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# International Trends in Science and Technology

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E-mail:
rsglobal.poland@gmail.com

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*ENGINEERING SCIENCES*

# FRACTALITY OF MEASUREMENTS OF QUANTITIES AND REAL PROCESSES

***Nona Otkhozoria,*** *PhD, Georgian Technical University, Georgia, Tbilisi*
***Vano Otkhozoria,*** *PhD, Georgian Technical University, Georgia, Tbilisi*
***Medea Narchemashvili,*** *PhD, Georgian Technical University, Georgia, Tbilisi*

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***Abstract****. In the present work, the measurement of quantities and time processes from the point of view of their fractal properties is considered, which implies the calculation of the dimension proposed by Mandelbrot in two ways: the first is the practical definition of the fractal dimension based on the calculation of the correlation dimension, the second is the empirical determination of the fractal dimension by the method of the normalized Hurst range. Experimental results were obtained using Labview and Mathcad technologies. experimental studies support the persistence in measuring dynamic processes and the ability to predict the behavior of an object in the future. It was revealed that the second method for determining the fractal dimension is obvious and easy to implement. However, for this we have to deal with data describing the dynamics of the process, i.e. with a time series. In the article, using specific examples, the use of fractals in metrology is shown, in particular, in relation to the uncertainty of the measurement result.*

**Introduction.** When it comes to fractals, it should first of all be emphasized that the idea of studying fractals arose due to the impossibility of measuring the length of the coastline of Norway. Measurements were carried out by various tools and methods offered by many scientists [1]. And only the introduction of fractals and fractal dimension made it possible to solve many problems and, in particular, to study the behavior of real-natural processes in terms of the possibility of predicting their behavior in the future [1-3]

Let's start by defining the fractal itself.

One of the definitions of fractal: fractal is a set, parts of which are similar to the whole. The principle of self-similarity is a characteristic determinant of the essence of fractals. The first most famous scientist to study fractals was B. Mandelbrot. In the mid-60s of the twentieth century, he developed fractal geometry, which he called the geometry of nature. He is the "father" of fractals, because he was the first to use them in the analysis of fuzzy, irregular forms. The idea embedded in fractals is in non-target dimensions. We usually use integer dimensions - dimensions. However, non-integral dimensions may exist, for example, 2.58, i.e., between two-dimensional and three-dimensional measurements. Mandelbrot called such measurements - dimensions fractal (fractional, divided into parts) [1, 2].

The logic of the existence of non-target dimensions is very simple. So, in nature there is no perfect ball or cube without scratches and other irregularities. And to describe such objects, there must be other dimensions. To measure such irregular, fractal figures, the concept of fractal measurement was introduced - fractal dimension [1-3].

For example, roll a sheet of paper into a lump. From the standpoint of classical Euclidean geometry, this object will be a three-dimensional ball in a three-dimensional dimension. However, in reality, this is still just a two-dimensional sheet of paper, crumpled in the likeness of a ball. Thus, it can be assumed that the new object will have a dimension of more than two, but less than three, i.e. it will be in the fractal dimension, i.e. it will have a dimension of about 2.5 pm. The physical meaning of this dimension means that in classical space there remains, due to the gaps and holes naturally present in the crumpled sheet of paper, part of the space. In his work [2], he showed that fractal dimension is the inverse of H, where H is Hurst's index. So, if H = 0.5 (Brownian motion) D = 2, (1/0.5), and at H = 0.8, the fractal dimension is 1.25 (1/0.8).

But there is another fractal dimension D, [1] (according to Mandelbrot), which is defined as D = 2-H, and this is an estimate of the degree of fracture of the time series, which will be discussed when assessing the persistence and antipersistency of actually observed data describing a dynamic process (Hearst's empirical law is the normalized scope of R/S) [1].

The purpose of this work is to consider the measurement of quantities and time processes from the point of view of their fractal properties, which involves calculating the dimension proposed by Mandelbrot in two ways: the first-practical definition of fractal dimension based on the calculation of correlation dimension, and then the Hurst index. Second application of Hearst normalized span (R/S) empirical law for direct measurement of H (Hearst index) followed by calculation of fractal dimension. The numerical value of H depends on the presence of a deterministic pattern in the object of measurement, and therefore the possibility of predicting its behavior in the future. The task was also to show, with specific examples, the use of fractals in metrology, in particular with regard to the uncertainty of the measurement result.

**2. Main part**

**2.1. Mathematical interpretation**

How to imagine the dimension of fractals mathematically? Let to fill an arbitrary geometric structure with a Euclidean dimension $D_E$ require N (a) circles for flat figures with a diameter? and spheres for figures in space (in a three-dimensional dimension). When dimensioned (ε→0) the sum of the circles tends to the volume occupied by the geometric object. In this case, the fractal dimension ($D_F$) is defined as

$$D_F = \lim_{\varepsilon \to 0} \frac{lnN(\varepsilon)}{\ln(1/\varepsilon)} \quad (1)$$

Follows from expression (1) that for a set of the points forming the smooth line, Euclidean $D_E = D_F = 1$. At the same time the structure of a geometrical object will be fractal if $D_E \neq D_F$. Clearly, $D_E$ always takes only integer values. Therefore, fractal dimension is non-numeric and characterizes objects with a complex structure.

In practical fractal dimensionality calculations, the correlation dimensionity $D_C$ is used, which is determined by the expression:

$$D_C = \lim_{\varepsilon \to 0} \frac{lnC(\varepsilon)}{\ln(\varepsilon)} \quad (2)$$

where $(\varepsilon)$ is a correlation function calculated as:

$$\mathrm{C}(\varepsilon) = \lim_{N \to 0} \frac{n}{N^2} \quad (3)$$

It follows from the expression (3) that the value of $(\varepsilon)$ is calculated as the ratio of the number of points n, the pairwise distances between which are less than sound, to the square of the total number of points N. Accordingly, in order to determine the correlation dimension $D_C$ first of all, it is necessary to calculate the number of points, the pairwise Euclidean distances (d) between which are less than the given distance?

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (4)$$

where $x_1, y_1 -$ are the coordinates of point 1, and $x_2, y_2 -$ are the coordinates of point d≤ ε.

Note that all the calculations of the fractal dimension of research objects presented below are implemented by Mathcad and LabVIEW technologies, and are a powerful mathematical tool for fractal research. In the present article it will be a question of application of fractals in the sphere of measurements (metrology) and, in particular, the modern concept of measurement uncertainty (types) and also at measurement and the analysis of temporary dynamic processes. (Heisenberg and Brillouin uncertainty principle) [5].

The relationship of the fractal to the uncertainty of measurements is easy to see. No matter how accurately we measure, we cannot approach the true value, and the reason is: firstly, due to the error of the standard itself, secondly, due to the influence of the measurement conditions, thirdly, due to the change in the measurement object itself (the principle of indeterminacy of Heisenberg and Brillouin).

It is impossible to talk about the size measured by the caliper, that it is equal to 24.5 ± 0.05 mm. Metrologically, it is more correct to represent this size in the form of an area from 24.50 to 24.60 mm. If the same size is measured with a micrometer, then the boundaries of the result will be from 24.554 μm to 24.558 μm. The uncertainty region decreases (0.004).

Let's say that we measure the same parameter by the verified measuring means: first by the working measuring means, then by the working standard, then by the standard of the 2nd digit, then by the standard of the 1st digit and, finally, by the main standard.

In this case, this process is similar to the fractal formation process. With each step, we get a decreasing measurement uncertainty, that is, the blur of the measurement result decreases. In work [4], the question of uncertainty is considered when assessing the quality of measurements. It should be noted that the fractal approach can be effective in applying uncertainty type B [5].

In the LabVIEW software, for example, [6] provides an example of measuring weights.

Our purpose is to define the fractal dimension offered by Mandelbrot, two ways of her definition - $D_F$.

In the first case, the dimension is calculated directly, and Hurst H is described by H = $1/D_F$, and in the second case $D_F$=2-H when H is determined experimentally. In both cases, the numerical value of H is necessary to judge the persistence and antipersistence of the process [1-3].

**2.2 Determination of fractal dimension by method 1**

When directly calculating the fractal dimension (method 1), the work consisted at the first stage in modeling a random variable distributed according to a uniform law, and at the second stage in processing real data obtained to determine the amount of gold (quartzite) in the ore. These works were carried out by Company in an open career way. The first figure shows the ore quarry, and the second figure 2, for example, a table containing the presence of quartzite (gold) in ore and without gold (K) in ore. According to the data obtained in a certain time, fractal processing was carried out (the first method of determining fractal dimension).

*Fig.1. Ore quarry*

| r i c xvi | o qr o |
|---|---|
| 1 | - |
| 2 | - |
| 3 | - |
| 4 | - |
| 5 | - |
| 6 | - |
| 7 | 3 034 |
| 8 | 8 139 |
| 9 | 15 840 |
| 10 | 15 840 |
| 11 | 15 840 |
| 12 | 15 840 |

| r i c x vi | gad axs na |
|---|---|
| 1 | 3 736 |
| 2 | 14 216 |
| 3 | 18 357 |
| 4 | 28 807 |
| 5 | 39 422 |
| 6 | 51 907 |
| 7 | 62 797 |
| 8 | 78 941 |
| 9 | 78 941 |
| 10 | 89 391 |
| 11 | 89 391 |
| 12 | 96 211 |

*Fig.2. availability of gold in ore and without gold*

As mentioned above, the proposed method was modeled in the LabView. fig.3-a shows the topology that is formed by an 800-point combination.

The coordinates of the points are formulated by random, evenly distributed numbers, and in image 3-b, corresponding to this topology, the distribution of the correlation dimension D (ε) depending on the distance ε. Abscissa axis is built on a logarithmic scale. Calculations are given at the initial value of ε0=0.1, step spacing Δε=0.1 the number of steps was 7.

