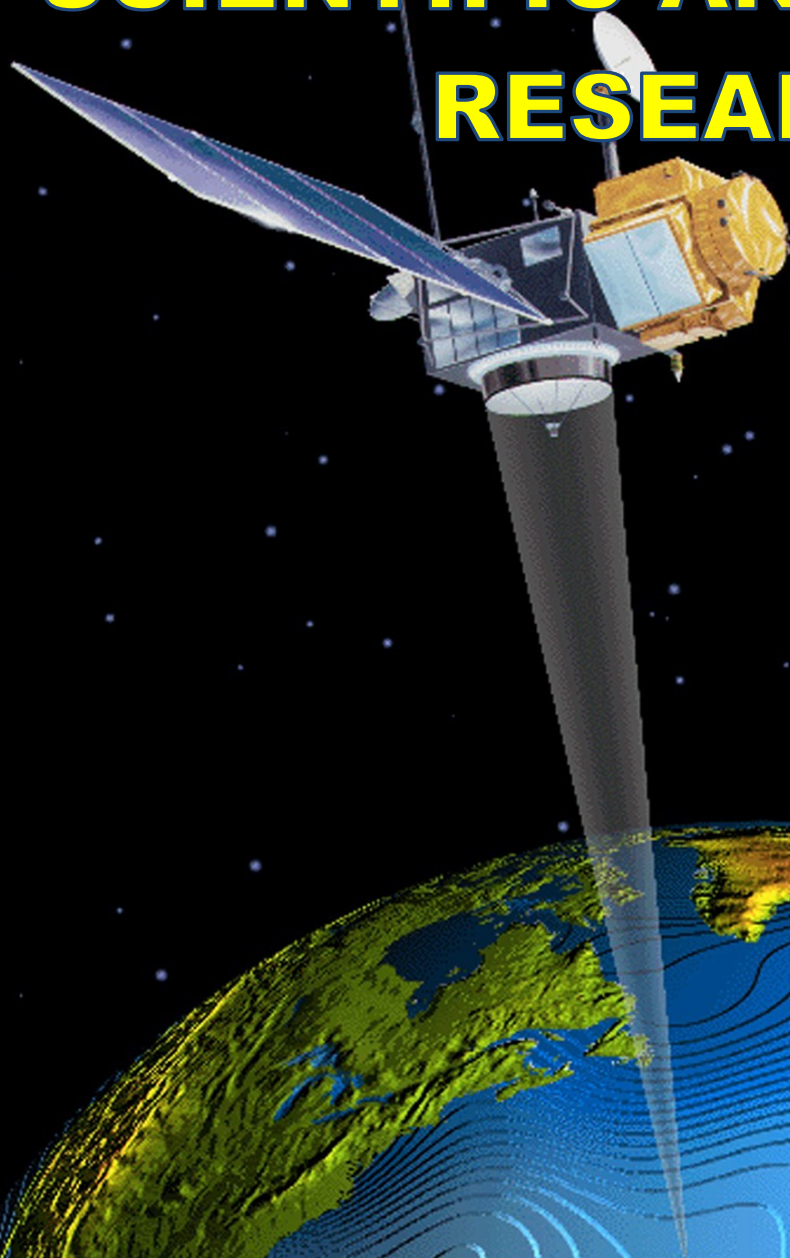


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Original Contribution

TIMELINESS OF THE SCIENTIFIC AND APPLIED RESEARCH

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Abstract: The contemporary science is developing with extremely fast pace. The current material emphasizes on the timeliness of the scientific job and the scientific and applied research. Special attention is being paid of the "inner" and "outer" motivation of the scientists when choosing the problems and the approach of the methodology in the scientific research. The role of the scientific leader has been defined as a highly knowledgeable person who knows the trends in the scientific development, the market needs and who is very well prepared to look in advance into current problems and niche markets.

Key words: scientific and applied research

The scientists are the most important and identifying factor for the development of science. Scientists have always played a crucial role in the scientific development and scientific and technological progress but in the current stage their role and responsibility seem to increase as to the humanity and earth survival. It is enough to mention nuclear energy production and the probability of a nuclear war, laser technology and the threat of "star wars", genetic engineering and the threat of creating new bacteriological weapon, the mass industrialization and the threat of ecological catastrophe.

