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Original Article

Testing *Nephrolepis exaltata* (L.) Schott. Ability to Be Used as Indoor Air Quality Biomonitoring Agent

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Abstract

Indoor air pollution ae refers to the physical, chemical and biological characteristics of the air in the interior environment of a house, buildings or institutions. Indoor air quality is the quality of air inside and around buildings and structures, especially in terms of health and comfort of the occupants of the building. This study was developed in order to emphasize the monitoring the capacity of *Nephrolepis exaltata* (L.) Schott. (apartment fence) to become agents of biomonitoring of indoor pollution in educational spaces. The values of the correlation coefficients and the resulting determination coefficients suggest the existence of interactions between the content of PM2.5 and PM10 in the ambient air and the bioaccumulation capacity of the leaf tissue of the plant taken in the study, which is why it is considered appropriate to deepen this research through further studies.

Keywords: *apartment fern, crude ash, dry matter, variability.*

1. Introduction

Most people are aware of the dangers of environmental air pollution, but many do not realize that air pollution in indoor spaces, homes, offices and schools, respectively, can have significant health effects, air quality being a regulated area both at the EU level, as well as of Romania [9, 10, 11, 12, 13, 14].

Indoor air pollution ae refers to the physical, chemical and biological characteristics of the air in the interior environment of a house, buildings or institutions. Indoor air quality is the quality of air inside and around buildings and structures, especially in terms of health and comfort of the occupants of the building [1, 2, 3, 5, 7].

Indoor air quality depends on 4 major factors:

1. the air quality from outside the building;

2. air exchange rate or air infiltration rate depends on the type of construction:

- simple constructions from the tropics are well ventilated, the whole air is renewed several times per hour;
- the constructions in the temperate areas are less airy, the air is renewed at one hour;
- energy efficient constructions are hermetically sealed, the air is renewed every 2-10 hours, the pollutants that are generated indoors accumulate in higher concentrations;

3. building materials used - modern polymer-based materials contain formaldehyde, traditional clay-based materials may contain radioactive metals;4. activities that take place inside the building - smoking, burning of heating fuels, activities using chemicals generate different types of pollutants [6]. The sources of indoor air pollution may be classified in exterior sources and interior sources.

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Among the exterior sources one may find: combustion gases, activities from agriculture, atmospheric photochemical processes, and natural microbial activity. The main indoor sources are: solvents evaporations, different physical processes, mushrooms and fungi, dust, etc.

Biomonitoring consists in using the responses of individual plants or plant associations to detect or anticipate changes in the environment and to track their evolution [4]. Plants play an important role in monitoring and maintaining the ecological balance by actively participating in the cycle of nutrients and gases, such as carbon dioxide, oxygen, and also provide a huge leaf surface for pushing, absorbing and accumulating atmospheric pollutants thus reducing the level of air pollution [8].

The present study aimed at monitoring the capacity of plants, respectively of the species *Nephrolepis exaltata* (L.) Schott. (apartment fence) to become agents of biomonitoring of indoor pollution in educational spaces.

2. Material and Method

The experiment was conducted between March and May 2019, within the L3 Laboratory of the Environmental Engineering studies program, of the Faculty of Agriculture of the USAMV Cluj-Napoca. In the present study, the biological material consisted of the fern species of the apartment - *Nephrolepis exaltata* (L.) Schott. The plant has its origins in the American continent, mainly in the area of South America and Mexico, as well as in the West Indies, Polynesia and Africa.

Suspended particle loading (PM10, PM2.5) of ambient air was quantified using GRIMM EDM 180 (Fig. 1.1). The ash content of the leaves of the plant, which constituted the analysis material, was determined gravimetrically, by calcination. The data were interpreted statistically using the software STATISTICA v. 8.0 for Windows.

3. Results and Discussions

Regarding the evolution of the PM2.5 from the experimental site (μg/m^3), during the period considered in the study, respectively March - May 2019, very fluctuating evolutions are highlighted. Thus, the smallest daily mean value equal to 2.7 μg/m^3 is recorded at the end of the experimental period, and the highest at the beginning (19.3 μg/m^3) and the middle of the experimental period (18.1 μg/m^3). It is found that a very large difference between two successive measurements results between measurement no. 4, which corresponds to the maximum load with PM2.5 of the analyzed period, respectively 19.3 μg/m^3 and the fifth measurement, which corresponds to a load of the enclosure with very small PM2.5, respectively equal to 5.8 μg/m^3 (Fig. 1).