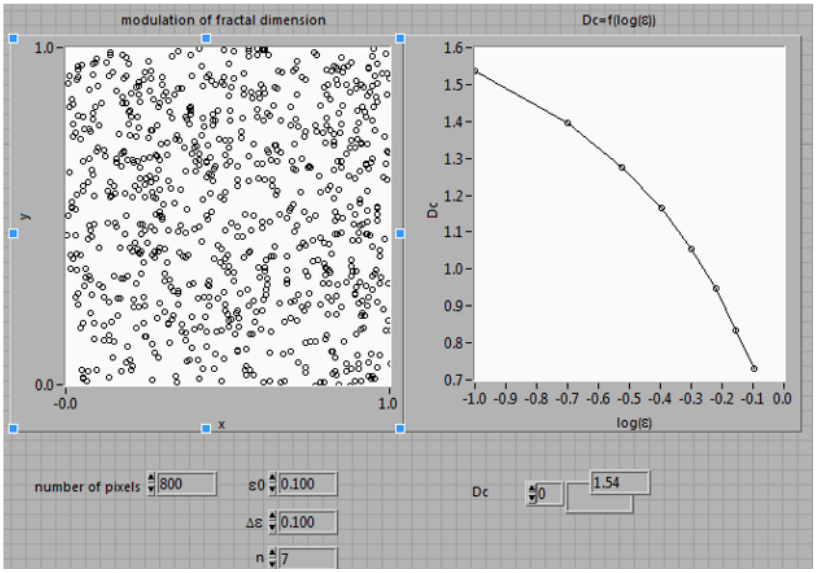


*Fig.3. a topology formed by the coincidence of evenly distributed points and the distribution of the correlation dimension Dc (ε) depending on the distance ε*

The experiment showed that:

1. Fractal dimension is less than Euclidean
2. As ε (ε→1) increases, the fractal dimension of the collection of points decreases Dε→0. With increasing resolution, i.e. ε → 0 the dimension tends to Euclidean $D_F$→Dε → $D_E$

As a result of processing the actually presented data, the dimension turned out to be equal to $D_F$=1,53, therefore H=1/1,53≈0,6, which indicates the persistence of the measurement results, i.e., the possibility of predicting: in this case, an increased amount of quartzite (gold) in the ore, if much more ore is subjected to treatment over a longer observation time.

**2.3 Determination of fractal dimension using the Hurst normalized rane method**

Now let's turn to the definition of fractal dimension using the Hurst normalized method (the second method of determining Mandelbrot dimension).

Algorithm of H indicator estimation consists in the following:

Empty (t) describes a random process to be evaluated by Hurst's score.

1. We will designate through

$$\langle\xi\rangle_\tau = \frac{1}{\tau}\sum_t^\tau \xi(\mathrm{t}) \tag{5}$$

$\langle\xi\rangle_\tau$ −_τ- average value.

2. We will designate through

$$X(t,\tau) = \sum_{u=1}^{t}\{\xi(\mathrm{u}) - \langle\xi\rangle_\tau\}\mathrm{X} \tag{6}$$

X(t,τ)- is the accumulated deviation from the average to the moment t.

3. The difference between the maximum and minimum accumulated deviation is called the span - R.

$$R(\tau) = max_{1<t<\tau}X(t,\tau) - min_{1<t<\tau}X(t,\tau) \tag{7}$$

In this formula, t is a discrete time taking an integer value, and $\tau$ is the duration of the time period under consideration.

4. The normalized span is defined as:

$$\frac{R}{S} \tag{8}$$

Where S is the standard deviation estimated by:

$$S = \left(\frac{1}{\tau}\sum_{t=1}^{\tau}(\xi(t) - \langle\xi\rangle_\tau)^2\right)^{1/2} \tag{9}$$

As Hurst discovered, the normalized span is very well described by the empirical ratio:

$$\frac{R}{S} = \left(\frac{\tau}{2}\right)^{\mathrm{H}} \tag{10}$$

from here:

$$H = \frac{logR/S}{log\tau/2} \tag{11}$$

We conducted many experiments in this regard, which dealt with the change in the frequency of cardiorhythm and the part of seismography. Hurst score for cardiogram is 0.795, for seismography 0.749. Hurst algorithm representation graphs obtained for temperature change data are presented below.

The Hurts score makes it possible to associate fractals with the generalized Brownian movement [3] and thereby determine the presence in the process of persistence and anti-persistence, that is, predictability (deterministic) and its absence (anti-persistence), when it is impossible to predict the behavior of the process in the future (a completely random process).

So, when H < = 1/2, the correlation of past and future values is absent - the process is anti-persistent when H > 1/2 maintains the current trend. The process becomes predictable - which is very important.

We have determined the H score for the processes showing the change in cardiorhythm frequency and seismogram segment. H = 0.795 for cardiorhythm frequency and for seismogram segment H = 0.749. There are presented graphs showing the implementation of the Hurst normalized span method for the temperature change process.

$V := READPRN("D:\Vector.dan")$

$\tau := 366$

$mean(V) = 20.806$

$Stdev(V) = 8.072$ $t := 0..\tau$

$$X(t,\tau) := \sum_{u=0}^{t} \left(V_u - mean(V)\right)$$

$rows(V) = 366$

$length(V) = 366$ $t := 0..rows(V) - 1$

$mean(V) = 20.806$ $\tau := rows(V)$ $i1 := 1..\tau - 1$

i

$X_{i1} := X(i1,\tau)$

$max(X) = 443.645$

$min(X) = -730.571$

$S := stdev(V)$

$$R := \frac{max(X) - min(X)}{S}$$

$R = 145.664$ $$H := \frac{\log(R)}{\log(\tau)}$$ $H = 0.712$

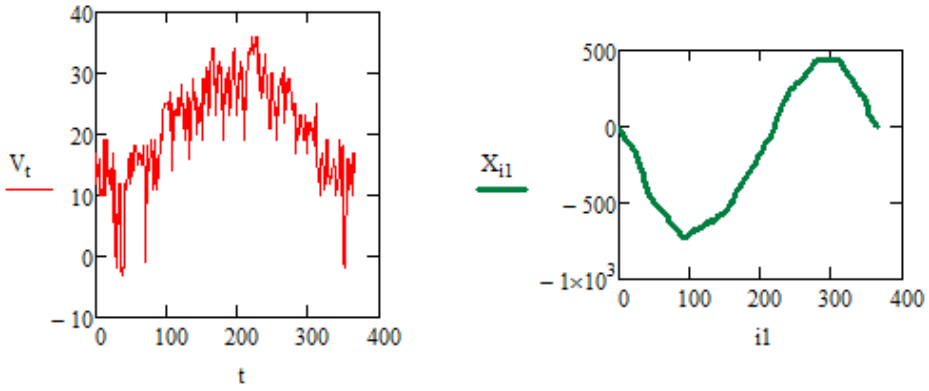


*Fig.4. a) dependence of temperature on time; b) the accumulated deviation from the mean until the moment t*

**5. Conclusions.**

As a result of the studies carried out, it can be concluded:

As a result of processing the actually presented ore data, the dimension was equal to $D_F$=1,53, therefore H=1/1,53≈0,6, which indicates the persistence of the measurement results, i.e., the possibility of predicting the behavior of the measurement object in the future (in this case, an increase in the amount of quartzite in the ore), if much more ore is subjected to treatment over a longer observation time.

The distribution of the correlation dimension Dc in relation to ε showed that with the increase of ε, the fractal dimension ($D_c \rightarrow 0$) of the collection of points decreases. In the process of decrease ($\varepsilon \rightarrow 0$), the dimension of the set of points increases, tending to the value DE.

According to the second method, we have determined the H index for processes showing the change in cardiorhythm frequency and seismogram segment. H = 0.795 for cardiorhythm frequency and for seismogram segment H = 0.712. Graphs are presented showing the implementation of the Hurst

normalized span method for the temperature change process. H = 0.81 The dimension is calculated by the expression: $D_F = 2-H$. This proves persistence in the measurement of dynamic processes.

A comparison of the above described methods has shown that the second method of determining fractal dimension is simpler, more obvious and relatively simple to implement. However, to do this, we must deal with data describing the dynamics of the process, that is, with a time series.

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# DETERMINATION OF THE ASSIGNED VALUE BY THE PARAMETER OF THE TEST CONTROL SAMPLE USING A COORDINATE MEASURING MACHINE

***Abelashvili Nodari,*** *Professor at the Georgian Technical University, Tbilisi, Georgia, ORCID ID: 0000-0003-4002-9177*
***Didenko Ekaterina,*** *Master at the Georgian Technical University, Process Engineer at Atlantic Georgia LLC, Tbilisi, Georgia*

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***Abstract.*** *In this paper will be discussed the theoretical and practical issues of preparing a control sample for geometric parameters of qualification testing using bridge type coordinate measuring machine (CMM) GLOBAL S GREEN 091208.*
*The use of a control sample prepared in this way ensures the high accuracy of the control parameters of the test item, usually manufactured on the cutting machine (CNC), and the high quality of the determination of measuring instruments, measurement methods and personnel competence.*
*Theoretical and practical studies have substantiated the possibility of using such a control sample in a machine-building, car-building, aircraft-building and other similar factories.*
***Keywords:*** *qualification testing, inter-laboratory comparison, control sample, Certified value, Assigned value.*

1. **Introduction.** Determining the competence of testing and calibration laboratories is the main purpose of the interlaboratory qualification comparison, the objectivity of which depends significantly on the preparation of a control sample. The accuracy of the production of control sample is not so important as the accuracy of determining the existing linear dimensions of the control geometric parameters, known as the Assigned Value.

2. **Purpose and Methods of Research.** The process of preparing a control sample for an interlaboratory comparison begins with the creation of a test item and control sample. It is necessary to consider requirements that the control sample should meet. Depending on the model, type, industry and other factors, the test requirements should be adapted to the specific test conditions, taking into account the relevant metrological requirements. The basic requirements that should be met in the control geometry of the inter-laboratory qualification comparison of geometric parameters, include:

- Requirements for control sample surfaces, curvatures, spherical, conical, curved and convex, circular, rectangular, oblong and bevel surfaces;
- Requirements for physical, mechanical, magnetic, chemical and corrosion resistance properties of the control material;
- Requirements for the possibility of making the sample without certain difficulties using standard metal-cutting machine tools;
- Requirements for the universality of the control sample, which means that one control sample should combine the maximum number of control points or surfaces listed above;
- The design and construction requirements should ensure the ergonomics of the control sample, and its dimensions should meet the limits of the measurement area of a particular measuring machine in the direction of the X, Y, Z axes;
- No special measurement requirements are needed for the accuracy of production of the control sample (surfaces, grooves, etc.), as the aim of the inter-laboratory comparison is to trace the real size with maximum accuracy and reliability;
- It is important that the control sample maintained the stability of geometric parameters, both in operation and transportation, as well as in the influence of environmental factors, such as temperature, humidity, dust, grease, mechanical damage, vibration, impact and other factors;

Given the above, a control sample of complex geometric shape was prepared (Fig. 1), aluminum was selected as the material based on physical, chemical, mechanical properties and requirements of the qualification testing.

