DEVELOPMENT OF STANDARD PROCEDURE FOR ANALYSIS OF NATURAL ENVIRONMENTAL OBJECTS BASED ON THE EPC/GDV METHOD

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This work is aimed on development of a standard procedure for measurement of different environmental objects using the EPC/GDV method. During investigation several destabilizing factors influencing the results of EPC/GDV measurements were found. These factors were analyzed and ways of overcoming them have been formulated. We have developed standard recommendations and a procedure for conducting experiments on EPC/GDV that ensure acquiring stable and adequate results. An algorithm of statistical and mathematical processing of obtained data has been developed.
Keywords: EPC /EPC/GDV method, standard procedure, natural environment

Introduction

The principles of gas discharge digital images registration with subsequent computer processing and analysis have been developed by Dr. Konstantin Korotkov in mid-90th. Basing on this principle and construction different modifications of Electrophotonic / Gas Discharge Visualization (EPC/GDV) devices have been developed. These devices are being used for examining human psycho-emotional and physiological state, and for research of different natural environmental objects. Using the EPC/GDV hardware-software complex one can register dynamics of changes of investigated objects, but can not evaluate the absolute values of object's intrinsic properties, such as, for example, electrical capacitance or other physical characteristics.

Different factors can influence the obtained results during measurements of natural environmental objects and most of them are of no interest to the researcher. In fact they just increase the inaccuracy of measurements. Till the present moment there were no scientifically proven rules of conducting such measurements. This drawback has led to problems with treatment, statistical processing and interpretation of obtained results.

The aim of this work is to discover destabilizing factors that influence the obtained results, to find ways of overcoming these factors, and the development of a standard procedure for conducting such experiments and processing of obtained data.

Method

The procedure for acquiring EPC/GDV images is as follows. The object under investigation is placed on the quartz electrode, which has a transparent conductive layer on the back side. The generator feeds high voltage impulses to this layer for some time interval. Both power and duration of these impulses can be set by the capture software. In the Gas Discharge Visualization process, a complex interaction between the subject, the electrical field which is applied, and the gas discharge, takes place. The spatial distribution of the discharge is being captured by a special video camera (based on CCD technology), which is situated under the transparent electrode. The video-converter digitizes the captured image and passes it to the PC. The EPC/GDV-grams are processed in a specially developed software: different parameters of the EPC/GDV-image like Area, average intensity, Fractality, Entropy and others are calculated.

In several scientific works it was shown that these two parameters: area and average intensity, correlate with physical characteristics of the studied sample, i.e. with electrical capacitance.

In this research we have used the "Compact" series EPC/GDV instrument with an analog video-camera (www.kti.spb.ru). The EPC/GDV devices with digital video-cameras need very long time for warming up comparing to ones with analog video-cameras. Experiments were held in standard environmental conditions: air temperature 21-25ºC, (70-80^{o}F) relative humidity 26-30%.

For conducting our experiments we placed a metal cylinder – test-object- on the transparent lens and connected it to the electrode-platinum electrode – for measurements of liquids and solids, or to a metal antenna – for measurements of gaseous materials.

