

Quantification of the health-improving action of phyto modules in the rooms of child care preschool facilities

Irina Novikova^{1,2}, *Natalya Chuenko*¹, *Natalya Tsybulya*^{3*}, *Tatyana Fershalova*³, and *Mariya Lobkis*¹

¹Novosibirsk Research Institute of Hygiene, Rospotrebnadzor (Federal Agency for Supervision of Consumer Protection and Welfare), 630108 Novosibirsk, Russia

²Novosibirsk Medical University, 630091 Novosibirsk, Russia

³Central Siberian Botanical Garden SB RAS, 630090 Novosibirsk, Russia

Abstract. The effect of three phyto modules – different combinations of indoor plants with the pronounced phytoncide activity – on the qualitative and quantitative composition of microflora in the air and on a decrease in the risk of acute respiratory diseases (ARD) in children was studied during autumn and winter in 2018-2020 in child care preschool institutions. Sanitary descriptive, epidemiological, sanitary bacteriological and statistical methods were involved. Observation revealed higher attendance rate in the observation group, in combination with lower recorded incidence of disease in comparison with the reference group. The fraction of facultative microflora (FM) with respect to the total microbial count (TMC) was about 30 % in the rooms equipped with phyto modules, while the ratio was 60% in the rooms without plants. The degree of antimicrobial activity depended on the assortment of plants and on the total leaf area per unit room volume. The phytoncide effect of the plants was traced to the most remote point of the room under investigation – 3 m. A favorable factor was an increase in the relative air humidity from 26 to 40%.

1 Introduction

The problem of the microbial contamination of indoor air in the child care facilities remains urgent in spite of advanced engineering measures, in particular up-to-date ventilation systems. This problem became determinative for health risks under the conditions of COVID-19 pandemic. A child's organism is most sensitive to the negative effects of environmental factors, in particular to those in the indoor air of child care facilities where children stay every day on average for 6 to 8 hours. Unfavorable effects of environmental factors slow down and weaken children's adaptation to the new social conditions [1, 2]. In the absence of adequate air exchange, the conditions promoting accumulation of facultative microorganisms in indoor air are created, which may lead to an increase in the rate of chronic diseases [3,4]. This is most urgent for the regions of the Russian Federation that are

* Corresponding author: ntsbulya@yandex.ru

situated in the moderate, sub-polar and polar climatic belts. One of the measures aimed at the improvement of indoor air quality is the use of tropical plants for indoor planting. We studied the plants with high all-year-round antimicrobial activity of their volatile emissions against facultative microflora excluding the plants with allergizing action and toxic sap. The use of phyto modules, or sets of indoor plants with environment-improving properties, in child care facilities may become a promising tool to decrease the risks for children's health [5]. It has been confirmed in the world practice that plant exo-metabolites, in addition to their sanitizing action, promote enhancement of the immunological response and reconstructive processes in the tissues in the case of cold-related diseases [6,7].

2 Material and methods

Investigation was carried out in two child-care preschool institutions (CPI) in Novosibirsk in November-December 2018-2020 during the period of rising ARD incidence in the children of preschool age (4-6 years old). Two groups of children were observed: the children of the first group (n = 82 children) attended the basic observation rooms – experimental rooms, in which phyto modules were mounted. These phyto modules included the plants possessing antimicrobial activity with respect to the gram-positive, gram-negative bacteria and the fungi of *Candida* genus [5]. The children of the second group (n = 78 children) attended the rooms where no plants were placed – reference rooms. The methods involved in the investigation included sanitary-descriptive, epidemiological, microbiological, biological (evaluation of phytoncide effect taking into account the total plant leaf area), and statistical analysis using the *Statistica for Windows* v.10.0 software package. Statistical hypotheses were verified using Student's criterion and descriptive statistical methods. The differences were considered to be significant in the case if $p < 0.05$. Air was sampled with the help of a PU-1B sampling device by means of impaction of biological aerosol on agarized solid nutrient medium. Air volume for the determination of TMC was 100 L, FM – 250 L. Evaluation of microbial contamination of the air was carried out simultaneously in the experimental and reference rooms. Quantitative and qualitative analysis of the composition of air microflora was carried out using standard differential diagnostic nutrition media, inoculation methods and the procedures for calculating the fraction of FM with respect to TMC [8]. Air sampling sites were located at a distance of 0.5, 1.5 and 3 m from the phyto module at the height of 0.8 m from the floor – in the breathing zone of a child. Experimental rooms were equipped with phyto modules composed of the combinations of indoor plants: phyto module No. 1 – *Ficus binnendijkii*, *F. retusa*, *Sansevieria trifasciata*, *Ch. comosum*; phyto module No. 2 – *Myrtus communis*, *Begonia bowerae*, *B. fischeri*, *B. Ricinifolia*, *Coffea arabica*, *Chlorophytum comosum*, *Coleus blume*; phyto module No. 3 – *B. bowerae*, *B. fischeri*, *Eucharis grandiflora*, *Ficus benjamina*, *Nephrolepis exaltata* «Vitale», *Ch. comosum*, *Schefflera octophylla*, *S. trifasciata* with the total leaf area per 100 m³ 0.7, 2.0 and 2.4 m², respectively.

3 Results

Acute respiratory viral diseases occupy the leading position in the structure of children's illness rate, especially during epidemic periods. During experiment, analysis of the attendance rate and illness rate was carried out for children in the observation group and in the reference group. Illness rates and attendance rates are presented in Fig. 1.

