

The impact of weather parameters on the microclimate inside the building intended for antelopes

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Abstract: *The impact of weather parameters on the microclimate inside the building intended for antelopes.* Microclimate inside the buildings represents one of major factors that affect animal welfare. The purpose of this study was to examine the impact of selected weather parameters on the microclimate of the building intended for sitatungas. The measurements covered temperature, relative humidity, air flow, concentration of particulate matter as well as the number of bacteria, fungi and actinomycetes. Experiments were conducted in the period from winter to summer inside and outside the building for antelopes. Measurement results show that analyzed weather parameters exert effect on the microclimate of investigated rooms. Both the temperature (summer) and air humidity (spring, summer) inside the building intended for housing sitatungas demonstrated a strong correlation with the conditions existing outside the building. Another observation made during the study regarded a significant statistical relationship between the concentration of PM10 inside and outside the building. No effect of the winds blowing outside on the air flow inside the studied building was detected. An increase in the concentration of bacterial and fungi aerosols in winter was most probably caused by poor ventilation of the building owing to low temperatures outside. Despite noticeable impact of the weather parameters on the microclimate of the studied building, acceptable standards recommended for the sitatunga were not exceeded, except for too low air humidity in winter caused by the intensive use of the heating system.

Key words: microclimate, bioaerosols, building, zoo, weather parameters, sitatunga

INTRODUCTION

Welfare is a state of complete physical and mental health that ensures maintaining perfect harmony between the animal and its surrounding (Hughes 1988). Animal welfare is assessed based on physiological, behavioral, health, productive and zoohygienic indicators (Kończak and Bodak 1999). Factors shaping microclimate inside the buildings are classified into zoohygienic indicators. Due to the fact that animals in zoos are kept in artificial environment, suitable microclimate in the facilities designed for them has a significant impact on animal health and reproduction. Microclimate inside animal houses is affected by both internal and external factors. Internal factors include: the number of animals in one building, proper ventilation and the type of materials that were used to put up the facilities. External factors consist of location of the building, its surroundings (roads, railways, airports, housing estate) and weather conditions). The term weather is used to describe atmospheric conditions at a particular time over a particular area. Weather is made up the following parameters: air temperature, air humidity, air flow, solar irradiance (insolation), wind speed

and direction, cloud cover, atmospheric precipitation and deposits as well as atmospheric pressure (Mills 2017).

The sitatunga (*Tragelaphus spekei gratus*) is one of popular antelope species inhabiting zoos. This species belongs to the order *Artiodactyla* and the family *Bovidae*. The sitatunga comes from the central and western Africa. Its natural habitat covers swampy areas (moors and marshes) as well as tropical equatorial rainforests. Sitatungas live in uniformly hot and humid climate year-round. Owing to its lifestyle it is also called “water-kudu”. This sessile animal is active both during the day and at night (AZA... 2009). When it comes to its conservation status, the sitatunga has been grouped as least concern (LC) in the IUCN Red List of Threatened Species (2018).

The study was aimed at examining the impact of selected weather parameters (temperature, humidity, air flow) on the microclimate inside the building for the sitatunga.

MATERIALS AND METHODS

Investigated facility

The experiments were carried out in the building for sitatungas located within the zoo premises. The facility is situated on the flat area at an altitude of 272 meters above sea level. The long axis runs north-south. The facility consists of two parts: the first with the dimensions 10.10 m × 6.20 m × 2.95 and the second 6.00 m × 7.60 m × 2.55 m. The building has four exits leading to the enclosures and one intended for animal caretakers. The building has been provided with 8 win-

dows (130 cm × 80 cm). The facility is used by 11 antelopes with the total mass amounting to 595 kg. The animals are kept in the free stall system. The building is equipped with electric heaters.

Experimental design

The experiments were carried out in three series (series I – winter, series II – spring, series III – summer). The measurements in each series were taken in the morning, afternoon and evening for three consecutive days, except for microbiological tests that were conducted once per each experimental series (the second day of taking measurements – afternoon).