The smallest variation of the ambient air load with PM2.5 corresponds to the first 2 samples taken, respectively at the beginning of the experimental period, when developments of only 1 μg/m^3 respectively from 11.5 μg/m^3 to 12.5 μg/m^3 are reported. m3 (Fig. 1).

Regarding the evolution of the suspended PM10 particles from the experimental enclosure (μg/m^3), during the study period, respectively March - May 2019, very fluctuating evolutions are observed, much more variable compared to those recorded for PM10. Thus, the smallest daily mean value equal to 4.6 μg/m^3 is recorded towards the end of the experimental period and the highest at the beginning (28.1 μg/m^3). It is found that a very large difference between two successive measurements results, as in the case of the study of PM2.5 evolution in the same experimental premises of the L3 laboratory, between measurement no. 4, which corresponds to the maximum load with PM2.5 of the analyzed period.

It corresponds to 28.1 μg/m^3 and the fifth measurement, which corresponds to a load of the enclosure with reduced PM2.5, respectively equal to 10, 3 μg/m^3 (Fig. 2).

The smallest variation of ambient air loading with PM2.5 corresponds to the taking of samples 2 and 3, respectively at the beginning of the experimental period, when developments of only 1.2 μg/m^3 and from 20.1 μg/m^3 to 21 are reported, 3 μg/m^3 (Fig. 2).

The calculation of the average evolution of PM2.5 and PM10, over the whole experimental period and the four experimental stages, shows their fluctuations, but the statistical analysis shows the representativeness of the average, in all cases the variability expressed by the coefficient of variation (CV%), being less than 30%. Thus, it is found that the most uniform evolution, during the whole experimental period, presents PM2.5 (CV = 23.86%) and the most uneven, as is also expected PM10, respectively CV = 24.77%.

Throughout the experimental period, an average PM2.5 was equal to 12.45 μg/m^3 and an average of PM10 in the experimental chamber equal to 16.32 μg/m^3 (Table 1).

The averages of the evolutions of the dry substance (%) and the ash, resulting from the study of the leaf tissue of the analyzed plant (*Nephrolepis exaltata* (L.) Schott.) throughout the experimental period and on the four experimental stages, show uniform distributions, the statistical analysis demonstrating the representativeness of the media, in all cases the variability expressed by the coefficient of variation (CV%), being less than 30% (Table 2).