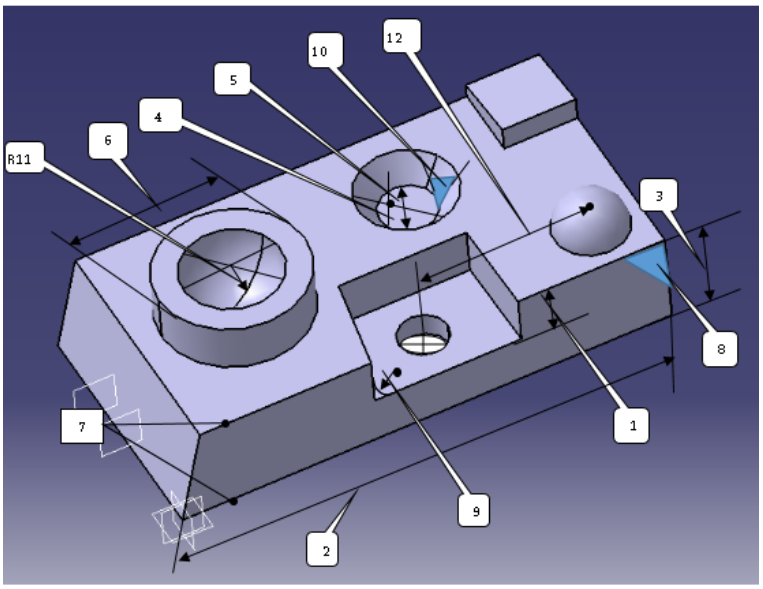


*Fig. 1. The control sample for qualification testing of geometric parameters*

In the table below are shown possible test parameters of the control sample which can become objects of measurement during the approbation and qualification testing (Table 1).

Table 1. Control sample study zones

| **Position on the drawing** | **Test parameter** |
|---|---|
| 1, 2, 3 | Linear dimensions |
| 4 | Depth |
| 5 | Inner diameter |
| 6 | Outer diameter |
| 7 | Parallelity of curves and planes |
| 8 | Perpendicularity of ridges and planes |
| 9 | Radius |
| 10 | Angle |
| 11 | The inner radius of the sphere |
| 12 | Distance between centers |

After production of the control sample, GLOBAL S GREEN 091208 bridge type coordinate measuring machine (CMM) approves measurements of the control points, and determines Assigned Values of the control parameters. To ensure this, we use the requirements of ISO 13528-2015 standard (Section 7.5) according to which: "An assigned value can be determined by a single laboratory using a reference method, such as, for example, a primary method. The reference method used should be completely described and understood, and with a complete uncertainty statement and documented metrological traceability that is appropriate for the proficiency testing scheme. The reference method should be commutable for all measurement methods used by participants." [1]. It (Section 7.5.2.) also states that "assigned value of the proficiency test item can be derived by a single laboratory using a suitable measurement method, from a calibration against the reference values of a closely matched certified reference material."

This approach assumes that data of certified (CRM) value is compatible with all measurement methods used by participating laboratories, requiring a series of measurements to be performed on a control sample using the same method of measurement under reproducibility.

In this case, to calculate the Assigned Value of the qualification testing, we can apply the following formula

$$x_{pt} = x_{CRM} + \bar{d} \quad (1)$$

where: $x_{CRM}$ - is the assigned value for the CRM;

$x_{pt}$ - is the assigned value for the proficiency test item;

$d_i$ - is the difference between the average results for the proficiency test item and the CRM on the $i^{th}$ samples;

$\bar{d}$ - is the average of the differences $d_i$.

The control sample with non-precision geometrical dimensions was made with respect to above mentioned requirements. Sample was manufactured from aviation grade aluminum on the CNC machine (Fig. 2).

For the approbation of the control sample measurements was chosen the distance between the Lowest Point-1 of a concave cylinder and the Highest Point-2 of the convex sphere. Here we have the values of the DIST_LOW-HIGH coordinates.

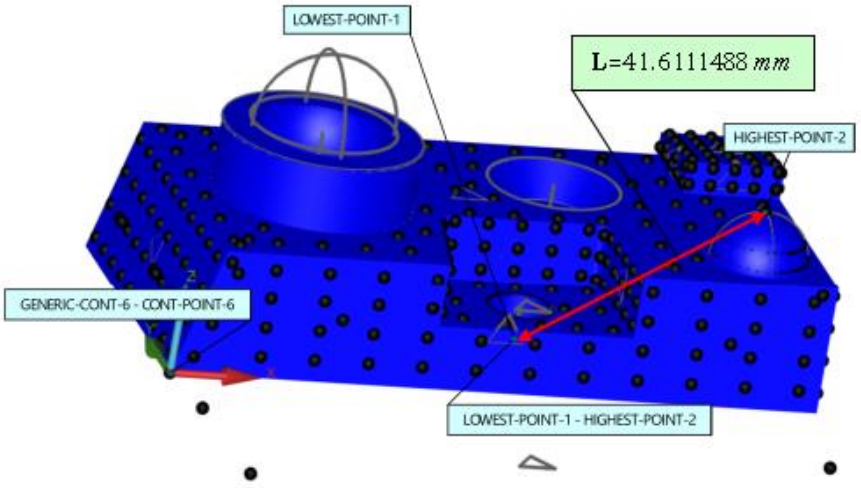


*Fig. 2. Control sample to be measured at points 1, 2 and 6*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ⟷ | MM | DIST_CONT_GEN TO 6 - GENERIC-CONT-6 TO CONT-POINT-6 | | | | | |
| AX | NOMINAL | +TOL | -TOL | MEAS | DEV | OUTTOL | |
| M | 100.000000 | 0.100000 | 0.100000 | 100.083732 | 0.083732 | 0.000000 | |
| ⟷ | MM | DIST_LOW-HIGH - LOWEST-POINT-1 TO HIGHEST-POINT-2 | | | | | |
| AX | NOMINAL | +TOL | -TOL | MEAS | DEV | OUTTOL | |
| M | 41.606670 | 0.100000 | 0.100000 | 41.611489 | 0.004819 | 0.000000 | |
| ⊕ | MM | LOC7 - LOWEST-POINT-1 | | | | | |
| AX | NOMINAL | +TOL | -TOL | MEAS | DEV | OUTTOL | |
| X | 55.000000 | 0.100000 | 0.100000 | 55.000432 | 0.000432 | 0.000000 | |
| Y | 10.000000 | 0.100000 | 0.100000 | 9.999665 | -0.000335 | 0.000000 | |
| Z | 5.000000 | 0.100000 | 0.100000 | 4.991922 | -0.008078 | 0.000000 | |
| T | 0.000000 | 0.100000 | 0.100000 | -0.008078 | -0.008078 | 0.000000 | |
| ⊕ | MM | LOC8 - HIGHEST-POINT-2 | | | | | |
| AX | NOMINAL | +TOL | -TOL | MEAS | DEV | OUTTOL | |
| X | 90.000000 | 0.100000 | 0.100000 | 90.001218 | 0.001218 | 0.000000 | |
| Y | 10.000000 | 0.100000 | 0.100000 | 9.998775 | -0.001225 | 0.000000 | |
| Z | 27.497000 | 0.100000 | 0.100000 | 27.496609 | -0.000391 | 0.000000 | |
| T | 0.000000 | 0.100000 | 0.100000 | -0.000415 | -0.000415 | 0.000000 | |

*Fig. 3. Measuring machine test protocol*

The result of the approbation performed on the control sample for inter-laboratory comparison of geometric parameters by CMM machine is shown in Fig 3.

**3. Research results**

In the report we see the nominal values of the X, Y, Z coordinates of the indicated points and for each of them a tolerance value of ±0,1 mm is indicated. (Fig 3.)

The spatial coordinates of point 1 and point 2 are also defined, limits of the tolerance interval are indicated for each, and spatial coordinates are given which indicate the deviation values. The report also indicates the measured distance between points 1 and 2 which is 41,611489 mm.

Based on the coordinate data of the CMM machine, it is possible to calculate the result algebraically.

For these points (1,2), according to the coordinates, we can calculate the distance between them using well-known formula

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} =$$
$$\sqrt{(90{,}001218 - 55{,}000432)^2 + (9{,}998775 - 9{,}999665)^2 + (27{,}496609 - 4{,}991922)^2} =$$
$$\sqrt{1225{,}055 + 0{,}0000007921 + 506{,}460936} = \sqrt{1731{,}515934} = \mathbf{41{,}611488}(\boldsymbol{mm})$$

Algebraically calculated distance value with a precision of 1 μm was actually matched with the value measured by the coordinate measuring machine, indicating the full adequacy of the theoretical and practical results.

In the same way, we can calculate the deviation values defined in the report, which literally represent the Type A uncertainty.

$$dev_{1-2} = \sqrt{(dev_{x1} + dev_{x2})^2 + \left(dev_{y1} + dev_{y\,2}\right)^2 + (dev_{z1} + dev_{z2})^2}$$
$$= \sqrt{0.0000027 + 0.000021 + 0.000072} = 0.00978 \approx 0.001mm$$

In such case in the formula (1) given for the calculation of the Assigned Value to the qualification testing, (1) $x_{CRM}$ - represents $d$ lengths of the search section and $\bar{d}$ - deviation with respect to each axis. Therefore formula (1) will be

$$x_{pt} = d + dev_{1-2} \quad (1)$$

Based on the above mentioned formula distance between the Lowest Point and the Highest Point will be:

$$x_{pt} = \boldsymbol{L = 41{,}611488 \pm 0.001[mm]}$$

which is the Assigned Value of the given parameter of control sample.

4. **Conclusions.** Based on the theoretical analysis and practical research, it was determined that the high-precision bridge type coordinate measuring machine can be used for qualification testing of geometric parameters, to determine the control parameters of the control sample with high accuracy and Assign Values to these parameters.

The requirements of ISO 13528-2015 standard have been met to determine the value given to a specific bridge type coordinate measuring machine (type GLOBAL S GREEN 091208**,** serial number GLCS001303IA), which has undergone the calibration procedure (Calibration Certificate No: SC20002771) with components according to the ISO 10360-2 (2001) methodology, meets the metrological traceability requirements according to which "The calibration equipment calibrated by accredited laboratories and are traceable to the national and international reference standards".