Test methods

Two measurement points were designated within the building (each in different part) inside the stalls and one outside, 15 m away from the facility. The measurements inside the building were taken at the height of an animal head, while those made outside 2 m above the surface of the ground. The measurements taken within the study included: air temperature, relative humidity, air flow (Airflow™ Instruments Velocity Meter TA440), concentration of the particulate matter (electronic particle counter PM10: DT-96, Accuracy 10 µg/m³, manufactured ACM). The microbiological examination was carried out stationary using a volumetric method, with a 1-stage MAS-100 impactor. The air samples were collected once, each sample in duplicate. The apparatus was placed at a height of 1.0–1.5 m above the floor or ground (external measurements) in order to take samples from the

animal's respiratory zone. The flow rate of the air stream during sampling was 100 l/min. In the bacterial and fungal aerosol investigations, 1.0-minute aspiration time was used, and the volume of air sample taken by the impactor was 0.10 m³. The following microbiological substrates were used for collection of bacterial aerosol samples: tryptic soy agar for the total bacterial count, Gauze's medium for actinomycetes, EMB medium for Gram-negative bacteria, Chapman's staphylococcal substrate and MEA malt agar for fungi. The incubation conditions of the air samples were as follows for the tested groups of microorganisms: bacteria: 1 day (37°C) + 3 days (22°C) + 3 days (4°C), fungi: 4 days (30°C) + 4 days (22°C). Prolonged incubation of the samples was aimed at allow to growth in the lower temperature range of slowly growing bacterial strains.

STATISTICAL ANALYSIS

The data obtained from this experiment were subjected to statistical analysis by calculating Pearson's correlation coefficient (*R*) using sigma stat 2.03 (systat software gmbh, Germany). Testing was preceded by examination of the normality of distribution using the Shapiro-Wilk test. It was found that the analyzed data have a normal distribution.

RESULTS AND DISCUSSION

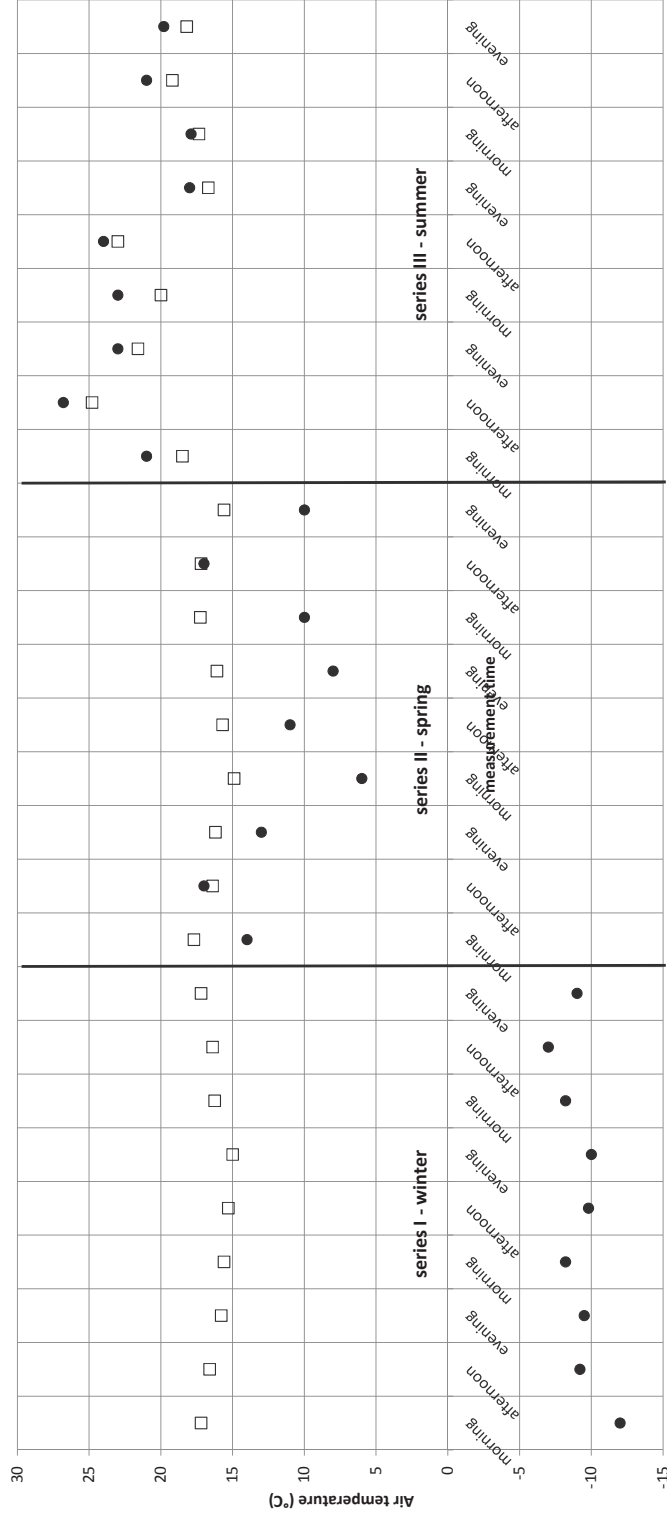
Microclimate created inside the building is one of the factors that affect animal welfare (McArthur 1987). It is extremely important especially in the case of animals kept at zoos, where the animals are housed in buildings with ar-