The paper gives a professional characteristic of the scientist. However, this is a very difficult task because of the complexity and diversity of the scientific research which are defined by the differences

in the scientific research in the different branches of science, by the different character of the job in the consequent stages of the cycle "research – application" (fundamental research, applied development, designer-constructor and technological activity), by the different position which the scientist occupies in the hierarchy of the organization (scientific leader, scientific organizer, scientific researcher, etc.) The personal qualities of the scientist, their talent and qualification, their way of thinking, inner and outer motivation for scientific creativity have a great influence on the success of the scientific process.

The contemporary science is characterized by a more profound differentiation [2]. It's difficult to enumerate the subjects and the

specialties in the different sciences because they are constantly increasing. Differentiation ensures going deeper when researching the facts and laws in the certain processes and phenomena and is a reason for the great progress in the scientific knowledge. It requires the contemporary scientist to be a good narrow specialist. The era of the universal scientists, of the Aristotles in the science, has gone away a long time ago. At the same time, there is a controversy between the integrity and complexity of the processes and phenomena. It is necessary to strengthen the integration links between the different sciences, subjects and specialties when researching complex processes and phenomena. It is not a coincidence that the new important discoveries are made in the cross sciences like physical chemistry, biochemistry, biophysics, molecular genetics, etc. To understand the complexity of the phenomena, to effectively take part in the integration relationships, the scientists must have broad fundamental knowledge as well. Consequently, the contemporary scientists should incorporate the good narrow specialization with broad fundamental base. At the same time, the narrow specialists cannot be universal specialists, regardless of their broad fundamental knowledge. The function of the universal specialist is taken successfully by the scientific team which integrates different narrow specialists.

The contemporary science is characterized by the changes and

complications of the methodology of the scientific knowledge. The scientific researchers have to be able to use complex technology and appliances which are getting more and more broadly used in the research activities. The mathematization and cybernation of all sciences, the use of computers in the experiments and the processing of the results, the mathematical modeling of the natural and social processes make it necessary to know the basics of all these methods by every contemporary scientist.

Science as a social system is developed by its own internal laws. They define the “inner motivation” of the scientists when choosing the problems and the methodological approach in the scientific research. All these internal laws should not be overlooked. Their significance can be an obstacle for the scientific progress. The contemporary science is only a part, a subsystem from a bigger system – society and its development, functions and tasks are defined by the relationships with this greater social system.

Having in mind the necessity to develop, the society forms its social contracts with science, i.e. there is an “outer motivation” in the selection of the problems, approaches and the methodology of the scientific research.

At the moment the institutionalization of science is increasing at a great speed and rate. Science is becoming an object of social management by government and other organs. A government

policy is formed in the science, i.e. the role of “outer motivation” increases in its development. It was only in the past when university professors, together with their lecturing and teaching practice, took part in scientific research on subjects which they wanted, as we can say “to satisfy their scientific curiosity”. The contemporary scientists should get used to working on the basis of preliminary prognoses, to consider the existing scientific organization, to be able to see the basic and complex problems which are extremely important for the society development, to be able to clearly identify the goals of their scientific research. They have to be ruled by the “inner”, as well as by the “outer” motivation in their jobs. Neither of them should be underestimated. The correlation between them is basically defied by the character of the scientific research. This way the end of the cycle “applied research – experimental – construction development – implementation” can bring the beginning of new research.

Science has turned into a direct production power and it has become a vital factor for the technical, economic and social progress. The cycle “research – applied development – implementation” is greatly shortened. The fast implementation into practice of national and foreign scientific results becomes very up-to-date and is the main goal of the currently continuing reorganization in the structuring and management of the scientific front – a new economic mechanism and

programming structuring in the science, the increase of the contract financing of the scientific research, etc. this brings new elements in the professional characteristic of the contemporary scientist. Regardless of the fact that there are scientists constructors, technologists, implementers, every scientist should include the implementation method of thinking, to seek and foretell a possible implementation of the results in reality, to participate in the development and implementation, to search multiplication of the effects. It is necessary to create such psychological attitude and such way of thinking and activity. We can point out many positive examples of such changes in Bulgarian Academy of Sciences during the recent years.