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# КОРИГУВАННЯ СПЕКТРІВ ВИПРОМІНЕННЯ СВІТЛОДІОДНИХ ОСВІТЛЮВАЛЬНИХ УСТАНОВОК ДЛЯ ПІДВИЩЕННЯ ЇХ ФОТОБІОЛОГІЧНОЇ БЕЗПЕЧНОСТІ

***О. С. Пітяков,*** *Аспірант Харківського національного університету міського господарства ім. О.М. Бекетова, директор відокремленого структурного підрозділу: «Полтавський політехнічний фаховий коледж Національного технічного університету «Харківський політехнічний інститут», м. Полтава, Україна,*
*ORCID ID: http://orcid.org/0000-0001-9306-4246*
***П. І. Неєжмаков,*** *Доктор технічних наук, професор, генеральний директор Національного наукового центру «Інститут метрології», м. Харків, Україна,*
*ORCID ID: http://orcid.org/0000-0002-5727-6089*
***С. В. Шпак,*** *Кандидат технічних наук, науковий співробітник Державного підприємства «Полтавський регіональний науково-технічний центр стандартизації, метрології та сертифікації», м. Полтава, Україна, ORCID ID: http://orcid.org/0000-0002-1417-3944*
***С. Г. Кислиця,*** *Кандидат технічних наук, доцент Національного університету «Полтавська політехніка імені Юрія Кондратюка», м. Полтава, Україна,*
*ORCID ID: https://orcid.org/0000-0002-2431-9900*
***Г. М. Кожушко,*** *Доктор технічних наук, професор Національного університету «Полтавська політехніка імені Юрія Кондратюка», м. Полтава, Україна,*
*ORCID ID: http://orcid.org/0000-0002-7306-4529*

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***Abstract.*** *The paper considers the issues of increasing the photobiological safety of LED lamps by adjusting the spectrum, which allows to fulfill the conditions of "melanopsin cross", the essence of which is that the radiation intensity at a wavelength of 480 nm should always be greater than the intensity at 460 nm and 450 nm. These conditions are met for a black body, but are not met at any correlated temperature (CCT) for LEDs emitting bands of blue and yellow-green light. In LEDs, one of the maxima of radiation is about 450 nm and coincides with the maximum of the weight function of the dangerous action of blue light, and the minimum - at 480 nm - the region of the spectrum that most effectively generates a signal to narrow the pupil. From the point of view of increasing photobiological safety, the maximum at 450 nm must be reduced, and the "failure" at 480 nm (for effective pupil narrowing) must be filled to a level exceeding the level at 450 nm. In order to achieve the "melanopsin cross" methods were proposed to adjust the spectral composition of the light environment, forming LED lighting installations, by additional use of light sources with a radiation spectrum that complements the spectrum of LED lamps in the region of 480 nm, and limiting the radiation intensity of 450 lamps nm by using selectively absorbing and permeable materials.*
***Keywords:*** *LED lamp, photobiological danger, blue light, radiation spectrum, "melanopsin cross".*

**Вступ.** Фотобіологічному впливу світла на здоров’я людей присвячена велика кількість сучасних досліджень [1-6]. CIE в [7] надано роз’яснення стосовно терміну «небезпека синього світла». Він має застосовуватись тільки при розгляді фотохімічного ризику пошкодження сітківки ока (фотомакулопатії), зазвичай пов’язаної з фіксацією погляду на яскраві джерела світла. Ризик фотохімічного пошкодження сітківки ока синім світлом залежить від довжини хвилі (з максимумом близько 435 – 440 нм). Міжнародна комісія з захисту від неіонізуючого випромінення (ICNIRP) опублікувала функцію вагомості небезпеки синього світла [8], яка тепер стандартизована в міжнародному стандарті IEC 62471 «Фотобіологічна безпека ламп і лампових систем» [9].

Теорія ризиків негативного впливу світла і методологія розрахунку фотобіологічної безпеки була розроблена на базі основоположних статей [1, 10]. З точки зору визначення надлишкової дози синього світла представляє зацікавленість робота [11]. В цьому

європейському звіті «Оптична безпека світлодіодного освітлення» у відповідності з вимогами міжнародного стандарту IEC 62471проведено порівняння спектрів сонячного світла зі світлом штучних джерел світла (з метою визначення надлишкової долі синього світла в спектрі світлодіодів). На рис. 1 представлено спектр світлодіодів в яких кристал, що випромінює синє світло, покритий жовтим люмінофором для отримання білого світла. На цьому ж рисунку наведено спектр випромінення чорного тіла і лампи розжарювання, а також показані точки, на які необхідно звертати увагу при аналізі спектру будь-якого джерела. В інтервалі колірних температур від 4000 К до 6500 К виконуються умови «меланопсинового хреста» при яких на енергетичному спектрі світла амплітуда для 480 нм повинна бути завжди вищою за амплітуду в інтервалі довжин хвиль 450-460 нм.

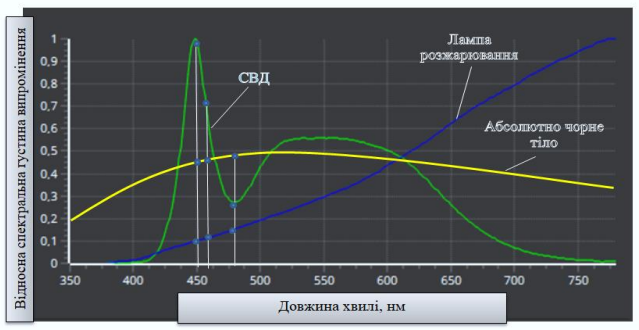


*Рис. 1. Відносний розподіл спектральної густини для чорного тіла, лампи розжарювання та світлодіода*

Порівнюючи спектр сонячного світла і світлодіодів наводяться наступні дані: світлодіодна лампа (ССТ=4200 К) має відносну амплітуду на 450 нм вищу, ніж у сонячного світла з ССТ 6500 К; в спектрі світлодіодної лампи з ССТ 4200 К провал на довжині хвилі 480 нм на порядок більше, ніж в спектрі сонячного світла з ССТ 6500 К; в спектрі світлодіодної лампи з ССТ 4200 К провал на 480 нм в рази більший, ніж в спектрі лампи розжарювання з ССТ 2700 К.

З цього слідує, що доза синього світла (довжина хвилі 450 нм) в спектрі світлодіодної лампи (світильника) з ССТ 4200 К при однаковому рівні освітленості буде значно перевищувати (на 40 %) дозу синього світла в спектрі сонця. Ця різниця і є надлишковою дозою (при однакових ССТ та рівнях освітленості). Але слід також враховувати, що доза буде збільшена за рахунок неадекватного управління розмірами зіниць, які залежать від амплітуди на довжині хвилі 480 нм.

В [12] зроблені висновки про те, що світло з довжиною хвилі 450-460 нм спричиняє окислювальний стрес сітківки а світло з 460 нм і 480 нм – через меланопсин гангліозних клітин управляє, відповідно, гормональною системою та діаметрам зіниці. При світлодіодному освітленні білими світлодіодами (синє світло кристала і жовте світло люмінофора), які мають провал в спектрі на 480 нм, відбувається неадекватне регулювання розміру зіниці. Адекватне регулювання діаметра зіниці відбувається при умові $I_{450\ нм} \leq I_{480\ нм}$, де $I_{450\ нм}$ – амплітуда яскравості при 450 нм; $I_{480\ нм}$ – амплітуда яскравості при 480 нм. Таке співвідношення яскравостей у сонячного світла і ламп розжарювання. Рівень фотохімічного ризику для очей від синього світла залежить від накопиченої дози, яка створюється як при високій яскравості протягом короткочасної експозиції, так і в результаті низько інтенсивного впливу протягом тривалого часу. При цьому особливому ризику піддаються такі групи, як діти, літні люди та працівники, діяльність яких проходить в умовах високого рівня освітленості джерелами світла з високою корельовано колірною температурою, тому дослідження факторів, що впливають на фотобіологічну безпечність світлодіодних ламп та світильників є актуальною задачею.

Підвищення фотобіологічної безпечності синього світла можна досягти шляхом зменшення енергетичної яскравості в синій області спектра та зміною спектрального складу випромінення в цій області. Зниження яскравості є фактором, що впливає переважно на фотобіологічну безпечність при прямому спогляданні на яскраве джерело протягом обмеженого часу і вирішується шляхом застосування різних розсіювачів світла. Зміна спектрального складу впливає на безпечність як при прямому спогляданні на яскраве світло,

так і при обмеженні доз опромінення від розсіюваного світла протягом тривалого часу. Суттєвих змін спектрального складу випромінювання сучасних світлодіодів, що масово використовуються при виробництві світлодіодних ламп та світильників, які б задовольняли вимогам «меланопсинового хреста» досягти неможливо без застосування кристалів і люмінофорів з іншими параметрами випромінення в областях спектру 450 нм, 460 нм та 480 нм. Такі розробки ведуться в [13], але на сьогодні вони ще не мають комерційного застосування. В таблиці 1 та на рис. 2 наведені дані фотометричних та спектральних вимірювань дослідного зразка лампи Soraa PAR38 [13].

Таблиця 1. Результати експериментальних вимірювань лампи Soraa PAR38

| Фотометричні, колориметричні та електричні параметри | Дані вимірювань |
|---|---|
| - світловий потік, лм | 1044 |
| - світлова віддача, лм/Вт | 58 |
| - корельована колірна температура (CCT), К | 3015 |
| - загальний індекс кольоропередачі, $R_a$, відн. одиниць | 95 – 96 |
| - потужність, Вт | 18 |

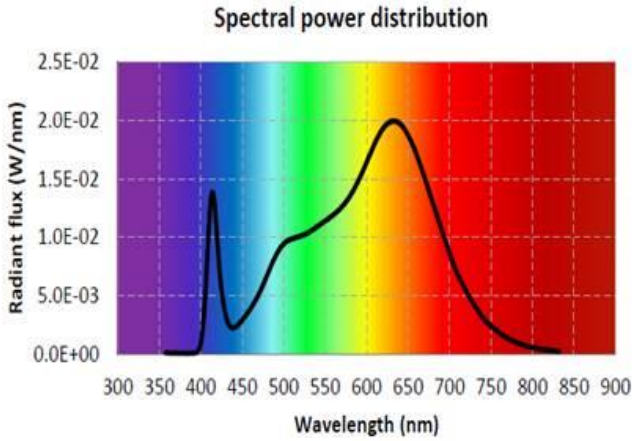


*Рис. 2. Спектр випромінювання лампи Soraa PAR38 [13]*

Аналізуючи ці дані слід відзначити, що світлова віддача дослідного зразка лампи, в порівнянні з лампами, в яких використовуються світлодіоди з синьо-жовтим світлом, значно нижча, досить низька також і CCT. Основні переваги лампи: високий загальний індекс кольоропередачі і відповідність спектру вимогам «меланопсинового хреста».

Для зміни спектрального складу розсіюваного світла, який впливає при тривалій експозиції на надлишкову дозу синього світла, то тут, крім вище згаданого, існує кілька варіантів: одночасне застосування джерел світла з різним спектральним складом для покращення співвідношення між спектральною густиною при 480 нм та 450 нм (наприклад, для загального освітлення застосовувати світлодіодні світильники з CCT 3000 К – 4000 К, а для місцевого – світильники з галогенними лампами розжарювання з CCT 2900 К); застосовувати в лампах та світильниках селективні фільтри, які обмежують яскравість випромінення в області 450 нм; використовувати у світлодіодних світильниках внутрішнє відбиваюче покриття з коефіцієнтом відбиття в області спектру 450 нм меншим, ніж в області 480 нм; використовувати для фарбування стелі та стін приміщень матеріали, у яких коефіцієнт відбиття в області спектру з максимумом при 450 нм є меншим, ніж в області 480 нм.