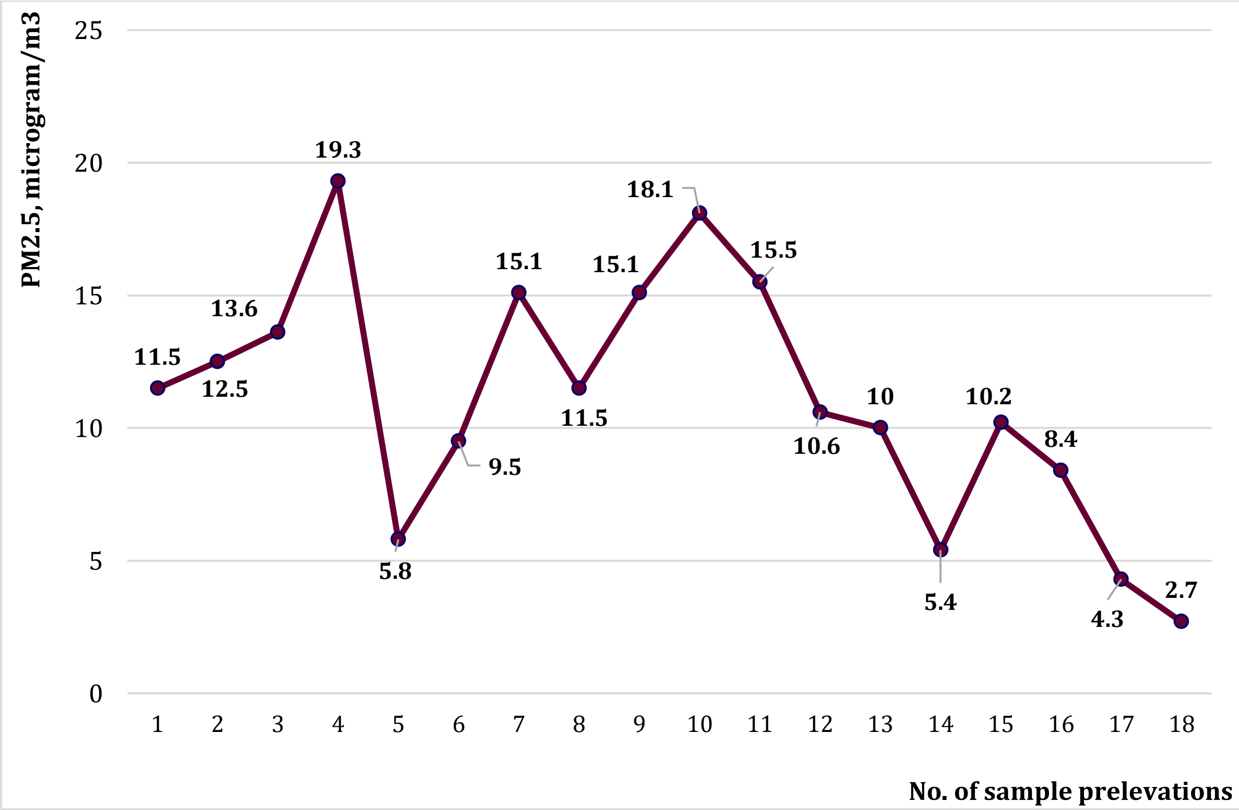

Figure 1. The evolution of the $PM_{2.5}$ samples identified from indoor air during experimental period, March - May 2019 ($\mu g/m^3$)