tificial microclimate. Such man-shaped conditions should be as similar as possible to the conditions existing in the wild, within the natural animal habitat. The factors that influence microclimate inside buildings for animals include, among others, air temperature outside the building.

Animals are characterized by different temperature requirements. Most species belonging to the subgenus antelopes display relatively high resistance to hot temperature. It has been assumed that the maximum temperature for these animals shall not exceed 38°C (Smith et al. 1997). According to the American Zoo and Aquarium Association (azaungulates.org) the minimum allowable temperature inside the buildings intended for the sitatunga shall not be lower than 10°C, while the optimum temperature is 26°C.

During the experiment the temperatures recorded inside the building did not exceed acceptable temperature range for these animals. Temperature inside the facility for sitatungas was quite stable and ranged between 15.0°C and 17.2°C in experimental series I and between 14.9°C and 17.7°C in experimental series II. During taking measurements in winter the building was warmed using electric heaters. The highest temperatures inside the building were recorded in summer. The highest temperature was recorded on the second measurement day in the afternoon (24.8°C), while the lowest on the third day in the morning (16.7°C) – Figure 1.

Temperature outside the building in winter ranged between –12.0°C and –7.0°C, in the series II – spring between 6.0°C and 17.0°C, in summer between 17.9°C and 26.8°C (Fig. 1).



□ mean temperatures inside the building for sitatungas ● air temperature outside the building

FIGURE 1. Air temperature in the following measurement days

Based on the obtained results it can be concluded that during experimental series I and II the construction and furnishing inside the building allowed to maintain stable thermal conditions despite highly unfavorable temperatures recorded outside.

In summer, during heatwaves, the temperature inside the building increased by 7.1°C as compared to the highest temperatures recorded during experimental series I and II. Despite the above, the temperature did not exceed limit values established for the sitatunga. The calculated correlation coefficient of temperature inside and outside the building was: winter -0.1 (heated building), spring 0.5, summer 0.9.

Air humidity is the second key factor which is always taken into consideration during evaluating microclimate inside buildings intended for animals. Too high concentration of water vapor in buildings for animals may lead to arthritis, upper respiratory tract infection, impaired immunity, poor feed usage and increased incidence of illnesses caused by mycotoxins (Xiong et al. 2017). Whereas too low water vapor content in air leads to drying out mucous membrane in the respiratory system and its rupture. Ruptured mucous membrane provides gateway for pathogenic germs, especially those responsible for developing infections of the upper respiratory tract (Herbut and Angrecka 2012). Optimum relative humidity (RH) in livestock buildings should range between 60 and 80% (Marciniak 2014). However, available reference materials do not include information on the limits inside buildings for sitatungas. It must be remembered that the natural habitat of these antelopes covers swampy areas

where the air humidity ranges between 77 and 88% (www.blueplanetbiomes.org).

In the studied period relative air humidity inside the building was vary changeable. In winter this parameter reached values between 40.5% and 57.0%. Considerably higher values were recorded during II and III experimental series. In spring the highest RH value amounted to 86.0%, while the lowest to 64.0%. In summer RH values were similar 85.0% and 64.0%, respectively (Fig. 2). It can be stated that, except for the winter season, air humidity in the investigated building was suitable for sitatungas. Too low air humidity recorded in winter was most probably caused by intensive use of the heating system.