**Метою даної роботи** є дослідження цих методів коригування спектрів випромінення світлодіодних світильників для забезпечення умов «меланопсинового хреста» і зменшення утворення надлишкової дози синього світла. Суть умов «меланопсинового хреста» полягає в тому, що рівень випромінення при довжині хвилі 480 нм має бути завжди більшим за рівень при довжині хвилі 450 нм.

В роботі наведені результати дослідження впливу розсіювачів на яскравість світла та корегування спектру в області 450 нм – 480 нм за рахунок одночасного використання ламп та

світильників з різним спектральним складом, селективно пропускаючих та відбиваючих світломатеріалів.

**Методи та результати дослідження.** Спектри випромінення світильників вимірювали з використанням спектрорадіометра МК350S. На основі виміряних значень спектральної густини випромінення з використанням програмного забезпечення МК350S розраховувались фотометричні (освітленість) та колориметричні (ССТ) параметри. Невизначеності вимірювань були в межах бюджету невизначеностей, рекомендованого європейським стандартом [14]. Для ССТ калібрована стандартна невизначеність становила 30 К, а загальна розширена невизначеність (к=2) – 60 К. Спектри пропускання фільтрів та відбиття непрозорих матеріалів вимірювали з використанням спектрофотометру λ950.

Сучасні світлодіодні лампи і світильники, в яких використовуються світлодіоди з кристалами, що випромінюють синє світло (частина якого для отримання білого світла поглинається люмінофором, що випромінює жовте світло) мають максимум випромінення в області 450 нм і мінімум в області 480 нм. Максимум при 450 нм співпадає з максимумом небезпечності дії синього світла, а при довжині хвилі 480 нм найбільш ефективно формується сигнал для звуження зіниці ока. Між цими областями, при λ=460 нм, синє світло максимально поглинається жовтою плямою сітківки, яка захищає її від його негативної дії. На рисунку 1 наведено спектр випромінювання світлодіода і вказані точки, на які необхідно звернути увагу для підвищення фотобіологічної безпечності синього світла. Для порівняння на рисунку наведені спектри випромінення чорного тіла при ССТ=6000 К та лампи розжарювання. З точки зору підвищення фотобіологічної безпечності синього світла максимум при 450 нм необхідно зменшувати, а «провал» в області 480 нм, для ефективного звуження зіниці, потрібно заповнити. Для спектрального складу випромінення джерела світла загального освітлення мають виконуватись умови «меланопсинового хреста», суть яких полягає в тому, що спектральна густина випромінення при λ=480 нм має бути завжди більшою за густину при 460 нм та 450 нм: $I_{480\text{ нм}} \geq I_{460\text{ нм}} \geq I_{450\text{ нм}}$, де $I_{480\text{ нм}}$, $I_{460\text{ нм}}$, $I_{450\text{ нм}}$ – відносні амплітуди на графіку спектрального розподілу при 480 нм, 460 нм та 450 нм.

Як видно з рис. 1 умови «меланопсинового хреста» виконуються для чорного тіла і для ламп розжарювання. В світлодіодних джерелах світла в спектральному діапазоні з максимумом при 450 нм є відносний надлишок синього світла в порівнянні з сонячним та лампами розжарювання. Ця різниця і складає надлишкову дозу синього світла відносно сонячного (при однакових рівнях освітленості та ССТ). Доза доповнюється також за рахунок більшого розміру зіниці, що має місце при освітленні світлодіодними джерелами з «провалом» в області спектру 480 нм. Саме сумарна надлишкова доза синього світла і призводить до прискорення деградаційних процесів, які збільшують ризик погіршення зору в порівнянні з сонячним світлом (при однакових рівнях освітленості, ССТ і ефективного захисту сітківки жовтою плямою).

Один із шляхів забезпечення умов «меланопсинового хреста» є використання в освітлювальних установках, крім світлодіодних світильників та ламп, лампи та світильники в яких ці умови виконуються, наприклад галогенних ламп розжарювання (ГЛР). В таблиці 2 та на рис. 3 наведені результати вимірювання світлотехнічних та спектральних характеристик освітлювальних установок зі світлодіодними світильниками для загального освітлення та світильниками з ГЛР для місцевого освітлення. ССТ світлодіодних світильників не перевищувала 3500 К.

Таблиця 2. Результати вимірювання параметрів освітлювальних установок з світлодіодними світильниками та світильниками з ГЛР

| Тип світильників | Загальна освітл., лк | Освітл., що створює світильник з ГЛР, лк | ССТ, К | $R_a$ | $I_{450\text{ нм}}$, відн. одиниць | $I_{460\text{ нм}}$, відн. одиниць | $I_{480\text{ нм}}$, відн. одиниць |
|---|---|---|---|---|---|---|---|
| Загальне освітлення | 292 | - | 2948 | 81,8 | 3,89 | 3,55 | 2,17 |
| Місцеве освітлення | - | 248 | 2909 | 98,7 | 1,35 | 1,58 | 3,03 |
| Сумарний результат | 540 | | 2800 | 91,7 | 5,24 | 5,13 | 5,20 |

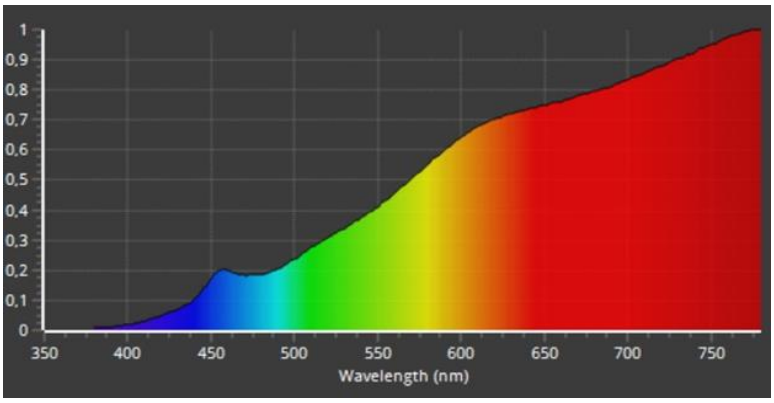


*Рис. 3. Спектр освітлювальної установки зі світлодіодними світильниками для загального освітлення та світильниками з ГЛР для місцевого освітлення*

Із отриманих результатів видно, що таким шляхом можна досягти виконання умов «меланопсинового хреста». При цьому можна також значно підвищити загальний індекс кольоропередавання Ra. Недоліком такого технічного рішення є те, що ефективність освітлювальних установок знижується до 40 – 45 лм/Вт, так як світлова віддача ГЛР значно нижча за світлову віддачу світлодіодних джерел світла. Але результуюча світлова ефективність світильників зі світлодіодами та ГЛР не набагато нижча від дослідних зразків нових світлодіодів, що застосовуються в лампах Soraa PAR38 (див. табл. 1).

Іншим шляхом покращення спектрального розподілу випромінення в області 450 нм – 480 нм є застосування в світильниках селективних фільтрів для обмеження рівня випромінення при довжині хвилі 450 нм і збільшити його в області 480 нм, де має місце «провал». Для дослідження ми використовували стандартні жовті фільтри ЖС3, ЖС4, ЖС10, ЖС11, ЖС12. Спектри пропускання цих фільтрів наведені на рис. 4. В якості відбиваючих матеріалів використовували зразок фарби з коефіцієнтами відбиття, наведеними на рис. 5.

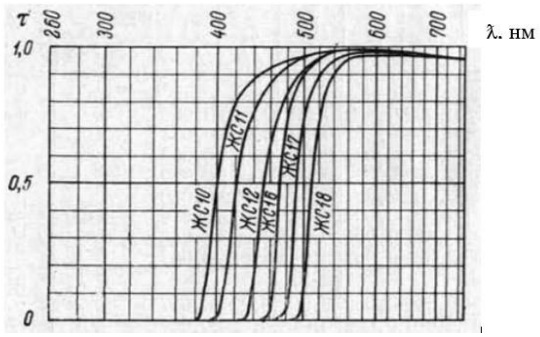


*Рис. 4. Коефіцієнти пропускання $\tau_\lambda$ жовтого скла товщиною 5 мм*

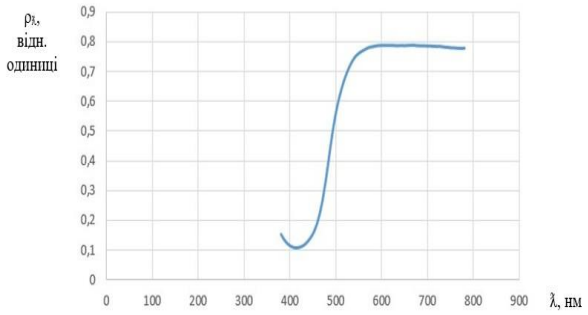


*Рис. 5. Коефіцієнт відбиття $\rho_\lambda$ зразка жовтої фарби*

В таблиці 3 та на рис.6 і рис.7 наведені результати вимірювання світлотехнічних та спектральних характеристик світлодіодних світильників з використанням цих матеріалів. Застосування фільтрів, що обмежують випромінення синього світла дозволяє більш ефективно коригувати спектр світлодіодного світильника для досягнення умов «меланопсинового хреста» в порівнянні з використанням ГЛР, але при цьому знижується якість кольоропередавання. Ми вибирали фільтр таким чином, щоб загальний індекс кольоропередавання $R_a$ не знижувався менше 80.