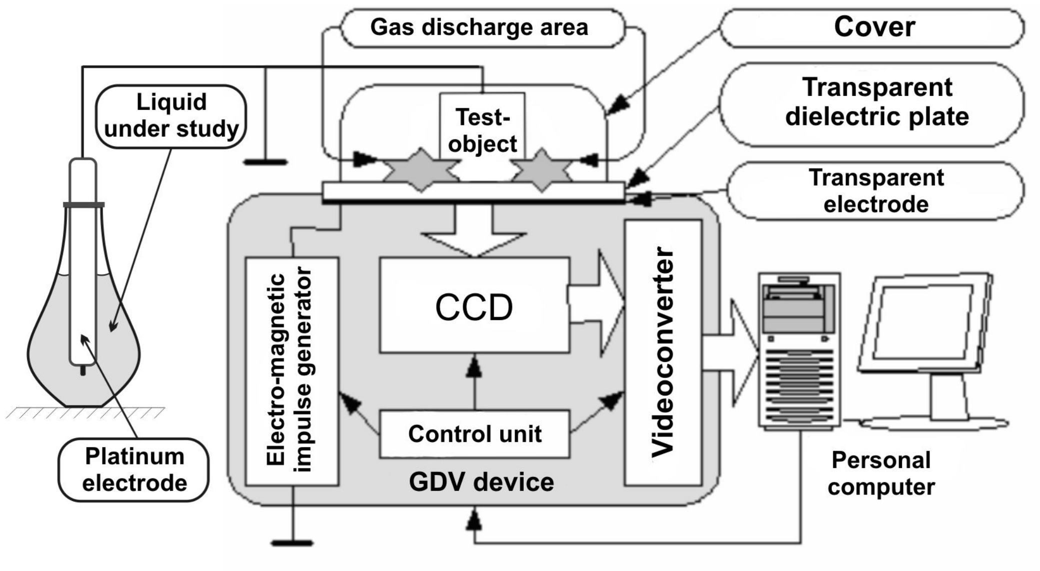

Fig. 1. Scheme of experimental setup

The obtained data was processed in a specially developed software "GDV Scientific Laboratory", produced by the "Kirlionics Technologies International"® company.

Results and discussion

Main destabilizing factors

Bad grounding

If EPC/GDV device and the computer connected to it have bad grounding an electrostatic charge is accumulated, and after some time this accumulated charge can discharge on something. During continuous series of measurements this effect can lead to spontaneous turning off or restart of the computer. The accumulated electrostatic charge influences the stability of the gas discharge, and therefore the reproducibility of the obtained EPC/GDV-grams. Fig. 2 demonstrates two series of measurements with and without grounding of the EPC/GDV device and the PC. Comparing these two trends we can see that the obvious difference in fluctuation.

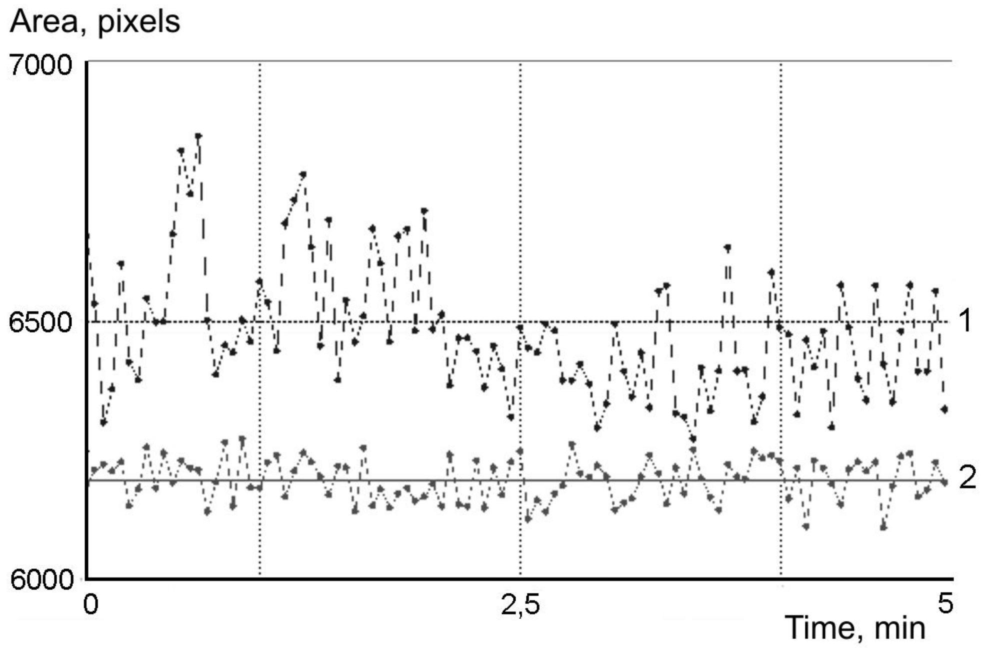

Fig. 2. Influence of grounding on fluctuation of the GDV-gram's area parameter: 1 – series without grounding; 2 – series with grounding

