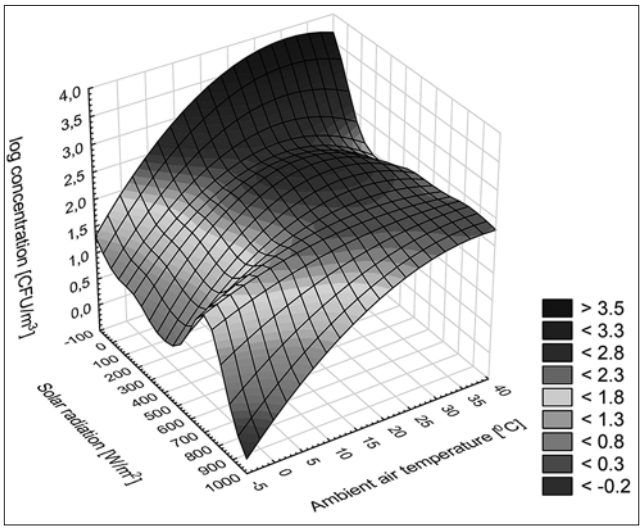

Figure 4. Simultaneous impact of air temperature and solar radiation on bacterial aerosol concentration

As can be seen, within the comparable temperature range, with the increase of solar radiation intensity, the concentration level of the bioaerosols was lower. Furthermore, this phenomenon was more strongly applicable to bacterial aerosol than fungal, from which it can be concluded that airborne bacteria are more sensitive to this type of radiation.

Obtained results are consistent with data of other authors who revealed the sterilization phenomenon connected with solar UV radiation during clear, sunny days in China [8]. Field experiment showed also the sensitivity of fungal spores to UV solar radiation [9].

CONCLUSIONS

- Ambient air temperature has a stimulating impact on the concentration of biological aerosols, but only within a limited range. It seems that the difference between the temperature breakpoint for the airborne fungi and bacteria is equal to about 10 °C, and is rather general in character (assigned breakpoint temperatures in Gliwice are: 16.5 °C for fungal and 7.5 °C for bacterial aerosol).
- Solar UV radiation has an sterilization potential towards bacterial and fungal aerosols, a phenomenon more effective for airborne bacteria.

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