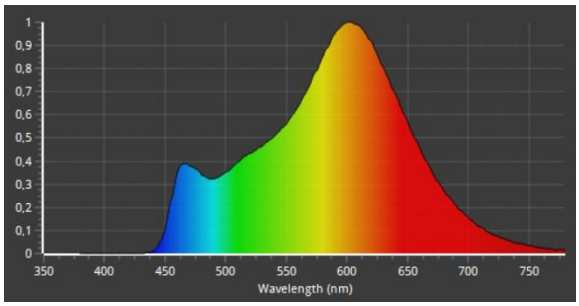


*Рис. 6. Спектр світлодіодного світильника з ССТ 2950 К з відбиваючою білою емаллю та корегуючим світлофільтром із жовтого скла ЖС12*

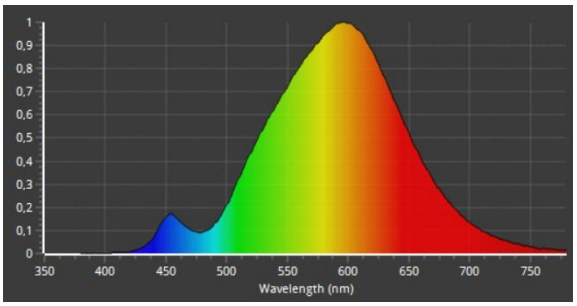


*Рис. 7. Спектр світлодіодного світильника з ССТ 2950 К (з відбиваючою жовтою емаллю та жовтим фільтром ЖС12)*

Таблиця 3. Результати вимірювання параметрів світильників з використанням фільтрів із жовтого скла та відбиваючих екранів з білої та жовтої фарби

| Характеристика фільтра або відбивача | Початкова освітленість (без фільтра і відбивача), лк | Освітленість з застосуванням фільтра та спектр | ССТ, К | $R_a$ | $I_{450\ нм}$, відн. од. | $I_{460\ нм}$, відн. од. | $I_{480\ нм}$, відн. од. |
|---|---|---|---|---|---|---|---|
| ЖС11, біла фарба | 329 | 245 | 2971 | 82,8 | 1,09 | 2,21 | 1,84 |
| ЖС12, біла фарба | 329 | 257 | 2905 | 81,6 | 0,59 | 1,87 | 1,86 |
| ЖС16, біла фарба | 329 | 232 | 2820 | 79,5 | 0,14 | 0,86 | 1,56 |
| ЖС11, жовта фарба | 329 | 329 | 2977 | 84,1 | 1,71 | 3,24 | 2,53 |
| ЖС12, жовта фарба | 329 | 301 | 2865 | 81,6 | 1,39 | 2,71 | 2,19 |
| ЖС16, жовта фарба | 329 | 307 | 2845 | 80,7 | 1,17 | 2,30 | 1,92 |

Застосування селективних відбиваючих матеріалів в світильниках також дозволяє змінювати спектральний склад випромінення і, за певних умов, разом з застосуванням фільтрів, що обмежують випромінення синього світла, можуть використовуватись для підвищення фотобіологічної безпечності світлодіодних світильників. Для покращення світло-колірного середовища, що створюють світлодіодні освітлювальні установки, можна також використовувати селективне відбивання стін та стелі приміщення.

**Висновки.** Світильники та світлодіодні лампи на основі світлодіодів, кристали яких випромінюють синє світло, що частково перетворюється за допомогою люмінофору в жовто-оранжеве мають надлишок синього випромінення відносно рівня при довжині хвилі 480 нм. Для підвищення фотобіологічної безпеки світлодіодних ламп та світильників необхідно значно знижувати рівень випромінення на ділянці спектру з довжиною хвиль 400 – 450 нм і збільшувати в області з максимумом при 480 нм.

Для зниження фотобіологічної небезпеки синього світла при освітленні житлових приміщень, дитячих та навчальних закладів необхідно застосовувати світлодіодні лампи та світильники з ССТ не вищою за 3500 К, які створюють не суттєву надлишкову дозу синього світла і є більш безпечні, ніж світильники з високими ССТ.

Розроблені технічні рішення щодо коригування спектрального складу випромінення освітлювальних установок шляхом спільного застосування світлодіодних ламп (світильників) та галогенних ламп розжарювання. При цьому для досягнення умов «меланопсинового хреста» ССТ світлодіодних ламп має не перевищувати 3500 К, а рівень освітленості, що створює ГЛР має бути не нижчий рівня, утвореного світлодіодними джерелами світла. Світлова ефективність при цьому знижується приблизно на 40 %, а індекс кольоропередавання зростає до 95 одиниць

З метою зменшення рівня випромінення в області спектру з максимумом при 450 нм та підвищення рівня випромінення в області з максимумом при 480 нм, що може забезпечити

виконання умов «меланопсинового хреста» для світлодіодних світильників з ССТ до 3500 К та $R_a \geq 80$, запропонована технологія коригування спектру шляхом застосування фільтрів з мінімальним коефіцієнтом пропускання при 450 нм і максимальним коефіцієнтом в інтервалі довжин хвиль 460 – 760 нм та відбиваючих світло матеріалів з мінімальним коефіцієнтом відбиття при 450 нм та максимальним в інтервалі 460 – 760 нм.

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*ECOLOGY*

# EXPERIMENTAL STUDY OF POLLUTION BY OIL AND OIL PRODUCT BATUMI PORT AREA

***Mzia Diasamidze,*** *Department of General education disciplines of the Batumi State Maritime Academy, professor, Faculty of Navigation, 6000, Georgia, Batumi,*
***Anna Shotadze,*** *Department of General education disciplines of the Batumi State Maritime Academy, associate Professor, Faculty of Navigation, 6000, Georgia, Batumi,*

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***Abstract.*** *As you know Artificial pollution is a serious environmental problem of the Black Sea, which is created by household, industrial, atmospheric and river waste, as well as garbage - intentionally or unintentionally dumped from ships. A significant part of sea transportation is occupied by transportation of energy carriers (crude oil, oil products). This represents our scientific interest as one of the leading maritime academies in the Black Sea basin. Previous studies were devoted to the study of the possible pollution of the Black Sea coast of Adjara by the inflowing rivers, (by 7 components). Our Research was of an experimental nature and was carried out using a multifunctional photometer and bathometer, purchased within the framework of a research project of an internal grant from the Maritime Academy. This study was conducted under the same project, which concerns the most urgent problem of pollution of the Batumi Black Sea water area with oil and oil products. Samples taken in different parts of the water area of Batumi were investigated. Laboratory studies were carried out to determine the content of petroleum products, the results of measurements were obtained. Research has revealed signs of water pollution.*
*The research results are presented in the form of tables and diagrams, consisting of the studied components. conducted environmental studies are of great practical importance. We are going to continue research in this direction, by comparing the results obtained with previous data and on the basis of causal conclusions, which will make it possible to identify trends in the processes associated with oil pollution of the Black Sea coast. As a consequence, it will be possible to outline and plan preventive measures to protect the environment.*
***Keywords:*** *Water area of the port of Batumi, pollution by oil and oil products, fractional distillation, waste water.*

**Little things from history**. The history of the Batumi oil terminal dates back to the XIX century and is closely related to the historical events of the development of the oil industry in the Caspian region. By 1876, Ludwig Nobel (founder of the Nobel Brothers) had become the principal oil tycoon of Baku, the Caspian "Black Pearl". In 1883, the Nobel Brotherhood built their first oil depot in Batumi. The history of Batumi Oil Terminal starts from the construction of this facility. In 1883, Baron Alphonse Rothschild financed the construction of a railway from Baku to the port of Batumi. In 1886, the Rothschilds founded the famous Caspian and Black Sea Oil Company, through which oil storage reservoirs and trading enterprises were built on the existing areas of the oil terminal in Batumi. With the new Baku-Batumi railway, Batumi has literally become one of the major oil ports in the world.

*Fig. 1. Batumi oil terminal.*

Shipping through ports, coastal waters and special economic zones, especially oil transportation by tankers, is associated with the risk of marine pollution as a result of possible collisions, accidents, oil overload and bunkering operations and other maritime incidents [3]. Such pollution can endanger recreational areas, sensitive environments, seabirds, marine life, coastal facilities, and fisheries. A large part of maritime shipping is occupied by shipments of energy carriers (crude oil and petroleum products). These purposes are served by two specialized facilities: the Supsa Oil Terminal and the Kulevi Port, as well as specialized terminals in the ports of Poti and Batumi. In turn, this causes pollution of the sea area with petroleum hydrocarbons. Due to the ability of oil and oil products to float on the water surface, coastal beaches are also polluted. The main pollutants are petroleum hydrocarbons. In this regard, the so-called. The "hot spot" is the coast of Adjara, in particular the water area of Batumi.

Batumi, Kobuleti, Poti, Ureki, Anaklia - are famous resort cities in the Black Sea basin. At least 50% of its population lives in the coastal zone. Added to this is a significant increase in coastal population during the holiday season. The role of shipping in global transport systems is growing. The so-called the vector of most of the "transport corridors" is directed towards the sea, which, in turn, leads to an increase in the cargo turnover of ports. This in turn leads to an increase in coastal pollution.

The attractiveness of Georgia's coastal zone and the strengthening of its economic potential are linked to the intensive consumption of natural resources in this zone. Therefore, knowledge of the potential of existing natural complexes and the current ecological condition of the environment is very important for achieving the goal of sustainable development of the coastal zone [4]. The pollution of the Black Sea environment is also facilitated by the accumulation processes that take place due to the limited exchange with other oceanic waters. Despite the multifaceted measures taken in the field of ecological protection of the Black Sea, interest and research are urgent in identifying sources of marine pollution and taking preventive measures.

Oil extraction, reloading and refining operations have been carried out in Batumi for a long time. Currently operating Batumi Oil Terminal provides services for the reloading of crude oil, petroleum products and liquefied hydrocarbon gas. In addition to the ongoing oil-related operations in the port of Batumi, the current unfavorable situation is significantly due to the historical pollution on the former territory of the Batumi oil refinery. The rivers Korolistskali and Bartskhana, in the direction of which the groundwater is discharged from the territory of the former oil refinery in Batumi, are practically a permanent source of hydrocarbon pollution Black Sea with oil.

*Fig. 2. pollution of coastal areas of Batumi.*

The composition of the industrial waste differs significantly from household. Table 1 shows data on the maximum permissible concentrations of oil products in wastewater.

Table 1. Maximum Allowable Concentration petroleum products in wastewater

| № | These norms are strictly regulated and have the following meanings: | mg/L |
|---|---|---|
| 1 | Maximum permissible concentration a lot of sulphurous oil in the drains | 0,1 |
| 2 | The maximum permissible concentration in wastewater of other types of oil | 0,3 |
| 3 | The maximum permissible content of gasoline in wastewater | 0,1 |
| 4 | The maximum permissible concentration of technical, oxidized, tractor kerosene | 0,01 |
| 5 | The limiting value of the content of lighting kerosene | 0,05 |
| 6 | Maximum allowable concentration of sulfated kerosene in drains | 0,1 |

We decided to study the Black Sea (Batumi and its vicinities) Pollution point and diffuse sources. Point sources - the discharge of polluted water from factories through pipes into rivers and then into the sea in this way. Diffuse sources - simultaneous pollution of various facilities at multiple points through drainage water generated by rains (which is abundant in Adjara). For this purpose, we carried out field I and field II field trips at the confluence of rivers and various points of Batumi water area. We took water samples at different points in sunny and rainy weather. The Maritime Academy owns a training vessel for "Cadet", which were used to take samples from various points of the coast.


*Fig. 3. Students in the process of research*

After laboratory research of water samples, we processed the data. Comparing the permissible norms, we made the relevant conclusions. Norms for the content of oil products in wastewater. Some of the Estimated Objects assume the presence of oil products in the effluent. In particular, this applies to enterprises in the automotive service sector - car washes, parking lots, service stations, etc.

And, of course, the content of oil products in the wastewater of oil refineries is inevitable. However, whatever the nature of the facility's activities, it must ensure the purification of its effluents from oil products in accordance with the established standards. The study was conducted on a laboratory apparatus for fractional distillation oil, through which we determined the content of the petroleum product in samples taken at eight different points. The obtained results are presented in Table 2. The obtained results are compared with the permissible norm, the corresponding conclusion is made.