Relative air humidity measured outside during experimental series I ranged between 57% and 80%, during series II between 50% and 75%, while during series III between 55% and 73% (Fig. 2). As shown by the data, relative air humidity inside the building, with the exception of the winter season ($R = 0.4$), is strongly depended on the water vapor content in the atmosphere (spring $R = 0.8$, summer $R = 0.9$). The correlation between water vapor content inside and outside the building arises due to the fact that even as much as 30% of water vapor inside the building comes from the air entering the building through ventilation system (Soldatosa et al. 2005).

Air movement in the buildings for animals is triggered by winds blowing outside as well as ventilation and heating systems. In the period from autumn to spring the value of this parameter should not exceed 0.3 m/s, while during the spells of extremely hot temperatures

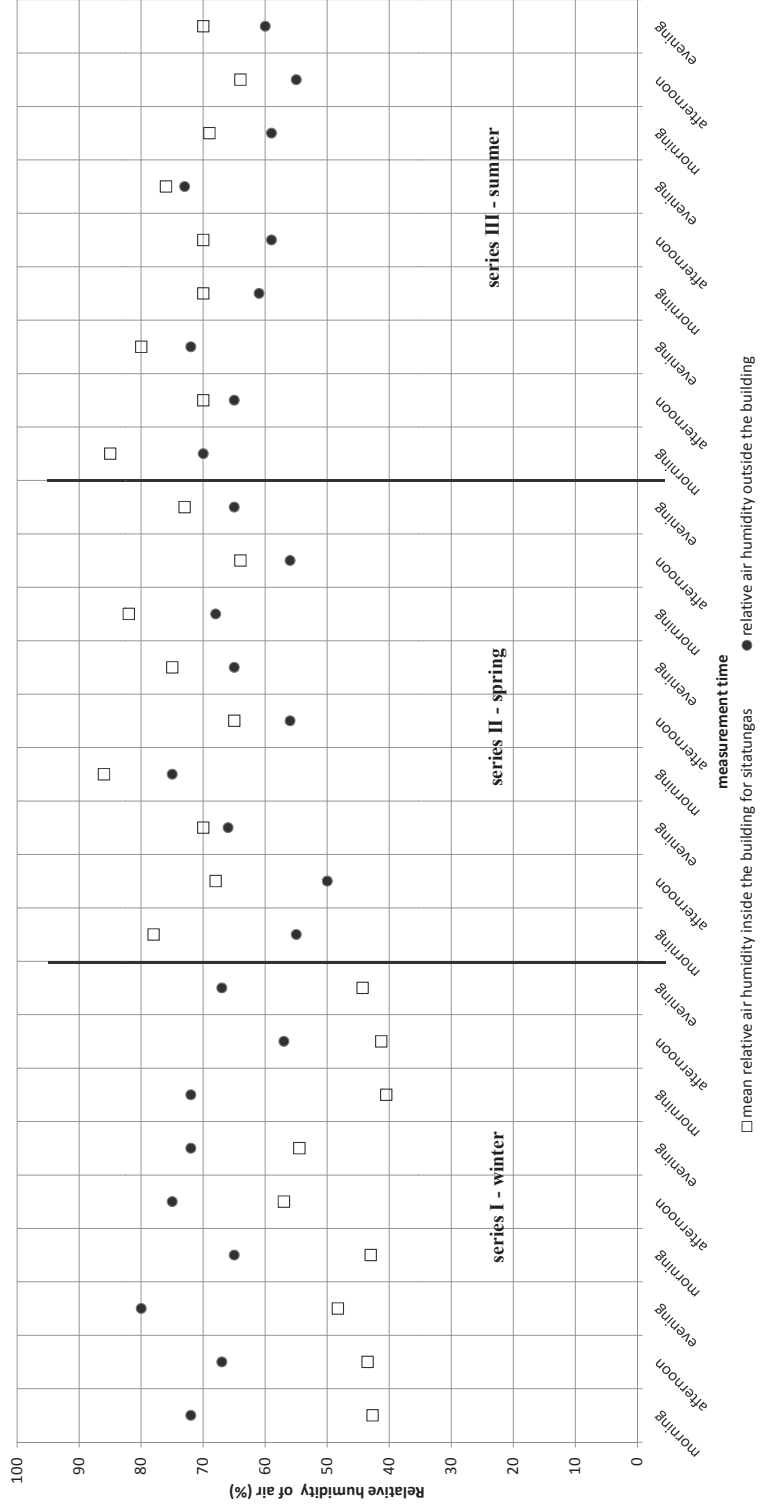


FIGURE 2. Relative humidity of the air in the following measurement days

it should not go beyond 0.5 m/s. Too fast air flow distorts electric charges accumulated in the animal coat and leads to damaging air layer that adheres to the skin. The consequences of such situation may cover a rapid decrease of skin temperature, immune deficiency and infections of the upper respiratory tract (Bustamante et al. 2015).

Air flow in the investigated building was stable. During I, II and III measurement series air flow ranged between 0.015 m/s and 0.122 m/s, between 0.001 m/s and 0.063 m/s, from 0.008 m/s to 0.120 m/s, respectively (Fig. 3). Given the data presented above, air flow did not exceed limit values recommended for the sitatunga. The speed of air flow measured outside in the first series fluctuated between 1.54 m/s and 6.17 m/s, in the second series between 1.50 m/s and 7.20 m/s, while for the third series from 1.00 m/s to 6.17 m/s (Fig. 3). Comparison of the measurements inside and outside the building revealed that air movement outdoors did not produce any significant effect on the conditions prevailing inside facilities for sitatungas ($R = -0.2$).