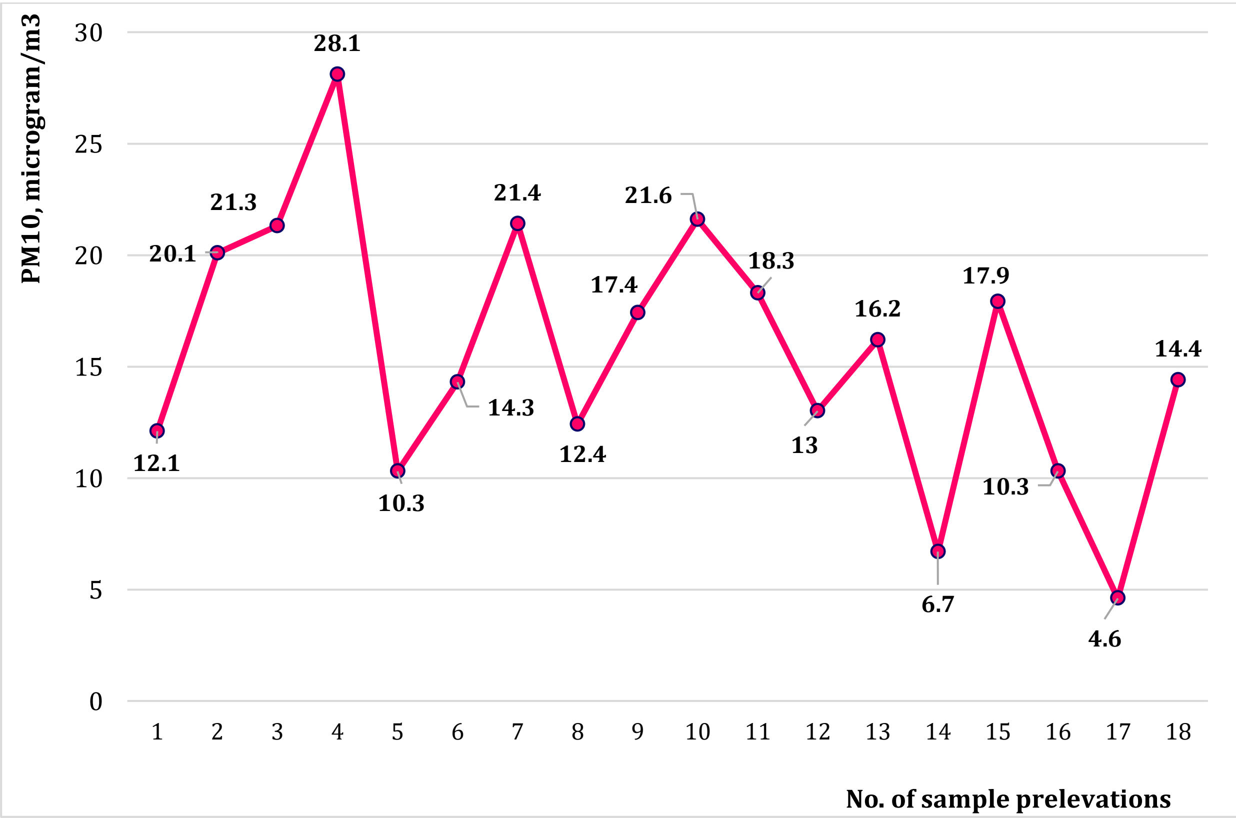

Figure 2. The evolution of the PM_{10} samples identified from indoor air during experimental period, March - May 2019 ($\mu g/m^3$)

Table 1. The means of the PM (PM_{10} and $PM_{2.5}$) evolutions identified from indoor air during entire experimental period, March - May 2019, and by stages (µg/m^3)

Indoor parameter	N	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation, %
Stage 1, 08.03-25.03.2019						
PM_{10}, µg/m^3	4	20.40	12.10	28.10	5.56	27.25
$PM_{2,5}$, µg/m^3	4	14.23	11.50	19.30	3.49	24.54
Stage 2, 27.03-03.04.2019						
PM_{10}, µg/m^3	4	14.60	10.30	21.40	4.02	27,53
$PM_{2,5}$, µg/m^3	4	10.48	5.80	15.10	3.12	29,77
Stage 3, 05.04-12.04.2019						
PM_{10}, µg/m^3	4	17.58	13.00	21.60	3.54	20.17
$PM_{2,5}$, µg/m^3	4	14.83	10.60	18.10	3.11	21.01
Stage 4, 15.04-10.05.2019						
PM_{10}, µg/m^3	6	11.68	4.60	17.90	3.35	28.68
$PM_{2,5}$, µg/m^3	6	6.83	2.70	10.20	1.14	16,69
Experimental period, 08.03-10.05.2019						
PM_{10}, µg/m^3	18	16.32	4.60	28.10	3.86	24.77
$PM_{2.5}$, µg/m^3	18	12.45	2.70	19.30	2.64	23.86

Table 2. The means of the dry matter and ash of *Nephrolepis exaltata* (L.) Schott. Foliar tissue, by entire experimental period, and by stages

Indoor parameter	N	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation, %
Stage 1, 08.03-25.03.2019						
Dry matter, %	10	17,21	16.99	17.32	3.41	19.81
Crude ash, %	10	1,25	1.20	1.31	0.33	26.4
Stage 2, 27.03-03.04.2019						
Dry matter, %	10	17.33	17.02	17.42	5.05	29.14
Crude ash, %	10	1.24	1.15	1.29	0.28	22.58
Stage 3, 05.04-12.04.2019						
Dry matter, %	10	17.26	17.18	17.39	3.54	20.50
Crude ash, %	10	1.15	1.02	1.22	0.33	28.69
Stage 4, 15.04-10.05.2019						
Dry matter, %	10	17.27	17.20	17.40	5.05	29.24
Crude ash, %	10	1.02	0.99	1.17	0.21	20.58
Experimental period, 08.03-10.05.2019						
Dry matter, %	40	17.26	16.99	17.42	4.27	24.73
Crude ash, %	40	1.16	0.99	1.31	0.25	21.55

Thus, it is found that the most uniform evolution, over the whole experimental period, is the gross ash content of the leaf tissue of the plant (CV = 21.55%), while the dry matter content of the plant showed slightly higher variability, respectively CV = 27.33%. Throughout the experimental period, an average of the ash content in the leaf tissue of the plant was equal to 1.16% and an average of the dry matter of the plant equal to 17.26%, with a minimum of the raw ash content of the leaf tissue of the plant equal to 0.99% and a maximum equal to 1.31%, while for the dry matter content of the leaf tissue of the plant there is registered a minimum equal to 16.99% and a maximum equal to 17.42% (Table 2). Implementation of the multiple regression analysis of the interrelationship between the dry matter content and the raw ash of the leaf tissue of Nephrolepis exaltata (L.) Schott. and the load with PM2.5 and PM10 of the ambient air in the studied area, over the whole experimental period, highlights a number of peculiarities (Table 2).