Table 2. Content of petroleum products (mg /L)

| (Norm in the sea – 0,05 mg /L, in industrial waters - up to 5 mg /L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| sea buoy mooring | | Terminal berth | | Batumi port water area | | External raid | |
| I | II | I | II | I | II | I | II |
| 0,5 - 1,8 | 0,8 | 1,1 - 2,0 | 0,3 | 0,5 – 2,2 | 0,15 | 1,3 – 2,7 | 0,35 |
| Increased. | Increased | Increased. | Increased | Increased | Increased | Increased | Increased |
| City beach | | Sea strip near Lake Ardagan | | river. Bartskhani Delta (at 50 m) | | river Kubistskali (at 50 m) | |
| 0,3 - 0,8 | 0,25 | 0,17 – 0,2 | 0,1 | 1,2 – 1,28 | 0,2 | 0,7 - 0,9 | 0,39 |
| Increased | Increased | Increased | Increased | norm | norm | norm | norm |

We have generalized the result of the verification of Samples taken at eight different points (during I and II flied trips), drew histogram (Figures 4 and 5) and came to the following conclusion:

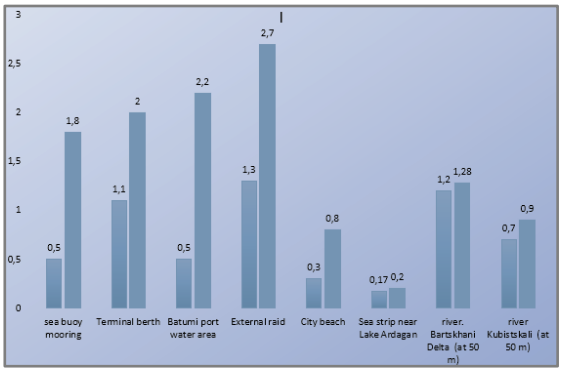


*Fig. 4. Bar graph (field I)*

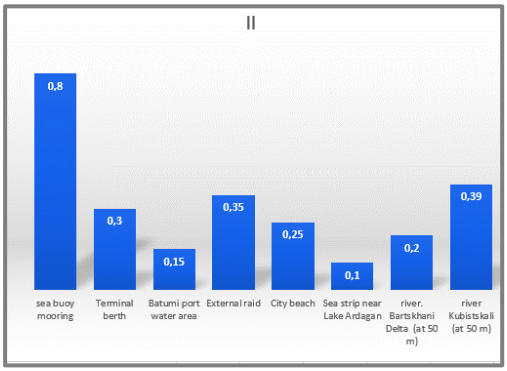


*Fig. 5. Bar graph (field II)*

Any ecosystem has the ability to self-clean. This also applies to organic substances of natural origin - oil and fuel oil produced from it, oils, diesel fuel, various types of gasoline, kerosene. They are subject to natural biological destruction, but it takes a very long time and proper conditions, as well as a very long process.

**Conclusions.** Thus, our field-scientific studies conducted in the Black Sea water area allowed us to determine the nature of the change in the ecological parameters of the Black Sea Batumi water area. In particular, we can assume that the oil pollution of the Batumi coastline is caused by drainage water. Using the results of the research in practice, it is possible to assess the ecological safety of the Batumi port in a complex way and to make a complex, optimal conclusion. Our research is complex in nature. It could not be otherwise, because any kind of pollution is equally harmful to the Black Sea, differing only in the issues of prevention and disposal. One of the reasons for the existing environmental problems is precisely that the well-established approaches and methods of complex management are not being used.

This creates the ground for conflicts between the ecological and economic interests of the society. To achieve a positive effect, it is important to consider the natural environment and economic activities as one system. Finally, by describing the cause-and-effect relationships of the research analysis, we came to the following conclusions:

- It is known that mechanical and chemical methods of combating pollution with petroleum products can not ensure its complete elimination. Unsustainable consequences and side effects of some methods (subsequent disposal of soils, oil contaminated with oil leachate and oils) significantly increase the environmental improvement measures using them. It is important to introduce modern, environmentally friendly, environmentally and economically viable innovative approaches and technologies. In modern approaches, more and more preference is given to different methods of cleaning the oil-contaminated environment (water, soil, soil and any other type of substrate) [5].
- Oil mostly pollutes the Black Sea coast, as it is where river confluences, wastewater discharge points, ports and industrial facilities are concentrated. Oil spills from ships pollute not only the coast but also the sea. Almost 111,000 tons of oil are spilled into the Black Sea every year, which, according to official data, is mostly due to negligence. Spilled oil damages the coastal ecosystem, destroys fish spawn and leaflets; This in turn directly affects seabirds, who face another threat: if they are trapped in oil, they lose the ability to fly and dive, can no longer maintain body temperature, their feathers lose their water resistance, and as a result, the birds get sick and die [6].
- Due to the poor condition of the communal infrastructure of the coastal settlements, the sea is polluted with wastewater, and the pollution of the beaches is sometimes close to the almost catastrophic limit. This leads to the impoverishment of the recreational resources of the coastal zone, the reduction of the flow of vacationers and tourists, as well as, ultimately, the deterioration of the socio-economic conditions of the part of the population that is self-employed in tourism and resort services - small hotels, apartment rental, transport services, food and Other [7].
- In addition to oil pollution, visual observations have identified cases of solid waste pollution of rivers and seashores. The Black Sea coast is highly polluted with plastic-containing solid wastes that pose a threat to marine mammals as they swallow them. Too often, foreign bodies are found in the stomachs of dead dolphins on the shore. The debris that floats on the surface carries the waves away from the shore, eventually forming large motive islands of debris in the middle of the sea. The plastic waste is broken down into small pieces, which are eaten by sea animals. As a result of consuming seafood, these wastes get into the human body and are harmful to health - this is the task of our next study [8].
- Air pollution (intense smell of oil) is also noticeable in this zone, which is very noticeable. Due to the oil pollution of the ground, several tens of hectares are practically unusable. From an ecological point of view, oil pollution has quite serious consequences. If we take into account the recreational and tourist importance of the Batumi coastline - the economic consequences of water pollution of beaches and beaches may be even more serious, although these two factors are closely interrelated [9].
- According to Article IX of the 1992 Convention on the Control of Pollution of the Black Sea (Bucharest Convention), all Black Sea countries are obliged to cooperate with other coastal countries in order to protect the ecological environment of the Black Sea from pollution caused by emergency pollution and disasters. Fight against it. Therefore, in the future, we aim to conduct joint studies on the ecological condition of the Black Sea basin together with the Turkish and Ukrainian naval academies, within the framework of which various unique observations will be made and complex results will be obtained [10].

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*MEDICINE*

# PARKINSON'S DISEASE MEDICAL REHABILITATION METHODS

***Elcin Huseyn,*** *Research Laboratory of Intelligent Control and Decision-Making Systems in Industry and Economics, Azerbaijan State Oil and Industry University, Baku, Azerbaijan,*
*ORCID ID: https://orcid.org/0000-0001-5965-7419*

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***Abstract.*** *Parkinson's disease ranks first among the neurodegenerative pathology. The approach to the treatment of Parkinson's disease must be comprehensive. Medical rehabilitation methods include not only basic drug therapy, surgical methods of treatment, but also methods of physiotherapy, reflexology, physiotherapy, speech therapy and psychotherapy. When prescribing physical factors in patients at different stages of the disease, it is possible to recommend those methods that will have a more pronounced effect on the clinical symptoms of Parkinson's disease. From physical factors, balneotherapy, thermal mud therapy, impulse currents, electrophoresis, electrostatic field, microwave therapy, phototherapy, barotherapy are prescribed. The use of trans cerebral Electrotherapy methods and computer-Stabil graphic programs in complex treatment based on biofeedback by statokinesogram will reduce the severity of the main symptoms of the disease.*
***Keywords:*** *medical rehabilitation, physiotherapy, Parkinson's disease.*

**1. Introduction.** Parkinson's disease remains a common neurological disorder in the elderly. The frequency of its occurrence ranges from 100 to 250 cases per 100,000 people [1]. Today in economically developed countries, there is an increase in life expectancy and the number of elderly people, which leads to an increase in the number of people with Parkinson's disease.

**2. Materials and Methods.** The etiology of Parkinson's disease is still unknown. However, it has been suggested that there is a hereditary predisposition to it. At the heart of the disease is a decrease in the number of substantial nigra neurons that produce the inhibitory neurotransmitter dopamine. In addition to the substantial nigra, degenerative changes are also observed in the hypothalamus, reticular formation, peripheral, autonomic system, cerebral cortex and some other structures. There is not only an imbalance in the dopaminergic system, but also in the noradrenergic, cholinergic, serotonergic mediator systems [2].

Psychotrauma can become a triggering external factor. In patients with Parkinson's disease, changes in psychoemotional and cognitive spheres are often observed [3]. The diagnosis of parkinsonism syndrome is made in the presence of hypokinesia, as well as one of the symptoms: muscle rigidity, resting tremor, postural instability not associated with visual, vestibular, cerebellar or proprioceptive dysfunction [4].

In the clinic, the forms of Parkinson's disease are distinguished: trembling, rigid, kinetic - and also "mixed" - according to the predominance of the symptom: tremor-rigid and akinetic-rigid.

Medicinal methods correct the rising imbalance in the dopaminergic, cholinergic and glutamatergic neurotransmitter systems. Prescribe drugs to increase the level of dopamine: dopa-containing drugs (levodopa, etc.), amantadine drugs (midantan, PK-merz), monoamine oxidase B inhibitors (selegiline), catechol-o-methyltransferase (entacapon, tolcapon). They use drugs that stimulate the receptors of the postsynaptic membrane of neurons sensitive to dopamine: dopamine agonists (bromocriptine, pramixol, etc.) And anticholinergic drugs (cycloidal, parkopan, etc.).

Surgical methods are used when the effectiveness of pharmacotherapy decreases, the occurrence of motor fluctuations. These include stereotaxic destructive and stimulation methods. The stereotactic method has a pronounced effect on tremor and rigidity, but does not affect akinesia. Deep brain stimulation is more effective and safer than stereotaxic surgeries. The method reduces the severity of tremor and rigidity, but does not affect gait disturbances.

Physical methods played a significant role in the treatment of Parkinson's disease until the 1960s, before the introduction of L-dopa drugs into medical practice. However, at present, interest in non-drug methods, especially in physiotherapy and exercise therapy, has increased again, since some limitations in the appointment of drug therapy and pronounced side effects of atyparkinsonian drugs have become apparent.

The comprehensive program of rehabilitation measures for Parkinson's disease includes physical factors, exercise therapy, reflexology, psychotherapy, speech therapy, which, when combined, have a positive effect on clinical manifestations. Under the influence of physiotherapeutic factors, hemo- and liquorodynamics improves, the permeability of the blood-brain barrier increases, the level of metabolic processes in the brain and vitality increase.