Particle pollution represents another important factor that affects animal welfare but it is often neglected during evaluating microclimate conditions inside buildings for animals. Until recently this issue has been addressed only in view of pollution in the rooms for animals generated by dried plants, excrement, feed, hay, straw, animal hair, epithelium and pollen (Hartung and Saleh 2007). Fine dusts emitted as a result of fuel combustion or traffic are responsible for producing smog. The quantity of particulate matter that is

generated in these processes is often few times greater than permissible limits. It is obvious that the highest concentration of particulate matter is recorded in atmospheric air but polluted air enters into the buildings for animals through the ventilation system.

The results demonstrate a strong correlation between the concentration of the particulate matter inside and outside the building ($R = 0.9$). The greatest concentration of PM10 in winter, both inside and outside, was recorded in the evening on the first measurement day (58.2 $\mu\text{g}/\text{m}^3$ and 135.2 $\mu\text{g}/\text{m}^3$, respectively), while the lowest in the morning on the second measurement day (30.1 $\mu\text{g}/\text{m}^3$ and 34.5 $\mu\text{g}/\text{m}^3$). In spring the highest concentration of particulate matter amounted to 39.4 $\mu\text{g}/\text{m}^3$ (inside the building) and 54.6 (outside the building), while the lowest to 4.1 $\mu\text{g}/\text{m}^3$ (inside the building) and 5.8 (outside the building). In summer the largest PM10 concentration was also recorded in the evening (44.0 $\mu\text{g}/\text{m}^3$ and 60.3 $\mu\text{g}/\text{m}^3$), while the lowest in the morning (5.2 $\mu\text{g}/\text{m}^3$ and 6.0 $\mu\text{g}/\text{m}^3$) – Figure 4. It should be pointed out that an increase in the concentration of the particulate matter in atmospheric air was associated with greater difference in particle pollution inside and outside the building.

Too high concentration of the particulate matter can lead to many pathological conditions. Fine dust floating in air is capable of obstructing sebaceous (dry and exfoliating skin) and sudoriferous glands (problems with thermoregulation), can cause conjunctiva irritation and conjunctivitis, allergy (hay fever), irritation and congestion of nasal mucosa as well as bronchitis. It must be remembered

