

SOFTWARE AND HARDWARE COMPLEX OF DIAGNOSTICS OF EXPIRATORY AIR FOR DETECTION OF ONCOLOGICAL DISEASES

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Abstract – Trends in the development of methods and tools for early diagnosis of oncological diseases have been analyzed. It has been shown that the success of treatment of cancer patients largely depends on the timely detection of this pathology. Since oncological diseases are manifested in an increasing number of the population and not only on the territory of Ukraine, but also beyond its borders. Scientific researchers from all over the world are trying to develop and find a diagnostic method, which, at the stage of the appearance of cancer cells, signaled the need for an extensive medical examination. The necessity of creating screening systems providing express diagnostics of pathologies for the implementation of mass preventive examinations is substantiated. It is proposed to use, as sensors, a set of selective gas analyzers of the amperometric type, which have sufficient sensitivity and do not require consumables for their restoration. A software and hardware complex has been developed for the analysis of expiratory samples from patients. The results of examination of a group of patients with lung cancer and a control group (conditionally healthy) are presented. According to the results of the study, three main chemical elements have been identified that signal the presence of cancer cells in the patient's body. Thus, there is reason to assert the relevance of the selection of chemical components that are in the expiratory air of a person for the detection of other diseases, such as diabetes mellitus, cirrhosis of the liver, cardiovascular diseases and others.

Keywords – oncology, electronic nose, selective gas sensors, statistical analysis, cancer prevention

I. INTRODUCTION

Oncological diseases were included in the ten most common diagnoses in Ukraine in 2018 [1, 2] and ranked second in terms of morbidity and mortality among the population, second only to diseases of the cardiovascular system. According to experts in the specialized industry, in 2020 the number of Ukrainians who can get cancer for the first time will exceed 200,000 [3-7]. This type of morbidity is steadily growing by 3% annually, continuing to “rejuvenate” [8, 9]. One of the most promising ways to overcome this problem is to prevent the onset of the disease and identify it in the early stages of the onset of the disease.

Statistics show that previous prevention and timely medical examinations can reduce the risk of cancer by 30%. Approximately 35-50% (depending on the region) of patients with oncology goes to doctors at 3-4 stages of the disease. Accordingly, the

patient receives more difficult and more expensive treatment, the likelihood of survival and life expectancy decrease. Therefore, the development of alternative methods for diagnosing oncological diseases remains an urgent task, which would provide an opportunity for doctors to diagnose the disease in the early stages in a short time (up to 10 minutes), non-invasively and cheaply and thereby prevent the active development of malignant cells.

The development and creation of diagnostic methods will help save financial costs not only for the patient of cancer hospitals, but also government spending on the purchase of expensive drugs. Below, let's consider one of the diagnostic approaches that is gaining development and popularity among researchers: assessing the state of the chemical composition of exhaled air, that is, expiratory tests in order to detect cancer of the human respiratory system.

II. LITERATURE REVIEW AND PROBLEM STATEMENT

Considering the incidence of cancer of the human respiratory system, consider the possibility of early detection of malignant tumors that are in the lungs and respiratory tract (bronchi). This type of cancer is considered dangerous, since its symptoms are similar to mild colds, which makes it difficult to diagnose cancer and contributes to the development of this disease. Lung cancer can develop over a long period and is found in advanced stages. Basically, it damages one of the lungs and is not limited to just one organ, creating metastases in other parts of the body.

It should be noted that the absence or incomplete implementation of screening programs and methodology, late diagnosis, and limited access to improved methods of treatment – entails difficulties for a cancer patient. One of the main problems is late detection of pathology. In Ukraine, about 50% of patients come at late stages, and 50% – at relatively early stages. Therefore, it seems urgent to create a method for express diagnostics and monitoring of the condition of the subjects, which will allow detecting the presence of pathology at an early stage of the development of the disease.

It is necessary to note the modern and new approaches that scientists are working on in this area. Their work is aimed at creating, first of all, portable tools that will make it possible to easily and wholeheartedly diagnose oncology in a patient, regardless of its place of residence.

Active work is underway to develop easy-to-use methods for diagnosing various types of cancer.

The D3 system [10] is a LED device that allows, using a smartphone, to obtain a high-resolution image. The system performs digital diffraction diagnostics, recording information on more than 100,000 blood cells or tissue samples in one image. The collected data is sent to an encoded server, where they are analyzed and in less than an hour it is possible to get an answer on the established diagnosis. The D3 System classifies specimens as high or low risk for existing oncology, or presence of a benign tumor, closely matching the results of routine histological examination.

For example, scientists from Stanford University [11] have developed a method of obtaining a diagnostic laboratory "on a chip" for repeated use using a conventional inkjet printer. The cells located on the electronic tape are influenced by

an electric charge, which separates the cells in accordance with their electrical properties. This process releases the required cell types. However, the system can handle only relatively small sample volumes. This technology can identify individual and specific mutations of cancer cells, help the doctor suggest targeted treatment, diagnose cancer at an early stage of development, by identifying tumor cells circulating in the bloodstream.