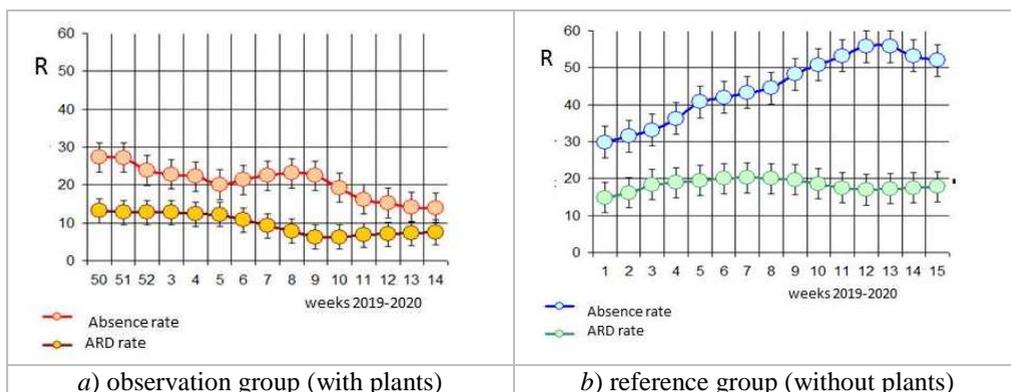


Fig. 1. The number (R) of absence cases (absence rate) and the incidence of acute respiratory diseases (ARD rate) per 100 children at the child care facilities over the weeks in 2019-2020.

Attendance rates for the children of both groups did not exhibit significant differences at the beginning of the experiment (50th-52nd weeks of the year 2019). Starting from the 3rd week of the year 2020, attendance rate in the observation group was gradually increasing, while in the reference group it was decreasing. Comparative analysis of the number of cases of acute respiratory diseases revealed statistically significant increase in the reference group in comparison with the observation group. Illness rate was 2.3 times lower in the observation group than in the reference group ($p < 0.05$).

To determine the spatial extension of pronounced phytoncide effect of the volatile emissions of plants on the microbial contamination, air was sampled at different distances from the phyto modules (Table 1).

Table 1. Dynamics of average TMC and FM (in CFU/m³) in the groups at different distances from phyto modules

Groups	Leaf area, m ²	Distance from phyto module					
		0.5 m		1.5 m		3.0 m	
		TMC	FM	TMC	FM	TMC	FM
Reference 1	0	1504.44	462.4	1540.11	410.2	1174.4	517.8
Reference 2	0	1486.67	497.25	1477.78	656.13	1315.56	444.5
Reference 3	0	3508	86	3724	98.6	3280	104.6
1	0.7	682.2*	235*	815*	269*	760*	174*
2	2.0	904*	279.20*	886*	325.22*	1043	340.4*
3	2.4	1111	30.2*	1156	18.5*	1406.25*	24.5*

Note. Reference groups 1, 2, 3 – phyto modules are absent; observation groups: 1 – phyto module No.1; 2 – phyto module No. 2; 3 – phyto module No. 3; * $p < 0.05$ for comparison with the corresponding reference group.

In the 1st observation group with phyto module No. 1, average CFU/m³ values for the total microbial count at a distance of 0.5 and 1.5 m were lower by a factor of 1.5 and 1.6, respectively ($p < 0.05$), in comparison with the reference group, while at a distance of 3.0 m

the difference became unreliable. The average CFU/m³ values for the facultative microflora at a distance of 0.5, 1.5 and 3 m from the phyto module were determined to be reliably 1.7 times lower than the corresponding value for the reference group ($p < 0.05$). The range of the efficient phytoncide action of phyto module No. 1 was 1.5 m as determined from the total microbial count and 3 m as determined for facultative microflora.

In the 2nd observation group, the values of total microbial count at a distance of 0.5, 1.5 and 3 m from phyto module No. 2 differed significantly from the corresponding values in the reference (2.3, 2.0 and 1.8 times lower, respectively, with $p < 0.05$). Average values of CFU/m³ for facultative microflora at the sampling points were lower in the observation group than in the reference group by a factor of 3.2, 3.9 and 4.7, respectively ($p < 0.05$). Therefore, the volatile emissions of plants incorporated into the phyto module under test exhibited pronounced antimicrobial activity, which was sufficiently efficient at a distance of more than 3 m.

The sanitary-bacteriological examination of air in the 3rd observation group with phyto module No. 3 showed that CFU/m³ values for the total microbial count at a distance of 0.5, 1.5 and 3 m were lower than the corresponding values in the reference group by a factor of 2.3, 2.6, 3.3, respectively ($p < 0.05$). So, investigation results provide evidence that the volatile emissions of plants possess phytoncide activity all over the room, and pronounced antimicrobial activity is still observed at a distance 3 m from the phyto module, which corresponds to the zone of children's activities.

4 Discussion

The efficiency of phyto modules for the prophylactics of respiratory diseases in children during the epidemic period has been proven. The experiment revealed higher attendance rate and lower recorded ARD illness rate in the experimental group in comparison with the reference group.

The fraction of CFU/m³ for FM was about 30 % with respect to the TMC in the rooms with phyto modules, while in the reference rooms it was 60 %. The degree of the antimicrobial activity of plants depended on plant assortment and on the total leaf area per unit room volume. For the leaf area of 0.7, 2.0, 2.4 m² per 100 m³, a decrease in CFU/m³ for TMC was 37.2, 65.7 and 75.0 %, respectively, and a decrease in CFU/m³ for FM was 26, 48 and 92%, respectively.

The results obtained during the investigation are in agreement with the statements of foreign experts in medicine and biology who claim the long-term efficiency of the prophylactic effect of phytoncides on the recovery and enhancement of protective forces of children, which is the evidence of the immensity of favorable action of phytoncides [6,7].

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