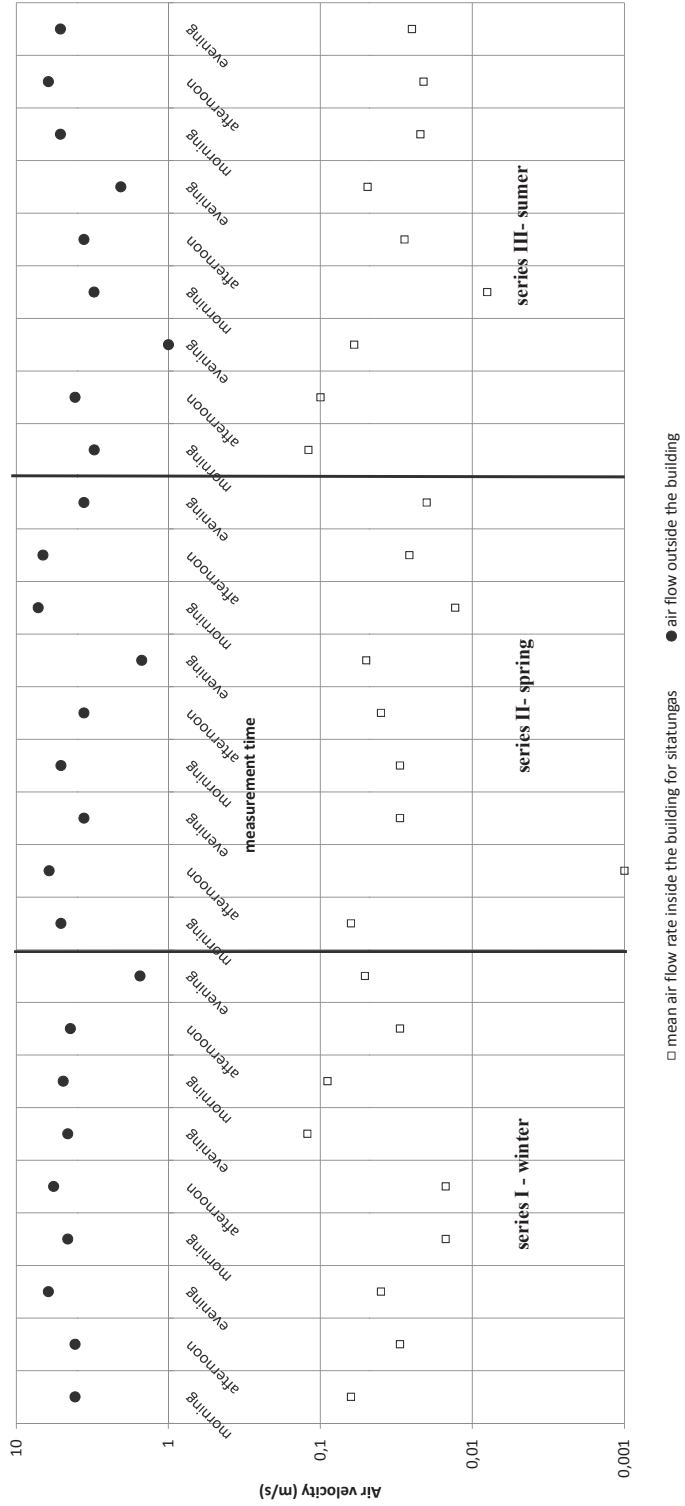


FIGURE 3. Air flow rate in the following measurement days (logarithmic scale)