Bad ventilation

When using the standard cover (that covers the transparent electrode) of EPC/GDV devices for long-term measurements the ventilation in area between this cover and the transparent electrode is insufficient. Because of this, ozone that is generated during the gas discharge is accumulated in this area. Accumulation of ozone strongly influences the obtained EPC/GDV-grams and their parameters. Fig. 3 demonstrates the results of comparison of two series: with and without ventilation. Ventilation was provided by a ventilator standing near the EPC/GDV device. Fig. 3 demonstrates average values of the EPC/GDV-gram Area parameter in series divided on 4 groups. Each group consists of four consecutive series of measurements with different values of the connected capacitors: 14pF, 23pF, 53pF, and 75pF. Groups 1A and 2A were made one after another without ventilation and groups 1B and 2B – with ventilation. As one can see from this comparison the ventilation has a very strong influence on the EPC/GDV-gram's Area. One can see that the B-groups have higher reproducibility of results during consecutive measurements than the A-groups. This can be explained by accumulation of ozone without ventilation that reduces the area of the gas discharge.

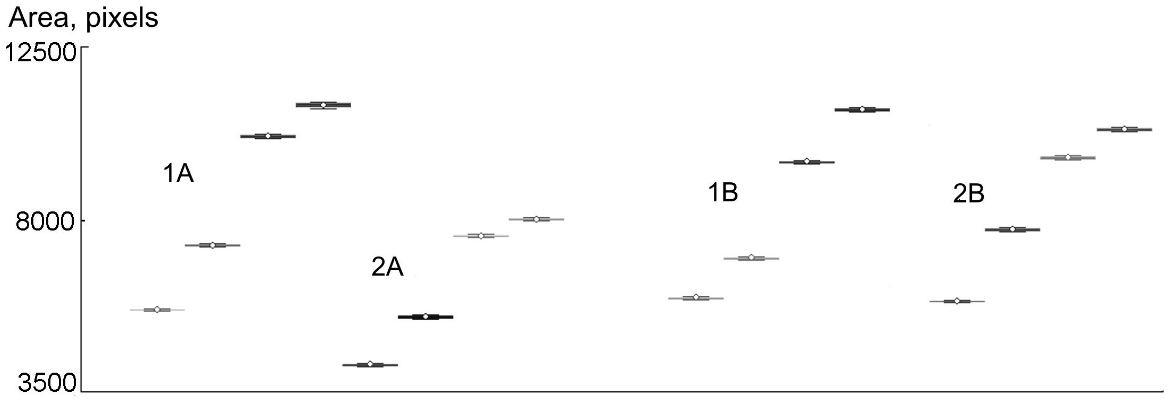

Fig. 3. Influence of ventilation during measurements on EPC/GDV-gram's Area parameter; 1A, 2A – groups of consecutive series without ventilation; 1B, 2B – groups of consecutive series with ventilation

Warming up of the device

The EPC/GDV device needs some time to reach a stable working state that is characterized by the most stable parameters of EPC/GDV-grams in series. For our model of EPC/GDV device a stable state is characterized by the following deviations of EPC/GDV-gram parameters in each series: 1,35% of Average intensity average value and 2,95% of Area average value. Warming up of the device is characterized by a slow increase of Average intensity and a decrease of the Area of EPC/GDV-grams after switching on the device till reaching the stable state (Fig. 4).

