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Методика измерения концентрации легких аэроионов на рабочем месте оператора персонального компьютера

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В статье проанализированы существующие методические указания по измерению концентрации легких аэроионов и руководства по эксплуатации счетчиков аэроионов «Сапфир-3к», МАС-01 и «AlphaLab Air Ion Counter». Выявлено отсутствие в проанализированных методических указаниях и руководствах по эксплуатации счетчиков аэроионов рекомендаций, необходимых для проведения измерений концентрации легких аэроионов при проведении научных исследований и получения наиболее точных и достоверных результатов. Предложено при разработке рекомендаций по проведению измерений руководствоваться пунктом из МУК 4.3.1675-03 «Общие требования к проведению контроля аэроионного состава воздуха» и ГОСТ 8.207-76 «Прямые измерения с многократными наблюдениями. Методы обработки результатов наблюдений. Основные положения» о пренебрежении величиной случайной погрешности при значительной величине инструментальной погрешности. Разработаны и обоснованы с помощью статистического аппарата указания по измерению концентрации легких аэроионов счетчиком аэроионов «Сапфир-3к».

Ключевые слова: легкие аэроионы, измерение, счетчик аэроионов, погрешность измерений, методика измерения.

The technique of small air ions concentration measurement at the PC operator working place

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The paper considers small air ions concentration measurements guidelines and operation manuals for small air ions counters “Sapphire-3k”, MAS-01 and “Alpha Lab Air Ion Counter”. The guidelines and manuals under analysis appear to lack recommendations required for small air ions concentration measurement in the course of the research work, as well as for obtaining the most accurate and reliable results. While working out measurement guidelines it is advisable to follow the provisions of Instructional Lines 4.3.1675-03 “General Requirements for Air Ionic Composition Control” and GOST 8.207-76 “Direct measurements with multiple observations. Observation results processing methods. Main principles” of disregarding random error value under instrumental error enormity. While using “Sapphire-3k” air ion counter the guidelines on small air ions concentration measurements have been worked out and provided.

Keywords: small air ions, measurement, air ion counter, measurement error, measurement technique.

Introduction

Computers are widely used in various spheres of human activity. The problem of safety working environment for computer operators is urgent because of considerable amount of environment factors, affecting operator. The important factor of working environment is a concentration of small air ions. Researches of scientists [2, 3, 5, 6] are devoted to the problem of nonconformance of small air ions concentration in computer operator work place to the regulatory sanitary standards [4]. Despite of mentioned scientific researches this problem requires further study, because proposed ways of small air ions concentration normalization are neither sufficient nor appropriate. The important task for further studies is development of substantiated measurement technique to provide the most reliable results. Legacy normative regulation [4] doesn’t include guidelines on small air ions concentration measurement technique. Therefore the question of small air ions concentration measurement technique development is the actual task.

Problem statement

The list of air ion counters, which are available for carrying out measurements in Ukraine, includes not many devices. The modern air ion counters MAS-01 (MAC-01), "Sapphire-3k", "Sapphire-3m", made in Russia, are present in Ukraine and it is possible to buy "AlphaLab Air Ion Counter" from the Internet. Also Ukrainian scientific research institutes have Soviet times air ion counters, which are mostly stationary laboratory devices. Thus, these counters can't be applied for the study of air ions at working places with computers and for air ion concentration measurements aimed at control of their compliance with the sanitary code.

In this paper we have considered small air ions measurements with the device "Sapphire-3k". According to the maintenance manual of this device the operational procedure includes making 10-20 consecutive measurements, then extreme minimal and maximal values are deducted and arithmetic average of the received measured results is calculated [9]. Calculated arithmetic average will be the result of measurement. It's obvious, that this manual is sufficient for small air ions concentrations measurement aimed at control of their compliance with the sanitary code, but it's not sufficient for scientific research.

Manuals of MAS-01 and AlphaLab Air Ion Counter devices also don't possess guidelines on necessary quantity of measurements for obtaining valid data [1, 8].

There is the Instructional Lines 4.3.1675-03 "General Requirements For Air Ionic Composition Control" (МУК 4.3.1675-03 «Общие требования к проведению контроля аэроионного состава воздуха») developed for air ions concentration measurements in the Russian Federation [7]. Exactly this document has been used as the basis for the development of measurement technique with the air ion counter "Sapphire-3k", as Ukrainian guidelines on air ions concentration measurements aren't developed. But mentioned instructional lines are not sufficient for scientific experiments measurements, because they are developed for air ionic composition control in work and public places and for sanitary-hygienic assessment of air ionization equipment. To obtain measurement result these lines propose to make 8 measurements, that is sufficient for control, but not for valid scientific result.