In addition, at Stanford University, scientists [12] proposed to use the deep learning method of the recognition system. This algorithm was developed by Google to create a photo screening method to detect skin cancer. Based on this technology, they plan to create an application for smartphones that can directly work with uploaded photos of skin areas.

It is advisable to dwell on the works describing the results of the analysis of endoscopic samples. This approach is based on the use of gas analytical information systems – this is a type of systems based on an analyzer of gas mixtures by combining dissimilar (unequal) sensors that simulate the work of the human olfactory organ to determine pathologies of the selected body system.

One of the first gas analysis systems include Haldane, Bohr-Tobizen, Zuntz and Goepfert, Benedict, Krogh, and the like. The Zuntz-Goepfert device, which measures the amount and composition of a person's exhalation sample, includes a gas analysis system and a clear gas clock in which an average sample is collected for the analysis of exhaled air.

The quality and accuracy of the response of gas analytical systems, first of all, depends on the developed hardware module, which performs the main function of collecting and determining the chemical components of the expiratory sample [13]. It is a system with a specific set of chemical sensors that selectively react to the presence of chemical molecules of a substance [14]. Each sensor reacts to a specific substance in its own way.

Cancer diagnostics usually involves various imaging techniques, examination of tissue samples (cells, genetic material) under a microscope, or testing them for proteins. Scientists have begun work on determining the portrait of a compound in breath samples that will correspond to a specific disease [15]. The collaboration of the researchers allowed the results of a developed small diagnostic array based on flexible gold nanoparticle sensors to be viewed for use in an "electronic nose." The

created system was tested on breath samples from 43 volunteers, 17 of whom were found to have ovarian oncology. As a result, an accuracy level of 82% was obtained, which shows the relevance of the work, the need to develop this method and the initiation of further clinical trials. As the scientists note, the new system will avoid the procedures that are required today for the diagnosis of cancer, many of which are complex, painful and, most importantly, can be performed only when the tumor has already formed.

In Hungary, the Cyranose 320 system has been tested for chemical indicators that indicate the presence of lung cancer [16]. Scientists examined several samples of exhalation: after a simple exhalation, exhalation after holding the breath, and exhalation after a deep breath of air. In practically healthy subjects, different results were obtained for each of the three methods of taking an expiratory sample.

The problem of cancer research is also being dealt with in England [17]. An information system for analyzing the content of volatile substances in urine has been developed. It is based on an array of 13 electrochemical and optical sensors. As a result of using discriminant analysis, high statistical indicators of correct classification were obtained (78% sensitivity and 79% specificity). Due to the combination of several types of chemical sensors, one cannot assert high competitiveness. Since the characteristics of the selected sensors require different approaches to their use.

Scientists from the USA [18, 19, 20] began to examine patients with small cells (these could be both malignant and benign tumors) in the lungs. According to the results of the research, they began to use a special silicon processor with a chemically active coating and a mass spectrometer to analyze the condition of patients who have been diagnosed with lung cancer. A microprocessor determines the level of carbonyl VOC in the air exhaled by the patient.

The developed microprocessor is coated with a substance that binds the carbonyl groups of the components exhaled by humans. In addition, aldehydes and ketones are analyzed (substances are created in the human body in very small quantities), and these, in turn, are organic compounds with carbon and oxygen atoms, which are linked by a double bond and belong to the carbonyl group of substances.

Scientists conducted an experiment and compared the results with analyzes that were obtained using standard diagnostic conditions and the conclusions of doctors. And it was determined that in cancer patients the level of these specific substances from the carbonyl group is significantly increased. Also, there is reason to believe that the "normal" level of the above substances, in 80% of cases, indicates a benign neoplasm in the lungs. These achievements make it necessary to create an express diagnosis of this disease.

The main disadvantage of the above systems for analyzing the gas composition of air is the lack of modularity. There is no possibility of making changes to their structures, which in turn gives the researcher the opportunity to use the system for the diagnosis of several diseases.

III. THE AIM AND OBJECTIVES OF RESEARCH

The conducted studies aimed to determine the relevance of the development of a software and hardware complex for prophylactic diagnostics and early detection of malignant lung tumors based on the analysis of expiratory air. The specified diagnostic method provides a non-invasive study of human expiratory air samples to determine the pattern (fingerprint) of its chemical composition, with the subsequent assignment of the subject to the risk group or healthy. In addition, the developed complex is easily modified and can be adapted for the analysis of other diseases.

To achieve this aim, the following objectives are solved:

- to determine a sufficient set of chemical sensors with the help of which it is possible to trace the signs of oncology;
- to develop hardware and software for the complex for the implementation of the diagnostic goal;
- to conduct practical studies of the expiratory air of cancer patients and to establish a combination of chemical sensors that determine the signs of oncological manifestations.