Thus, it can be observed that between the dry matter content of the leaf tissue of *Nephrolepis exaltata* (L.) Schott. and the load with PM2.5 and PM10 of the ambient air in the studied area, during the experimental period, establishes an interrelation, evidenced by the value of the multiple correlation coefficient (R = 0.300). This value corresponds to a weak correlation, representing only 5% of the sample analyzed (Table 3). Between the raw ash content of the leaf tissue of *Nephrolepis exaltata* (L.) Schott. and the load with PM2.5 and PM10 of the ambient air in the studied area, during the whole experimental period, establishes an interrelation, evidenced by the value of the multiple correlation coefficient (R = 0.400). This value corresponds to an average correlation, representing 15.60% of the sample analyzed (Table 3).

Table 3. The analysis of multiple regression of the interrelationship between the dry matter and ash content identified in the foliar tissue of *Nephrolepis exaltata* (L.) Schott. and indoor air charge in PM2.5 and PM10, by entire experimental period

No.crt.	Regression line	R	R^2
1	$Y1= 1.426 + 0.053X1 + 0.102X2$	0.300	0.090
2	$Y2 = 3.009 +0.097X1 + 0.235X2$	0.400	0.160

Y1 – dry matter content (%) of the foliar tissue; Y2 – crude ash content (%)of the foliar tissue; X1 – PM2.5 content from indoor air (µg/m^3); X1 –PM10 content from indoor air (µg/m^3).

The values of the correlation coefficients and the resulting determination coefficients suggest the existence of interactions between the content of PM2.5 and PM10 in the ambient air and the bioaccumulation capacity of the leaf tissue of the plant taken in the study, which is why it is considered appropriate to deepen this research through further studies.

4. Conclusions

The calculation of the average of the evolution of the environmental parameters, on the whole of the experimental period and on the four experimental stages, shows their fluctuations, but the statistical analysis demonstrates the representativeness of the average, in all cases the variability expressed by the coefficient of variation, being less than 30%. Thus, it is found that the most uniform evolution, over the whole of the experimental period, presents the pressure and the most uneven, as is expected the outside temperature. Also an evolution characterized by a degree of non-uniformity is also presented by the relative humidity, while the average interior temperature has a uniform evolution.

The calculation of the mean evolution of PM2.5 and PM10, over the entire experimental period and the four experimental stages, shows their fluctuations, but the statistical analysis shows the representativeness of the mean, in all cases the variability expressed by the coefficient of variation, being less than 30%. Thus, it is found that the most uniform evolution, during the whole experimental period, presents PM2.5 (CV = 23.86%) and the most uneven, as is also expected PM10, respectively CV = 24.77%. Throughout the experimental period, an average of PM2.5 was equal to 11.06 µg/m^3 and an average of PM10 in the experimental area was 15.58 µg/m^3. Between the dry matter content of the leaf tissue of *Nephrolepis exaltata* (L.) Schott. and the load with PM2.5 and PM10 of the ambient air in the studied area, during the experimental period, establishes an interrelation, evidenced by the value of the multiple correlation coefficient (R = 0.300). This value corresponds to a weak correlation, representing only 5% of the analyzed sample. Between the raw ash content of the leaf tissue of *Nephrolepis exaltata* (L.) Schott. and the load with PM2.5 and PM10 of the ambient air in the studied area, during the whole experimental period, establishes an interrelation, evidenced by the value of the multiple correlation coefficient (R = 0.400). This value corresponds to an average correlation, representing 15.60% of the analyzed sample.

The values of the correlation coefficients and the resulting determination coefficients suggest the existence of interactions between the content of PM2.5 and PM10 in the ambient air and the bioaccumulation capacity of the leaf tissue of the plant taken in the study, which is why it is considered appropriate to deepen this research through further studies.

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