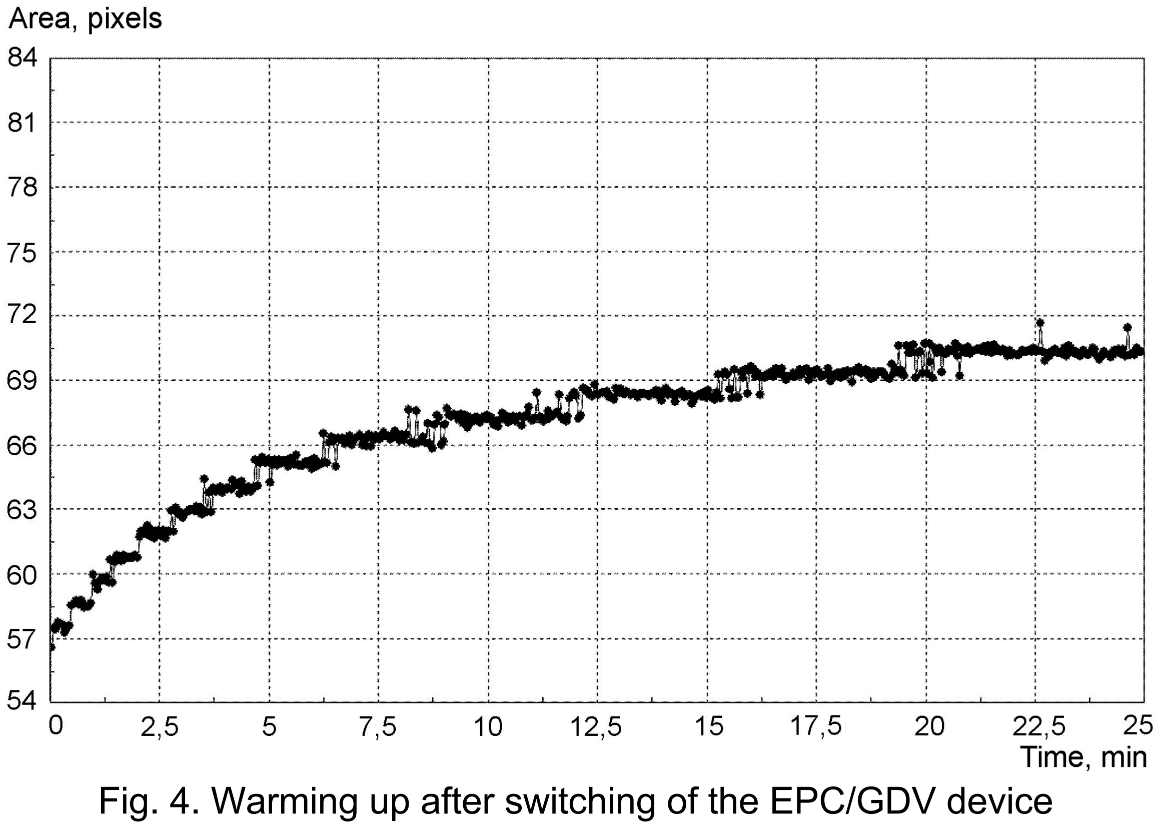

Fig. 4. Warming up after switching of the EPC/GDV device

To reach a stable regime considering the Average intensity parameter you need to warm up the EPC/GDV device once after turning it on, but a decrease of the Area parameter is present in each series during the first 40 captures.

Moving of the test-object

One of the destabilizing factors is moving of the test-object on the surface of the transparent electrode. If you move the test-object between series it will significantly increase the fluctuation and lead to a decrease of stability in the obtained results.

Changes of environmental conditions

Environmental conditions like relative humidity, air temperature andelectromagnetic fields influence the development of the gas discharge. For example, turning on some electric device in the room where the EPC/GDV device is working can change the electromagnetic background that will affect characteristics of the gas discharge.

We have stated, based on our experiments, that for high a reproducibility of long-term measurements the variation of environmental conditions should not exceed: ±2.5 %

Time interval between captures

Our experiments demonstrated that the time interval between captures of EPC/GDV-grams influence the fluctuation of EPC/GDV parameters in capture series. If a 3 seconds time interval is set (minimum available) this fluctuation is much higher than for a 5 seconds interval, but there is no such big difference between 5 and 10 seconds.

Common recommendations

Based on the above listed destabilizing factors we have developed common recommendations for an EPC/GDV standard measurements procedure :

1. Properly ground the EPC/GDV device and the personal computer.
2. During continuous measurements (more than ten minutes) one needs to provide constant ventilation, for example using a ventilator standing near the EPC/GDV device (not closer than 0,5 meter) .
3. Before starting of measurements after turning on the EPC/GDV device it is necessary to warm up the device by connecting the test-object to the ground of EPC/GDV device and conducting 600 captures with 3 seconds time interval between captures.
4. For measurements of environmental objects the time interval between captures should be not less than 5s.
5. The test-object should be set firmly on the transparent electrode at the beginning of the experiment and should not be moved till the end of the experiment.
6. One should track the environmental conditions during experiments:
   - Shifts in relative humidity shouldn’t exceed 5%.
   - Shifts in air temperature shouldn’t exceed 5 ºC.