IV. TECHNICAL MEANS AND EXPRESS DIAGNOSTICS OF LUNG ONCOLOGY

It is known that the air exhaled by a person contains about 600 different compounds. Approximately twenty compounds are the most sensitive to changes in health and can be considered biomarkers of certain diseases, as shown by Fig. 1.

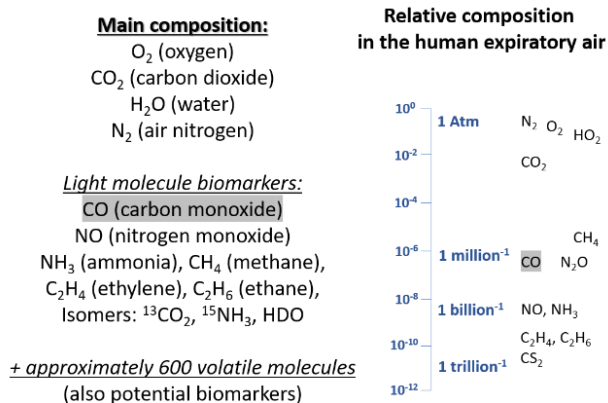


Fig. 1. Molecules-biomarkers in expiratory air

Since the 80s of the last century, scientists have established a connection between expiratory air and the human condition. The chemical composition of the exhaled air by a healthy person differs from the composition of the patient's expiratory air. A relationship has also been established between the molecules found in the exhaled air and some diseases are shown in Table 1.

Table 1 Biomarker molecules and corresponding diseases

Biomarker molecule	Diseases
Oxygen (O ₂)	lung diseases (chronic obstructive pulmonary disease, pulmonary fibrosis), diseases of the cardiovascular system (heart weakness, heart failure)
Carbon dioxide (CO ₂)	respiratory tract infection, asthma, etc.
Nitric oxide, nitrogen dioxide (NO, NO ₂)	chronic obstructive pulmonary disease, asthma, bronchiectasis, upper respiratory tract infection, digestive system cancer, chronic infectious inflammatory processes (gastritis, hepatitis, colitis), etc.
Ammonia (NH ₃)	acute and chronic radiation sickness, monoamine metabolism in the lungs, etc.

In the course of research and analysis of scientific sources, the necessary characteristics were determined that the complex being developed should have: accuracy and speed of analysis, concentration sensitivity, volume of expiratory air (gas sample), selectivity of analysis, method of sampling and taking into account the possible destruction of the object under study during analysis.

The above described characteristics are implemented in a hardware-software complex, it is shown by Fig. 2, with the help of which the analysis

of the exhaled by a person is carried out, and the chemical compounds that make up it are determined.

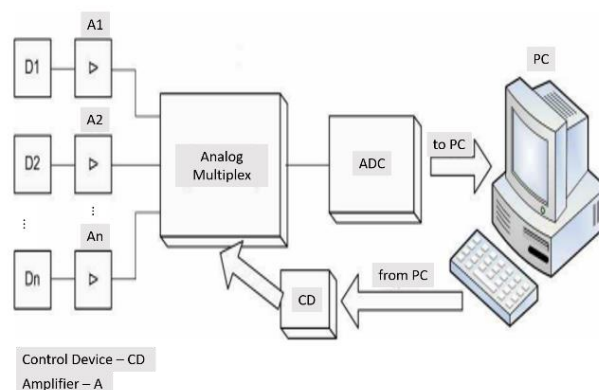


Fig. 2. Functional diagram of the hardware and software complex

The hardware module of the system includes several components: a reagent, a set of sensors, a sampler, analog signal amplification circuits and an analog-to-digital converter. According to these components, four stages of the electrical signal of the sensors in the hardware module of the system were formed.

Work with the device begins (stage 1) after connecting the bag with an exhalation sample to the desiccant. The moisture filter was specially developed during research, since the condensate that can settle on the tube, when taking a sample from the subject, negatively affected the performance of several sensors [21]. For example, the signal from the ammonia sensor becomes unstable and does not distinguish between the patients being examined.

The design of the desiccant is quite simple. Product material – stainless steel. It consists of two parts, which are connected by a thread (outer diameter $d = 74$ mm, inner diameter $d = 50$ mm). In the middle there is a special place for a cotton pad (width is 4 mm), which is a water filter. The disc is changed with each new measurement. The research results showed that the attachment of such a filter does not affect the concentration level of a chemical element in the sample [13].

In stage 2, the expiratory sample is in direct contact with the sensors, which create electrical signals corresponding to the concentrations of the chemical parameters of the exhaled air. This stage is realized using a cylindrical sampler. The sensor holes are through and arranged in a circle. It is possible to install seven sensors at the same time. The outer diameter of the holes ($d = 26$ mm) is equal to the diameter of the sensors, and the inner one (the

back of the sampler) is 16 mm less, that is, 10 mm. The sensors are installed with a diffuse window inside the sampler, and with contact legs (electrodes) outside, which makes it possible to isolate the sensors from contact with ambient air.