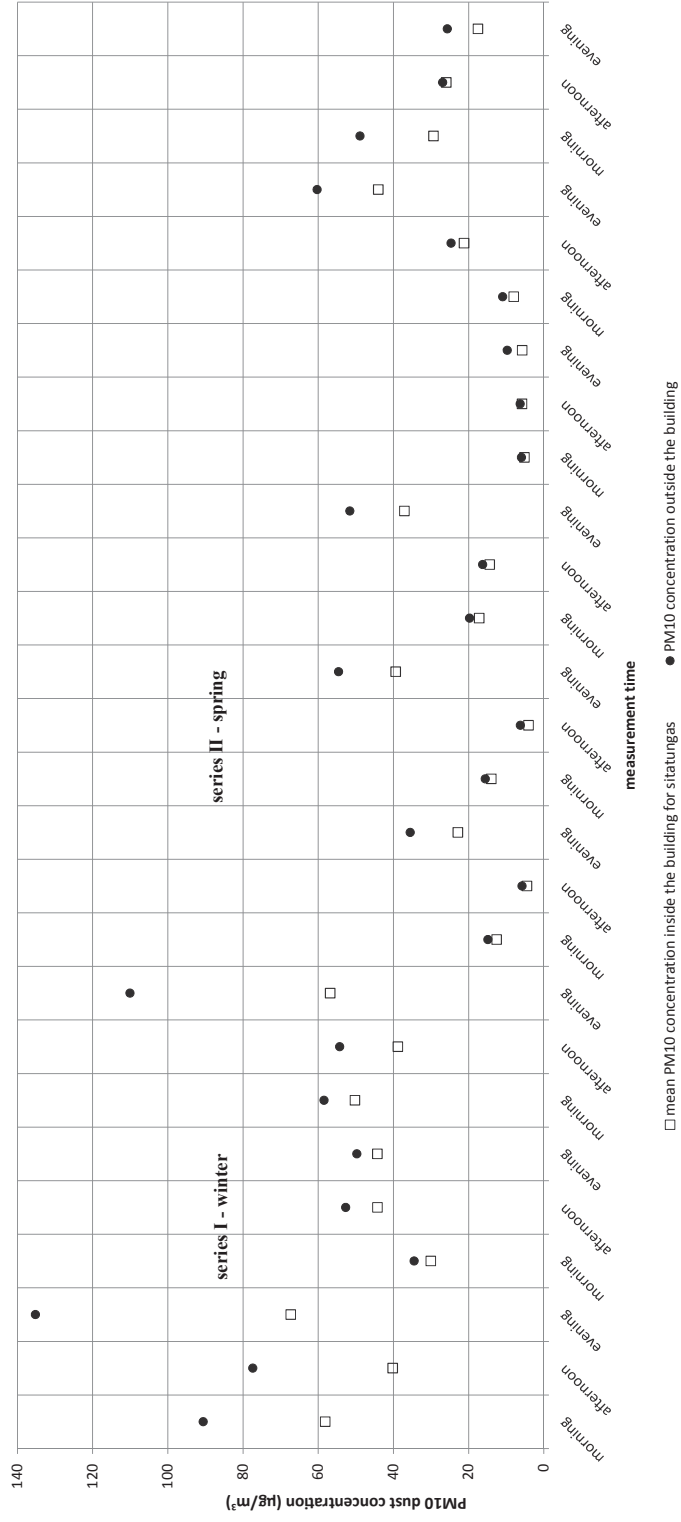


FIGURE 4. PM10 dust concentration in the following measurement days

that particulate matter may carry fungal spores that can cause pulmonary mycosis. Moreover, some fine dusts contain heavy metals, dioxins or asbestos that are known for their carcinogenic effects (Bruce et al. 2015).

Available research data does not contain information about permissible limits of particulate matter inside the buildings at the zoo. Daily 24-hour limit value for PM10 for people amounts to $50 \mu\text{g}/\text{m}^3$. In the investigated facility this limit was slightly exceeded only twice.

The quantity and quality of microorganisms in air is one of the hygiene indicators for assessing the conditions inside buildings for animals (Tombarkiewicz et al. 2004). Microbial pollution includes bacteria, viruses as well as fungal and actinomycete spores that are suspended in air as bioaerosols. Unfortunately, allowable limit values for microbes inside the buildings intended for animals have not been defined (Ropek and Frączek 2016).

There are only recommended values of the permissible concentrations of the most common categories of microorganisms in the internal environment, namely work rooms contaminated with organic dust ($1.0 \times 10^5 \text{CFU}\cdot\text{m}^{-3}$ and $5.0 \times 10^4 \text{CFU}\cdot\text{m}^{-3}$, respectively for bacteria and fungi) (Augustinska and Pośniak 2016). Quantity of germs in air inside the building for the sitatunga was presented in Table. In the analyzed building the greatest number of bacteria and fungi was recorded in winter. An increase in the quantity of fungal and bacterial aerosol was most probably caused by poor ventilation owing to low temperatures outside. The number of actinomycetes in air inside the building for sitatungas did not show any correlation with any investigated microclimate factors (correlation coefficient: number of actinomycetes and air temperature 0.2; number of actinomycetes and air humidity -0.2 ; number of actinomycetes and air movement -0.1 , number