- Do not turn on/off electrical devices during experiments in the room where the EPC/GDV device is standing.
- Do not talk on a cell phone near the EPC/GDV device.
- The number of people in the room should be the same during the whole experiment.
- Do not make measurements during strong atmospheric pressure changes.
- Watch changes in the geomagnetic background (Sun and Moon rise/recess and so on).

7. The length of each measurement series shouldn't be less than 140 EPC/GDV-grams.
8. In the processing of obtained results the first 40 EPC/GDV-grams should be excluded from each series.
9. After changes of environmental conditions one should make a new calibration. For this purpose one can use the last 10 EPC/GDV-grams from the "warming up" series.

Standard procedure

In each experiment the researcher should thoroughly plan and develop the measurement procedure. All researchers should follow the abovementioned recommendations. Let us discuss the particular examples.

Study of the external influence

(for example, mobile phones influence, electromagnetic fields, human intention, etc).

Each experimental study of an influence can be divided into three stages: 1 – before influence (background), 2 – influence, 3 – after influence.

Before starting an investigation on an influence under study the researcher should check the measurement procedure for its stability. For this purpose the researcher should complete the following steps without the influence:

1. Repeat experiments at least 4 times.
2. Check each series for fluctuations of the Area and Average intensity parameters inside the series to be sure that the environmental conditions are stable and equal during all series. Use the following formula for calculating the fluctuation of the Area and Average intensity parameters in each series:

, (1)

where Δ_{int} is fluctuation of the respective EPC/GDV-gram parameter in the series in %; σ is the root-mean-square deviation; is the average value of the

EPC/GDV-gram parameter in a series.

The σ and $\overline{A}$ values can be calculated in the program "EPC/GDV Scientific Laboratory". Resulting values should not exceed the following threshold values: 3% for the Area and 1,5% for the Average intensity. If the calculated values for some of the series are exceeding the threshold values then such series should be captured one more time.

3. Check if the conditions of conducting experiments are equal for each of the two obtained groups. Calculate the average value of the EPC/GDV-gram's average values in a series inside each group using the formula:

$$\overline{A}_{ext} = \frac{\sum_{i=1}^{n} \overline{A_i}}{n}, \qquad (2)$$

where $\overline{A}_{ext}$ is the average value of the EPC/GDV-gram parameter average value inside a group, $\overline{A_i}$ is the average value of the EPC/GDV-parameter in the i-th series, *n* is the number of series in a group (in our case n = 4).

If the average value $\overline{A_i}$ of some series is higher than ±2% for the Area or ±1,5% for the Average intensity from the $\overline{A}_{ext}$ value, such series should be captured once again.

4. Using the statistical non-parametric method of Mann-Whitney find out if there is a statistically proven difference between the groups (in GDV SciLab program).

If a series of experiments is conducted well then there should be no statistically significant difference between the EPC/GDV parameters of the 4 groups. If there is such difference then check your procedure on meeting all abovementioned requirements and repeat all the steps from 1 to 4. If it doesn't work out then you can increase number of experiments –higher number of experiments leads to more accurate calculation of results using statistical methods. If there is still a statistically significant difference between the groups check the EPC/GDV instrument or contact the producer.

After adjustment and accurate checking up of the measurement procedure the researcher can proceed to study the influence.

Each experiment should meet the following requirements:

- Each experiment must be repeated the same way at least 4 times (minimal number of experiments is limited by statistical criteria which is being used for statistical evaluation of series "before" and "after" the influence);

- The resulting series should be divided into three groups: 1st consists of all series from the stage before the influence (background), 2nd consists of all series from the influence stage; and 3rd consists from all series from after influence stage.

Complete all steps (1-4), and include the stage of the studied influence. If there is no statistical difference between the stages then repeat all measurements once again. If there is still no difference then you can conclude that the influence under study can't be statistically registered using this method.