Inside the sampler is a piston that moves with a metal tube. Thanks to this metal tube and the piston attached to it, the sample from the bag is forcibly drawn in due to the movement of the piston and is there under atmospheric pressure.

The main elements of the system for diagnostics are electrochemical sensors of the amperometric type, which perform the main function of studying the concentration of chemical indicators of the expiratory sample. The formation of qualitative and quantitative analysis depends on the functioning of chemical sensors. They analyze the patient's exhalation for chemical elements. The technical parameters of the hardware module of the system depend on the parameters of the electrochemical sensors; therefore, the choice of the type, number and sensitivity parameters of the sensors is an important step in the design of diagnostic systems.

The selected set of sensors is connected (stage 3) to the analog multiplexer, on which the corresponding signal amplifiers are placed (a spare center is provided for connecting the amplification circuit).

At the last stage of the passage of the electrical signal of the sensors (stage 4), the outputs from the analog multiplexer are connected to the analog-to-digital converter (ADC) to convert the analog signal into digital and transmit it to the researcher's PC, where the system data accumulation module is organized. In this work, an NI USB-6009 data collector (NI-DAQmx ADC driver, version 8.6) is used as an ADC. It connects to a computer via a full-speed USB interface and contains eight analog signal input channels, two analog signal generation channels, 12 digital I/O channels, and a 32-bit counter. To visualize the results of the study of a human expiratory sample and create a database of clinical material, it is necessary to install the selected application software of the information system on the PC.

The system allows registering signals based on the concentrations of chemical components of exhaled air, graphically displaying the dynamics of changes in sensor signals in real time, saving all information to a database. The input transducer of the complex includes selective electrochemical

sensors sensitive to O₂, NH₃, CO₂, NO, NO₂, H₂S, HF [22].

V. STUDY OF THE EXPIRATORY AIR OF PATIENTS WITH LUNG CANCER

With the help of the developed complex, a study was conducted of patients from the National Cancer Institute and conditionally healthy individuals with National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" [14].

The analysis included two groups: 20 sick individuals and 11 practically healthy individuals. The total sample consisted of 31 subjects, including 17 men and 14 women. All measurement data are divided into two groups: a group of patients (conditionally with lung cancer) 20 people (64.5%), of which 10 men (50.0%) and 10 women (50.0%), the control group is 11 people (35.5%) of them 7 men (63.6%) and 4 women (36.4%), the Table 2 shows the difference between these groups [14].

Table 2. Study groups with sick and conditionally healthy, average age by group

Diagnosis	Men n (%)	Women n (%)	Total n (%)	Average age years	Min years	Max years
Group with patients	10 (50)	10 (50)	20 (64,5)	53,58	33	68
Control group	7 (63,6)	4 (36,4)	11 (35,5)	60,64	51	76
Total	17 (54,8)	14 (45,2)	31 (100)	57,11	42	72

The collection of expiratory air samples took place in the primary examination room of patients with the consent of the subjects and in the presence of an oncologist, on the basis of the National Cancer Institute. Patients with lung pathology were selected for the study:

- 4 patients – with a confirmed diagnosis of lung cancer,
- 14 patients – with a preliminary diagnosis of lung cancer,
- 2 patients – breast cancer with lung metastases.

The air exhaled by the patients is a sample for further analysis. Subsequently, the package with the sample was attached to the sampler of the complex. During pumping into the sampler, expiratory air passed through a set of electrochemical selective

sensors: O₂, NH₃, CO₂, NO, NO₂, H₂S, HF. In the sampler system, for 60 seconds, the sample was analyzed, after which the feedback from the sensors was recorded into the database using an analog-to-digital converter. The following information was also recorded in the database: gender, age, weight, symptoms, presence of other diseases. For each patient and person in the control group, digital responses of seven sensors were stored in the database, which were measured within one minute. The collected data was analyzed and processed using statistical analysis using some of the IBM SPSS Statistics 22.0 software packages.

Descriptive statistics of the data obtained from the selected sensors have been carried out and described in Table 3. The Kolmogorov-Smirnov test was used to check the data for normal distribution. And it was found that all sensor signals except oxygen (O₂) correspond to the normal distribution.