The aim of this study is the development of guidelines on small air ions concentration measurement with the air ion counter "Sapphire-3k" for obtaining valid results, which can be applied in scientific research and occupational safety practice.

Materials and results of study

First of all it should be noted that unlike its posterior analog "Sapphire-3m", "Sapphire-3k" doesn't have option of data output on computer. Air ions counter MAS-01 also doesn't perform the option of data output to the computer. AlphaLab Air Ion Counter is supplied with this option at extra cost. In the case of "Sapphire-3m" there is no problem with determination of necessary quantity of measurements, because measurement data automatically transmit to computer, thus measurements can be conducted uninterruptedly, and that's not reflected on laboriousness of experiment. Uninterrupted measurements with "Sapphire-3k" are quite labor-consuming; therefore determination of optimal and sufficient quantity of measurements is urgent.

The distinctive feature of the counter "Sapphire-3k" is simultaneous measurement of both positive and negative air ions, unlike counters MAS-01 and AlphaLab Air Ion Counter, which can measure only single polarity air ions at particular moment. According to its maintenance manual "Sapphire-3k" measures concentration of air ions with 0,4 $cm^2/V\cdot sec$ and higher mobility, data output on display proceeds each 5 seconds, counter has three measurement ranges (I – from $2\cdot10^2$ to $2\cdot10^3$ ions/cm^3; II – from $2\cdot10^3$ to $2\cdot10^4$ ions/cm^3;

III – from $2\cdot10^4$ to $2\cdot10^5$ ions/cm^3). The system instrumental error of "Sapphire-3k" is not over

$$0{,}4+0{,}01\cdot(n_к/n_x-1), \qquad (1)$$

where $n_к$ – maximum value of measurement range, n_x – reading on the counter.

This study has used data of measurements conducted for the investigation of factor impact (activity of computer operator at work place) on small air ions concentration. Measurements have been conducted continuously in the regime: 15 minutes – 1 hour – 15 minutes – 1 hour – 15 minutes, for the 15 minutes range operator has leaved his work place for break, during 1 hour operator has been working on computer without breaks [10]. Measurements have been conducted in room with the dimensions 8 × 9 × 3,5 m, situated at the 5th floor. The room hasn't been equipped with the systems of induced ventilation and conditioning, on the measurement day windows have been closed in the room. Measurements have been conducted in the absence of people on day off; there have been only operator and another person to record measurement results in the room. The distance between operator and observer has been about 1,5 m. Measurements have been conducted in the breathing zone of computer operator, for this aim the counter has been placed at 20 cm height above the work table surface. Measurements of the equivalent dose rate (0,13 µSv/hour) with the dosimeter SINTEX-DBG-01S and measurements of the air temperature (20°C), the relative humidity (78%) and the atmospheric pressure (750 mmHg) with multifunction environment meter DT-8820 have been conducted simultaneously with small air ions concentration measurements. As microclimate conditions have been close to standard and haven't changed during experiment, measurements have been conducted with the assumption that mentioned parameters influence on small air ions concentration have been minimized and therefore it is not necessary to take them into account.

The logic of sufficient measurements quantity determination for the obtaining valid data is described below. According to the Instructional Lines 4.3.1675-03 measurement error Δ equals systemic (instrument) error δ if random error $\Delta\rho < \delta/3$; $\Delta = \Delta\rho$ when $\Delta\rho > 3\delta$; and in the case $\delta/3 \le \Delta\rho \le 3\delta$ measurement error is determined as $\Delta = \pm0{,}76\cdot(\delta + \Delta\rho)$. The procedure of measurement error determination in Instructional Lines is taken from the Soviet guidelines on measurement results processing (GOST 8.207-76 "Direct measurements with multiple observations. Methods of processing the results of observations. Basic principles"), which are used by scientists till now.

The study has considered 5 data ranges of small air ions concentrations, whereat each range has been a considerable data sample of uninterrupted measurements during activity (or influence absence) of factor. For all of data ranges the distribution normalcy test with build-in statistical functions and procedures in Excel has been done. The analysis has shown that all data ranges have been subject to the normal distribution law according to the value of Pierson criterion (with confidence interval 0,95), and general random error for each range hasn't been over 0,1 of systemic error.