Measurements with syringe

The common recommendations are almost the same for measurements of liquids with a syringe except paragraphs 7 and 8 about length of series. There are some special additional recommendations due to additional destabilizing factors:

1. Air bubbles in liquid inside the syringe.
2. Evaporation of the liquid drop during series of measurements.
3. Significant deviation of the liquid drop radius between series, because of the human factor.

Considering these factors we have developed additional recommendations:

1. Before every new series of measurements with a syringe fill the syringe with an equal amount of liquid. Check the filled volume for presence of air bubbles because they influence the gas discharge of the drop. If there are bubbles then refill the syringe again.
2. During every series of capturing GDV-grams the liquid evaporates from the surface of the drop. Therefore, the radius of that drop changes and vapor is condensed on the lense. Because of this, parameters of GDV-grams change during every series and the deviation increases. That is why for every kind of liquid the researcher should find out the maximum length (paragraph 7 of Common recommendations) of series during which the fluctuation of GDV parameters doesn't exceed 5% for the Area and 2% for the Average intensity. For example, for filtered tap water the series of measurements should not exceed 140 GDV-grams. Make at least 10 consecutive series to calculate average parameters. For calculation of fluctuations of GDV parameters use Formula 1.
3. Also, based on these 10 series, one should find out the period during which the Area parameter decreases at the beginning of each series (paragraph 8 of Common recommendations). GDV-grams taken during this period should be excluded from further processing.
4. Because of evaporation of the liquid and condensation of vapor on different parts of the experimental setup the researcher should thoroughly wipe dry the bottom of syringe holder, the bottom of the syringe, and the inner side of the electrode-cover with pulp and paper material.
5. the operator, who prepares the drops causes an additional deviation in the

GDV-gram parameters because one can not make equal drops every time. In most cases the deviation caused by the operator is comparable to the deviation caused by device itself. That is why special attention should be paid to this process. We recommend increasing the minimum number of experiments (more than 4) to make experiments more statistically significant.

Nonparametric comparison of two groups of data by Mann-Whitney Rank Sum test

"Statistical Methods", Eighth Edition, Snedecor and Cochran, 1989, Iowa State University Press, pp. 142-144.

Measuring water we very often need to compare two groups of measurements, say one and the other water samples. We need to make several measurements of every sample, at least 4, but better up to 10. So you will have at least 4 series of dynamic measurements. You need to calculate an average value for every parameter and make the test. Let us explain it with an example.

In an experiment the initial water sample was measured 4 times with a new suspended drop every time. Then to 1 liter of water KCl salt with a concentration of 0.25 g/L was added to the water and measurements were done 4 times.

Table 1 presents the values of the average area.

Table.1. Area of water samples

Initial water		Water with salt	
Area, pxl	Rank	Area, pxl	Rank
6423	4	6607	8
6339	1	6498	5
6368	2	6577	7
6395	3	6513	6
	$T_1 = 10$		$T_2 = 26$

For every value of the area we give a Rank – its position in the row of all the values. Minimum Rank = 1, maximum Rank = 8 in our case. In the case when several values are the same, they are given an averaged Rank. For example, if three values divided 2^nd^, 3^rd^, and the 4^th^ place, the Rank = 2+3+4 = 9/3 = 3, and every value have this Rank =3. But the next Rank will be 5.

Then we need to compare the Sum Rank T with the table values. Some values are given in Table 2. When T_1 is equal to or less than the table value, and is equal or higher then the table data, the two groups of data are statistically different. In our example they are different with $p < 0.026$.

So we can conclude that the EPC technology allows distinguishing the difference in salt concentration of 0.25 g/L.

Pay attention that the Mann-Whitney test does not depend on the values of particular parameters.

Table 2. Critical values of the Mann-Whitney criteria

Number of measurements in every group	Level of α parameter					
	0,05			0,01		
	T values		α level	T values		α level
4	11	25	0.057	10	26	0.026
5	17	38	0.032	15	40	0.008
6	26	52	0.041	23	55	0.009
7	37	68	0.053	33	72	0.011
8	49	87	0.050	44	92	0.010

Conclusions

Following all developed recommendations, a standard procedure of measurements, and mathematical processing of obtained results allow researchers to get statistically proven results and their interpretation.