Table 3. Descriptive statistics of electrochemical sensor feedback

Diagnosis	Sensor	Min	Max	Average	Std. deviation
Group of patients	O ₂ , μA	-1,906	1,247	0,051	1,073
	NO ₂ , μA	-1,519	1,251	-0,089	0,773
	NH ₃ , μA	-2,636	1,197	-0,204	1,019
	NO, μA	-1,579	0,707	-0,403	0,752
	HF, μA	-1,398	1,198	-0,487	0,763
	H ₂ S, μA	-1,347	2,256	-0,039	0,942
	CO ₂ , μA	-1,630	0,776	-0,401	0,709
Control group	O ₂ , μA	-1,906	0,435	-0,088	0,902
	NO ₂ , μA	-1,429	2,412	0,154	1,335
	NH ₃ , μA	-0,720	2,310	0,352	0,902
	NO, μA	-0,436	2,486	0,696	1,020
	HF, μA	-0,133	2,397	0,841	0,790
	H ₂ S, μA	-1,060	2,501	0,067	1,139
	CO ₂ , μA	-1,099	3,106	0,693	1,077

VI. ANALYSIS OF SIGNALS FROM SENSORS AND DETERMINATION OF CORRELATION

Within the study groups (20 people with lung cancer and 11 practically healthy people), the differences between the obtained indicators of electrochemical sensors of patients examined and those of practically healthy people were compared. The differences in expiratory air values are summarized in Table 4. The analysis of differences in expiratory indices values revealed a statistically significant difference in three indices.

Table 4. Analysis of differences in expiratory air values

Sensor (indicator)	Group of patients with lung cancer	Control group	p
O ₂ , μA **	0,05 ± 1,07 (-1,90598; 1,24711)	-0,09 ± 0,9 (-1,90598; 0,43519)	0,722
NO ₂ , μA	-0,09 ± 0,77 (-1,51877; 1,25073)	0,15 ± 1,34 (-1,42940; 2,41187)	0,530
NH ₃ , μA	-0,2 ± 1,02 (-2,63586; 1,19657)	0,35 ± 0,9 (-0,71963; 2,30984)	0,145
NO, μA	-0,4 ± 0,75 (-1,57929; 0,70728)	0,7 ± 1,02 (-0,43625; 2,48555)	0,002*
HF, μA	-0,49 ± 0,76 (-1,39819; 1,19844)	0,84 ± 0,79 (-0,13318; 2,39689)	0,000*
H ₂ S, μA	-0,04 ± 0,94 (-1,34682; 2,25562)	0,07 ± 1,14 (-1,06032; 2,501251)	0,796
CO ₂ , μA	-0,4 ± 0,71 (-1,62986; 0,77647)	0,69 ± 1,08 (-1,09867; 3,10611)	0,002*

For HF hydrogen fluoride ($p = 0.000$), NO₂ nitric oxide ($p = 0.002$) and CO₂ carbon dioxide ($p = 0.002$), the average value between patients and practically healthy people differs significantly [14].

A possible factor influencing the registered changes, a decrease in the levels of CO₂ and NO in the expiratory air of patients with lung cancer and practically healthy people, may be disturbances in the oxide metabolism of the body of patients with lung cancer. Regarding changes in HF, permit plan to carry out additional studies to interpret the results obtained.

Based on the results of using correlation analysis for sensors O₂, NO₂, NH₃, H₂S, a moderate positive relationship of high significance was found between the levels of NH₃ and NO₂, as well as NH₃ and H₂S. Note that there is no correlation between CO₂, NO and HF sensors.

The next analyzed issue is choosing the method for building the mathematical model. The group method of data handling (GMDH) was chosen for the construction of mathematical models. Using the combinatorial algorithm GMDH – COMBI, with a full enumeration of variants of the model structure, permit to find the best one [23, 24]. Practically, were tried several variants of combinations of indicators, which on the exam showed a high probability of

determining the presence of an oncological disease in a person.

The mathematical model (classifier), which included only symptoms and age, showed a low percentage of definition, which indicates the need to include chemical indicators of the model. They also considered the option of constructing a mathematical model without indicators of symptoms, but with indicators of chemical sensors – they received a negative result. Considering the practical enumeration of the inclusion of various indicators in the structure of the model, obtain a second-order mathematical model, as in Eg. (1).

$$\begin{aligned}
 Y_1 = & -3,970 + x_1 \cdot 0,147 + x_1 \cdot \\
 & x_3 \cdot 0,003 - x_1^2 \cdot 0,001 - x_2 \cdot \\
 & 1,308 - x_2 \cdot x_3 \cdot 0,199 - x_2 \cdot x_4 \cdot \\
 & 0,176 - x_3 \cdot 0,119 - x_3 \cdot x_4 \cdot \\
 & 0,014 - x_3^2 \cdot 0,009 - x_4 \cdot 0,054 - \\
 & x_4^2 \cdot 0,002.
 \end{aligned} \tag{1}$$

where x_1 – the patient's age;
 x_2 – symptoms (presence of cough, shortness of breath, chest pain);
 x_3 – indicator of the chemical sensor HF;
 x_4 – value of the chemical CO₂ sensor.