Among three mentioned alternative approaches to the measurement error determination the first case is the most optimal, because it gives the lowest value of measurement error. The simple calculations have been performed to prove that. Systemic error equals approximately $\delta \approx 0{,}4$ (first case); second option is not real at all, because $\Delta\rho$ can't be over $3\delta = 1{,}2$, and measurement error can't be over 120%; in the third case if $\Delta\rho = \delta/3 = 0{,}4/3 = 0{,}13$, then $\Delta = \pm0{,}76\cdot(0{,}4 + 0{,}13) = 0{,}41$, in the third case general error will always be over systemic error. Thus, task has turned into finding such quantity of measurements, at which inequality $\Delta\rho < \delta/3$ will be true in all cases or in most cases.

For the investigation purposes the ranges have been divided into smaller samples of data. Selection of the sample range has been done based on the following conditions: sample has to be subject to the normal distribution law, sample has to include few measurements and comfortable time interval. Thus, we have considered samples with 48 values of both polarities air ions concentrations, which correspond to the results of 4 minutes continuous measurements.

Then the ratio $\Delta\rho/\delta$ has been calculated in each sample with developed pattern of calculations in Excel for 2; 3; ...; 48 measurements separately for air ions of each polarity. In the process the minimal quantity of measurements for which the conditions $\Delta\rho/\delta < 1/3$ is true in all cases has been searched for. I.e. for which the minimal number of measurements of 48 measurement error equals systemic error. As a result the values in the range from 11 to 30 measurements have been obtained in the samples with average 18 measurements value for all samples.

It should be noted, that results of computer operator influence on air ions concentration study have shown absence of this factor influence and difference between concentrations with active factor and without it hasn't been significant. Also there haven't been noted dynamics of air ions concentrations during measurements except periods when operator had started to work on computer after 15 minutes break. Exactly for these periods the minimal quantity of measurements with $\Delta\rho/\delta < 1/3$ has comprised from 25 to 30 measurements. It is obvious that task of sufficient minimal quantity measurements determination is appropriate only in the case of concentration dynamics absence; in the case of dynamics continuous measurements should be made and changed to discrete measurements only at relative stability of concentrations. Usually, it is stipulated with the character of factor activity, this activity can be dynamical or relatively static.

The next step has been substantiation of assumption about acceptable minimal quantity of measurements of 48, which provide sufficient level of results reliability. It has been taken into consideration that average value for all samples has been 18 measurements and in 17 samples the sufficient minimal quantity of measurements has been higher than this average value. Deducting data samples with concentration dynamics and taking into consideration the necessity of chosen measurements quantity correspondence to suitable time interval, the value of 24 measurements has been chosen as it has followed the condition $\Delta\rho/\delta < 1/3$ for all samples, except samples with concentration dynamics, and corresponded to the suitable interval of 2 minutes. Besides, in the range of 2 minutes interval it is possible to reveal unplanned influence of external factor, which is not considered in experiment, and reject the results of measurement distorted by this factor.

To check the equivalence of the average concentration values received for 24 measurements to the average concentration values received for 48 measurements the hypothesis about equality of average values has been applied. The Excel statistical procedure "t-Test: Two Sample Assuming Unequal Variances" has been applied for verification. Null-hypothesis about equality of average values of both samples has been confirmed for all samples, except for samples with air ions concentration dynamics. To check proposed assumption about sufficiency of 24 measurements of 48 the data of repetitive experiment (which has been conducted under the same conditions and the same factor with the same quantity of measurements) have been also analyzed. The result of repetitive test has been the same – hypothesis about equality of average values of both samples has been confirmed for all samples, except samples with concentration dynamics.

Conclusions

As a result of conducted study such conclusions have been made:

1. To study small air ions concentrations, which dynamically change under factor or factors

influence, it is necessary to conduct continuous measurements to obtain valid results.

2. To study small air ions concentrations, which are in dynamic balance, with the aim of experiment laboriousness decreasing it is allowed to conduct measurements in the mode "2 minutes of measurements – 2 minutes break" instead of continuous measurements and such mode will characterize ionic composition of air with the same accuracy as continuous measurements.

3. Given approach for determination of optimal quantity of measurements can be applied for air ion counter MAS-01, AlphaLab Air Ion Counter and others.

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