It is recommended to prescribe balneotherapy to patients with the initial stages of the disease to reduce the severity of clinical symptoms, reduce depressive and anxiety symptoms. If patients have concomitant diseases of the cardiovascular system, hydrogen sulfide baths are used with a hydrogen sulfide concentration of 50-100 mg/l and a temperature of 34-37°C, lasting 8-10 minutes, every other day, for a course of 10 baths. Radon baths are prescribed with a radon concentration of 40 nCi/l (1.5 kBq/l) and a temperature of 36-37°C, lasting 10-15 minutes, every other day, 10-12 baths, if there are concomitant diseases of the musculoskeletal system and peripheral nervous systems. Mineral baths are used with a salt concentration of 20-40 g/l, a temperature of 36°C, a procedure duration of 10 minutes, daily or every other day, for a course of 10-12 procedures in the presence of concomitant pathology of the musculoskeletal system. Iodine-bromine baths are recommended to reduce the depressive and anxious symptoms of the disease with a temperature of 36-37°C, lasting 10-15 minutes, every other day. The course of treatment includes 10 procedures.

When using thermal mud therapy, the excitability of spinal motoneurons decreases, the functional lability of the neuromotor apparatus increases, and the functions of the central nervous system (CNS) are activated. Thermal mud therapy is prescribed to reduce the symptoms of stiffness, hypokinesia and tremors. Apply paraffin wax with a temperature of 46-52°C or ozokerite 50-60°C on the lower thoracic and upper lumbar spine lasting 20 minutes, every other day, 12-15 procedures. Prescribe mud therapy with a temperature of 40-44°C in the form of applications in the same areas, 15-20 minutes, every other day, 12-15 procedures per course [5].

Patients are recommended to electrophoresis of various medications using the "collar" or orbital-occipital techniques, duration 15-20 minutes, daily, 12-15 procedures. The procedures help to improve the tropism of the brain structures, to reduce the severity of the symptoms of the disease. From medications for electrophoresis, a solution of nicotinic (0.5-1%) or ascorbic (2-5%) acid, potassium or sodium iodide (2-5%), noshpa (1-2%), dibazol (0.5-2%), aminophylline (0.5%). Electrophoresis of levodopa is used according to the endonasal or frontal-occipital technique. A solution of the drug is injected from the cathode, daily or every other day. The course is prescribed 10-15 procedures.

Electrosleep procedures are carried out according to the orbital-occipital technique with a frequency of 10 Hz, the exposure time is usually from 15 to 40 minutes, daily or every other day, the course of treatment includes 12 procedures [6]. Electrosleep is prescribed for patients with mixed forms of the disease in the presence of depressive symptoms and cognitive impairments.

The method of mesodiencephalic modulation is used, which is based on the activation of brain structures located in the mesodiencephalic (subcortical) region. The procedures are carried out according to the front-occipital technique (the anode is placed on the forehead, the cathode is in the occipital region) with a pulse frequency of 70-90 Hz, duration of 20 minutes, every day or every other day, 10 procedures per course of treatment.

Sinusoidal modulated currents (CMT therapy) can be recommended after stereotaxic surgery and to reduce rigidity and hypokinesia. CMT-therapy procedures are prescribed paravertebrally on the cervicothoracic and thoracolumbar spine, level CIII — ThI and ThIX — LI, variable mode, type of work - III — IV, frequency 80—30 Hz, modulation depth 50—100%. The exposure is carried out for 5 minutes on each zone, until a feeling of moderate vibration, daily, 20 procedures.

**3. Results and discussion.** In previous years, medical complexes were developed at the Central Institute of Balneology and Physiotherapy, which included the appointment of UHF-(decimetwave) and CMT-therapy procedures, hydrogen sulfide and radon baths [7]. Complex I consisted of the sequential application of CMT therapy, hydrogen sulfide or radon baths. The purpose of the complex has a significant effect on the severity of the symptoms of parkinsonism. Complex II included UHF-therapy, hydrogen sulfide baths, exercise therapy procedures. UHF-therapy was carried out on the occipital or the collar region from the "Volna-2" apparatus with an exposure power of 20-30 W, lasting 7-10 minutes, 10-12 procedures.

In order to improve microcirculation, reduce muscle rigidity, darsonvalization of the head, collar or paravertebral zone is prescribed. The procedures are carried out with a spark discharge for 5-10 minutes of the total exposure time, daily or every other day, 10-15 procedures.

High, UHF electric field procedures (e. UHF) has a positive effect on the main manifestations of Parkinson's disease. The capacitor plates are positioned bitemporally with an air gap of 3 cm on each side. During the first 5 procedures, the exposure power is 15–20 W, in the rest - 20–30 W. The duration of exposure is 7-15 minutes, with a gradual increase in time by 3 minutes. Treatments are scheduled daily. The course consists of 12 procedures.

The combined method of influence, developed by the Department of Physiotherapy of the Russian Medical Academy of Postgraduate Education, includes the use of e. p. UHF, on the second - the appointment of procedures for electric sleep. The method is used to enhance the influence of physical factors of various nature of the clinical manifestations of this disease. The method of combined exposure is prescribed to patients with mixed forms of the disease, cognitive impairment.

In the method of transcerebral magnetotherapy, a "running" pulsed magnetic field from the A limp apparatus is used, with a pulse frequency of 100 Hz, an intensity of 30% of the magnetic induction in the first 2 procedures, and 100% in the subsequent ones. The procedures are carried out daily, lasting 15 minutes. The course of treatment involves the appointment of 10 procedures. Magnetotherapy has a pronounced effect on depressive-anxiety and cognitive impairments [8].

Ultraviolet irradiation (UFO) has a beneficial effect on the autonomic nervous system, helps to normalize the psychoemotional status of patients. UFO is prescribed for the cervicothoracic, thoracic and lumbar segments along the spine. An erythema dosage is usually used. With the extinction of ultraviolet erythema, follow-up procedures are carried out in 2-3 days 2-3 times a week. The next irradiation is carried out at a dose that exceeds the previous one by 25-50-100%. 3-5 procedures are prescribed for the course of treatment.

Under the influence of light therapy procedures (treatment with bright white light), the main symptoms of parkinsonism are reduced: rigidity, hypokinesia and symptoms of depression. For this, the "Biolamp" apparatus is placed at a distance of 60 cm and at an angle of 45o in the eyes of a sitting patient. The exposure time is 30 minutes. The procedures are carried out in the morning. The course of treatment includes 10 sessions [9].

Hyperbaric oxygen therapy procedures are recommended for patients under the age of 65 and disease duration of 1 to 5 years. Barotherapy helps to normalize the neurotransmitter imbalance of the brain and sympathoadrenal system. In the course of the course of treatment, a gradual increase in pressure is carried out — from 1.6 to 2 am. The procedure takes 40 to 60 minutes. 8-12 procedures are prescribed for the course.

The alternating electrostatic field from the Khivamat apparatus is used in patients with restless legs syndrome, which occurs in the clinical picture of Parkinson's disease and refers to the motor manifestations of the disease. Restless legs syndrome is a condition in which unpleasant, painful sensations develop in the lower extremities, which most often occur at rest in the evening and at night and lead to sleep disturbance. The appointment of an alternating electrostatic field significantly reduces pain and movement disorders, has a positive effect on the emotional sphere, the quality of life of patients. Procedures with a pulse frequency of 85 Hz are prescribed for the muscles of both legs. A handheld applicator is used in the work. The duration of exposure to one limb is 10 minutes, the total time is 20 minutes. 10 procedures are used in the course of treatment.

Massage procedures are carried out with the aim of significantly affecting the neuromuscular apparatus, providing a relaxing effect. Massage of the collar and segmental zones of the spine is prescribed. The course of treatment includes 10-20 procedures. It is necessary to use medication and acupressure massage, avoiding rigid techniques. The massage method is used when the symptoms of rigidity prevail and the presence of distortion in the clinical picture of the disease.

The tasks of exercise therapy as one of the important methods of medical rehabilitation for this category of patients include the maintenance and development of motor stereotypes that help reduce injuries and falls, the prevention of arthropathies that occur when the symptoms of rigidity and hypokinesia increase. In the initial stages of Parkinson's disease, the goals of prescribing exercise therapy procedures are: 1) reduction of the symptom of rigidity; 2) increased range of motion, increased endurance and muscle strength; 3) training in muscle relaxation. In the later stages of Parkinson's disease, the goal of exercise therapy is to reduce the postural instability that occurs in these stages of the disease.

To correct posture disorders, increase stability, reduce falls, computer stabilographic games are used, which are based on the use of visual feedback according to a stabilogram [10]. The computer stabiloanalyzer with biofeedback "Stabilan 01" is used. To improve and consolidate the motor

stereotype, walking skills, a method of tempo-rhythm correction of walking is prescribed, based on the synchronization of the patient's step with individually selected sound stimulation.

Tai chi gymnastics classes have an effective impact. It is based on a complex that includes smooth and slow movements that promote a relaxing effect, reduce rigidity and improve balance.

The speech therapist conducts the correction of speech disorders in patients, in addition, independent exercises are recommended. Patients are encouraged to read poems aloud, repeat phrases from television and radio broadcasters, use dictaphone recordings to correct speech. Reflexology can be recommended for patients with akinetic-rigid and rigid-trembling form of the disease. The effectiveness of the method decreases in the presence of severe tremor. Acupuncture points of the extremities, heads are used, oral acupuncture can be used for speech disorders.

The psychotherapy method includes hypnosis and auto-training. Their use in clinical practice has a sedative effect, a decrease in hypokinesia is noted, but there is no effective effect on resting tremor.

Patients in the early stages of the disease in a resort and the sanatorium are prescribed balneotherapy, Electrotherapy, massage, exercise therapy, walking, swimming, aerobics, sports games (badminton, golf, towns) [7]. It must be remembered that in the early stages of the disease, when the manifestations of the main clinical symptoms of parkinsonism are not pronounced, depressive disorders may be present. Therefore, the complex of rehabilitation measures should include sedative therapy, psychotherapy, auto-training. As the disease progresses and the ability to self-service is preserved, treatment is prescribed in local sanatoriums without changing the climate or in the physiotherapy departments of polyclinics.

To maintain employment, it is recommended to maintain habitual life stereotypes, professional activities, and social contacts. Removing the patient from work can negatively affect his condition. Social adaptation of the patient in the work collective is possible even with the progression of the disease in the conditions of creating a sparing work regime, organizing early medical rehabilitation.

As the disease progresses and the development of a pronounced deficit of motor functions, the patient is released from work, however, it is necessary to maintain and maintain a motor stereotype and self-service skills. To date, medical and social groups for medical examination and rehabilitation and schools for people with Parkinson's disease and their relatives have been organized at the Center of the Ministry of Health of the Russian Federation and its regional branches [2].

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