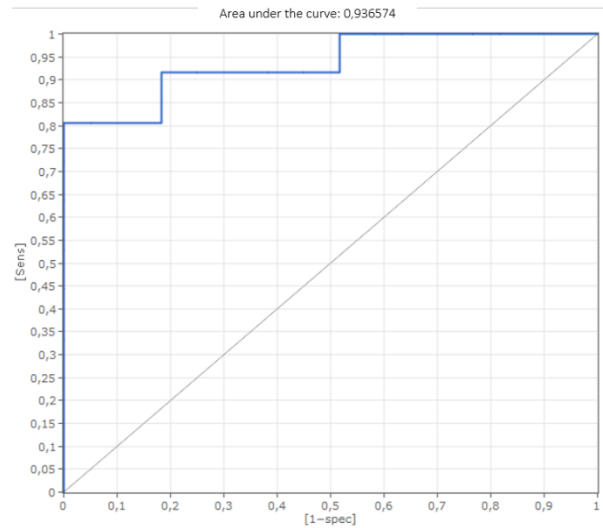
The quality of the model, as in Eg. (1), was assessed in terms of sensitivity and specificity, calculated on the training (80% of the sample) and examination (20% of the sample) samples are shown in Table 5.

Table 5. Assessment of the quality of the results of modeling the classifier (1) for the detection of indicators in the expiratory air

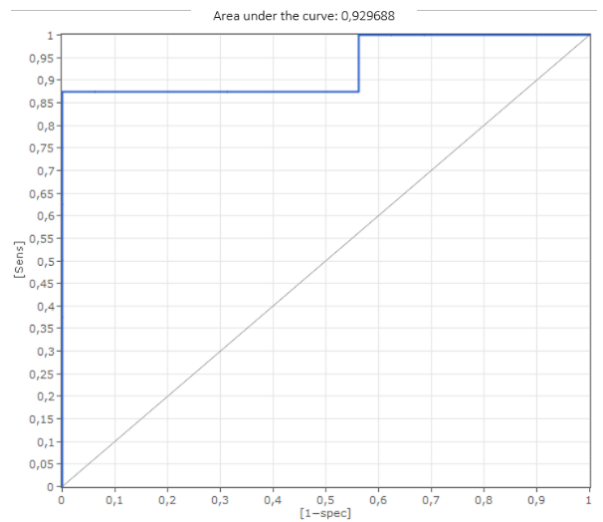
	Training	Exam
Sensitivity	0,950	0,938
Specificity	0,806	0,875
Accuracy	89,6%	91,7%

ROC curves are also presented in Fig. 3, which reflect the quality of the classifier for patients with possible lung cancer. The area

under the ROC-curve on the training sample is 0.937, on the examination sample – 0.929.



a) for training sample (AUC = 0,937)



b) for training sample (AUC = 0,929)

Fig. 3. ROC curves reflecting the quality of the mathematical model (1)

For comparison, present a classifier that includes the indicators of only two NO and CO₂ sensors; a first-order mathematical model is obtained, as in Eg. (2).

$$\begin{aligned}
 Y_2 = & -2,441 + x_5 \cdot 0,143 + x_4 \\
 & \cdot 0,055.
 \end{aligned} \tag{2}$$

where x_4 – indicator of the chemical CO₂ sensor;

x_5 – value of the NO chemical sensor.

The quality of the model (2) was assessed in terms of sensitivity and specificity, calculated on the

training (80% of the sample) and examination (20% of the sample) samples are shown in Table 6.

Table 6. Assessment of the quality of the results of modeling the classifier (2) to identify indicators in the expiratory air

	Training	Exam
Sensitivity	0,938	1,000
Specificity	0,875	0,667
Accuracy	97,7	83,3%

ROC curves are also shown in Fig. 4, which reflect the quality of the classifier for patients with possible lung cancer. The area under the ROC curve on the training sample is 0.929, on the examination sample – 1.0.

After analyzing the quality assessment of the modeling results of the classifiers (1) and (2), let's

obtain different accuracy on the examination sample: according to the classifier (2), the determination accuracy is much lower (by 8.4%) and specificity as well.

According to the classifier (1), we are considered it working, since it includes not only the indicators of sensors as a classifier (2), but also indicators of symptoms. The developed models are used in the software part of the system to create a system for automated risk assessment of lung cancer.

The general architecture of the developed software and hardware complex has several main components: a hardware module, an analog-to-digital converter, and a data storage module, are shown in Fig. 5.