TABLE. Average values of the number of microbes in air in the following experimental series $\text{CFU}\cdot\text{m}^{-3}$

Experimental series	Measurement location	Total number of Bacteria	Total number of Actinomycetes	Gram-negative bacteria	Staphylococci	Total number of Fungi
I winter	inside the building	8.5×10^3	0.2×10^3	3.2×10^3	1.8×10^3	5.1×10^3
	outside the building	1.3×10^3	0.06×10^3	0.03×10^3	0.1×10^3	0.5×10^3
II spring	inside the building	3.3×10^3	0.2×10^3	0.5×10^3	0.4×10^3	0.9×10^3
	outside the building	0.8×10^3	0.06×10^3	0.05×10^3	0.2×10^3	0.3×10^3
III summer	inside the building	3.0×10^3	0.2×10^3	0.9×10^3	0.6×10^3	1.2×10^3
	outside the building	0.7×10^3	0.07×10^3	0.5×10^3	0.1×10^3	0.4×10^3

of actinomycetes and dust concentration 0.2). The concentration of bioaerosol (Bacteria $1.3 \times 10^3 / 0.7 \times 10^3$, Fungi $0.5 \times 10^3 / 0.3 \times 10^3$ [cfu·m⁻³]) (Table) in air within zoo premises was significantly lower as compared with investigated facility. These observations regard both fungal and actinomycete aerosols.

CONCLUSIONS

Providing suitable microclimate conditions is one of major functions of the buildings intended for animals. Measurements taken in our study show that weather parameters affect microclimate in the investigated building. Both temperature (summer) and air humidity (spring, summer) in the building for sitatunga strongly correlated with conditions observed outside. The experiment also showed significant correlation between PM10 concentration outside and inside the building. No relationship was found between the winds blowing outside and the rate of air flow inside investigated building. An increase in the concentration of bacterial and fungal aerosols detected in winter was most probably caused by poor ventilation that resulted from low outdoor temperatures. Despite producing detectable effects on the microclimate of the building, limit values for investigated weather parameters recommended for the sitatunga were not exceeded, except for too low air humidity in winter caused by intensive use of the heating system.

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Streszczenie: *Wpływ składników pogody na mikroklimat budynku dla antylop.* Jednym z czynników wpływających na dobrostan zwierząt jest mikroklimat pomieszczeń, w których przebywają. Celem niniejszej pracy było zbadanie wpływu wybranych wskaźników pogody na mikroklimat budynku dla sitatung. W trakcie pomiarów oceniano temperaturę, wilgotność względną, ruch powietrza, stężenie pyłów, oraz ilość bakterii, grzybów i promieniowców. Badania zostały wykonane w okresie zima–lato wewnątrz i na zewnątrz budynku dla antylop. Przeprowadzone pomiary wykazały, że badane wskaźniki pogodowe miały wpływ na mikroklimat ocenianego pomieszczenia. Zarówno temperatura (lato), jak

i wilgotność powietrza (wiosna, lato) w obiekcie przeznaczonym dla sitatung kształtowały się w ścisłej korelacji z warunkami panującymi na zewnątrz. W trakcie badań zauważono również ścisłą korelację między stężeniem pyłu P10 na zewnątrz i wewnątrz budynku. Nie stwierdzono wpływu wiejących na zewnątrz wiatrów na prędkość ruchu powietrza wewnątrz badanego pomieszczenia. Obserwowany w okresie zimowym wzrost poziomu aerozolu bakteryjnego i grzybowego był najprawdopodobniej spowodowany słabym przewietrzaniem budynku, wynikającym z niskich temperatur panujących na zewnątrz. Pomimo zauważalnego wpływu wskaźników pogodowych na mikroklimat badanego budynku, nie stwierdzono przekroczenia dopuszczalnych norm zalecanych dla sitatung. Wyjątek stanowiła zbyt niska w okresie zimowym wilgotność powietrza, spowodowana intensywną pracą systemu grzewczego.

Słowa kluczowe: mikroklimat, bioaerazol, budynek, ogród zoologiczny, składniki pogody, sitatungi

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