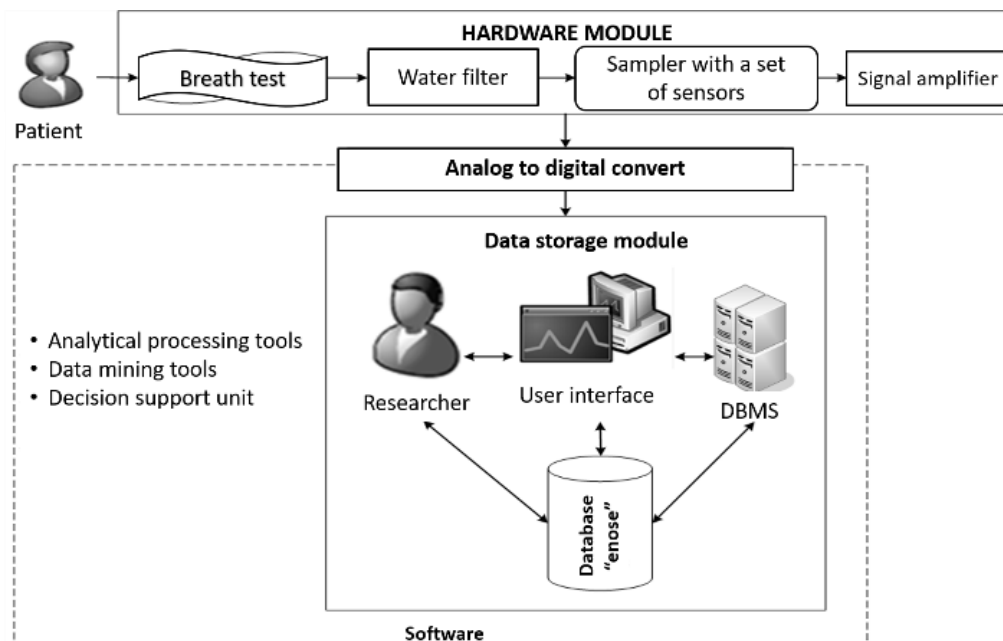
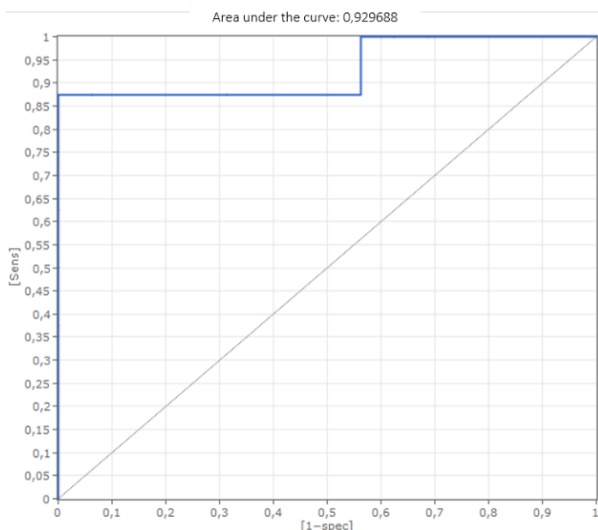
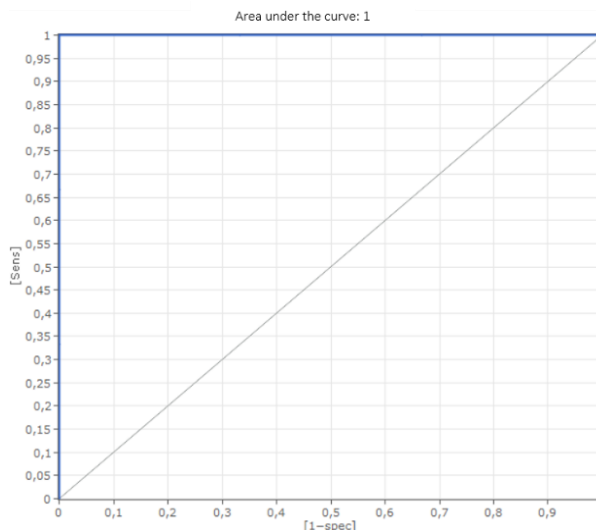


Fig. 5 Architecture of the software and hardware complex



a) for training sample (AUC = 0,929)



b) for training sample (AUC = 1,0)

Fig. 4 ROC curves reflecting the quality of the mathematical model (2)

VII. CONCLUSIONS

The peculiarities of the formation and development of a complex, which includes electrochemical sensors, is that it is necessary to find a special set of such chemical elements, the pattern of which should correspond to the disease and show the need for treatment or its absence.

Thanks to the proposed technology and the implementation of the mechanism of the technique, organized on the basis of a combination of technical means, chemical elements and an approach to the development and analysis of data, four main elements were identified that can signal the presence of cancer cells in the human body: the patient's age, symptoms, an indicator of chemical sensors HF and CO₂. This indicates the possibility and need to improve the methodology, conduct new research, and improve the material and technical base with the upcoming bringing the technology to the industrial level.

The paper shows the relevance of using the method of group consideration of arguments in the development of mathematical models for diagnostic systems. Its application made it possible to obtain several classifiers, to analyze the sensitivity and specificity of each. The decision was finally made to use a second-order classifier, which showed the general sensitivity of the model on the examination (control) sample of 93.8%, specificity of 87.5% and the total percentage of correctly predicted values of 91.7%.

Based on the research results, the architecture of the hardware-software complex for the diagnosis of oncological diseases is presented, evaluates, and analyzes the expiratory samples of a person, and can be used for early diagnosis of lung diseases. The structure of the complex is quite simple, which allows to change

the set of sensors and adapt it for the diagnosis of other diseases.

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ПРОГРАМНО-АПАРАТНИЙ КОМПЛЕКС ДІАГНОСТИКИ ЕКСПІРАТОРНИХ ПРОБ ДЛЯ ВИЯВЛЕННЯ ОНКОЛОГІЧНИХ ЗАХВОРЮВАНЬ

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Реферат – Проаналізовано тенденції розвитку методів і засобів ранньої діагностики онкологічних захворювань. Показано, що успіх лікування онкохворих великою мірою залежить від своєчасного виявлення цієї патології. Оскільки онкологічні захворювання виявляються у все більшій кількості населення і не лише на території України, але й за її межами. Наукові дослідники з усього світу намагаються розробити та віднайти метод діагностики, який на етапі появи онкоклітин сигналізуватиме про необхідність обширного медичного огляду. Обґрунтовано необхідність створення скринінгових систем, що забезпечують експрес-діагностику патологій для реалізації масових профілактичних обстежень. Запропоновано, у якості датчиків, використовувати набір селективних газоаналізаторів амперметричного типу, що мають достатню чутливість і не вимагають витратних матеріалів для їх відновлення. Розроблено програмно-апаратний комплекс для аналізу експіраторних проб пацієнтів на основі сенсорів O₂, NH₃, CO₂, NO, NO₂, H₂S, HF. Приведено результати обстеження групи хворих раком легень та контрольної групи (умовно здорових). Проаналізовано статистику результатів вимірів концентрацій газових компонентів у видиху обстежуваних, яка підтвердила можливість виявлення раку легень на основі хімічного аналізу експіраторних проб. До статистичних результатів включено сім записів від електрохімічних сенсорів, стать, вік, вага, наявність симптомів або інших хронічних захворювань обстежуваного. За результатами проведеного дослідження встановлено три основних хімічних елемента, які сигналізують про наявність ракових клітин в організмі пацієнта. Завдяки цьому стало можливим далі розвивати запропонований метод та підбирати інші хімічні елементи, які можуть вказувати на наявність онкоклітин у людини. Таким чином, є підстави стверджувати про актуальність підбору хімічних компонентів, які є в експіраторному повітрі людини, для виявлення інших захворювань, таких як цукровий діабет, цироз печінки, серцево-судинні захворювання тощо.

Ключові слова: онкологія, електронний ніс, селективні газові сенсори, статистичний аналіз, профілактика раку.

ПРОГРАММНО-АППАРАТНЫЙ КОМПЛЕКС ДИАГНОСТИКИ ЭКСПИРАТОРНЫХ ПРОБ ДЛЯ ВЫЯВЛЕНИЯ ОНКОЛОГИЧЕСКИХ ЗАБОЛЕВАНИЙ

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Реферат – Проанализированы тенденции развития методов и средств ранней диагностики онкологических заболеваний. Показано, что успех лечения онкобольных в большой степени зависит от своевременного выявления данной патологии. Поскольку онкологические заболевания проявляются у все большего числа населения и не только на территории Украины, но и за ее пределами. Научные исследователи со всего мира пытаются разработать и найти метод диагностики, который на этапе появления онкоклеток сигнализировал о необходимости обширного медицинского осмотра. Обоснована необходимость создания скрининговых систем, обеспечивающих экспресс-диагностику патологий для реализации массовых профилактических обследований. Предложено использование, в качестве датчиков, набор селективных газоанализаторов амперометрического типа, обладающих достаточной чувствительностью и не требующих расходных материалов для их восстановления. Разработан программно-аппаратный комплекс для анализа экспираторных проб пациентов на основе сенсоров O₂, NH₃, CO₂, NO, NO₂, H₂S, HF. Приведены результаты обследования группы больных раком легких и контрольной группы (условно здоровых). Проанализировано статистику результатов измерений концентраций газовых компонентов в выдохе обследуемых, которая подтвердила возможность выявления рака легких на основе химического анализа экспираторных проб. К статистическим результатам включено семь записей от электрохимических сенсоров, пол, возраст, вес, наличие симптомов или других хронических заболеваний обследуемого. По результатам проведенного исследования установлено три основных химических элемента, которые сигнализируют о наличии раковых клеток в организме пациента. Благодаря этому стало возможным дальше развивать предложенный метод и подбирать другие химические элементы, которые могут указывать на наличие онкоклеток у человека. Таким образом, есть основания утверждать об актуальности подбора химических компонентов, которые есть в экспираторном воздухе человека, для выявления других заболеваний, таких как сахарный диабет, цирроз печени, сердечно-сосудистые заболевания и другие.

Ключевые слова: онкология, электронный нос, селективные газовые сенсоры, статистический анализ, профилактика рака.