A basic moment in the professional characteristic of the contemporary scientist is that he has to be able to work as part of a team. [1]. The team method of scientific research is becoming more popular because of the deepening differentiation and the necessity of effective integration links between the “narrow specialists” when getting to know the complex phenomena in nature and society. The scientific collective ensures “the broad specialist” with deep knowledge in many “narrow” scientific subjects, universal methodical and methodological preparation and better information which are necessary when scientifically solving the problem. The lonely inventors and the “Edissons” in the science are now in the past. The scientific collective is

turning into a collective subject of the scientific research and gradually takes the role of the individual subject in this respect. [5].

The work of the scientific collective brings many significant changes in the professional characteristic of the scientist researchers. Depending on their role in the research process, they can become methodologists, experimenters, theorist, etc. The scientist experimenters in the contemporary collective should maintain themselves as creative people. And this is the reason why regardless of the division of labor in the research process in the collective, they should have certain qualities and knowledge of a methodologist, experimenter, theorist, etc.

There are complex relationships and links among the three basic types of scientists who participate in the research process (scientific leader, scientific researcher and scientific organizer) as well as among the scientific researchers among themselves. One of the most discussed problems is the contradiction and the unity of the individuality and the collectiveness in the creative process of the collective. Undoubtedly, the scientists in the scientific collective should sacrifice part of its individuality, to put it under the control of the aims and goals of the collective and the division of labor in it. At the same time the collective, with its conditions of tasks, with the competency of the separate scientists and rich methodological and informational possibilities, is the

place where the individual creative skills can be fully developed. What is more, the participation in collective “brain attacks”, “expertise evaluations”, “conferences of ideas”, etc. creates a specific beneficial environment for such development. The question is for the personal estimation of the achievement of the separate scientist in the collective. Every scientist pursues demonstration, approval and social respect. This is one of the drivers in their creative activity. Some methods of estimating the activity of the scientists do not stimulate their participation in collective tasks. For example the fact is emphasized in how many scientific papers the author is the only one or the first author in the reports for habilitation.

The job of the scientific leaders of the scientific collective is very responsible. They have to be very knowledgeable, to know the trends in the scientific development, the social necessities of the scientific provision of its development, to have a broad preparation which enables him to see the “big picture” and the links among its aspects, to have analytical, synthetical and heuristic skills, to be honorable scientists, to have self-criticism towards their own work and towards the collective work which they manage, to be able to work with people and evaluate them objectively, to create prerequisites for democracy and tolerance to the different opinion which do not coincide with their own and which are highly important for the science.

With the institutionalizing of the science, the role of the scientific organizers has increased dramatically. The skills which the scientific organizers have to possess mean that they have to be selected amongst the scientists. Science is being managed, it is not administered. It is true that with program structuring of science, the manager of the scientific program and of the program collective combines the characteristics and activities of the scientific leaders and the scientific organizers. They have to be prominent scientists and at the same time very good specialists in the sphere of the scientific organization of the scientific research.

It is impossible to create science in isolation, within the borders of one country. Science is constantly internationalizing, regardless of the fact that there are big differences in the statute of the science and scientists in the different countries [4]. International scientific cooperation becomes necessary for its development. The contemporary scientists should know foreign languages in order to be able to communicate with their colleagues abroad. This requirement is specifically valid for small countries like Bulgaria. It is a fact that about 99% of the whole world scientific information is in foreign languages. On one hand, international cooperation is necessary for the scientific development and experience exchange and on the other hand – the turning of the science into a direct productive power and the shortening of the cycle “research – applied

development – implementation” force the scientific organizations and their management to keep the results with greater economic value secretive so that later they can copyright them and obtain the greatest profit out of their implementation in life. International competition in the economy becomes competition in science. International cooperation should follow strictly “the rules of the game” of the international economic cooperation. Consequently, when announcing their scientific results, the scientists should take into consideration not only their wish to show their colleagues what they had achieved, to ensure priority in science but also they have to take into account their countries’ interests.

The relationship between stability and mobility takes an important place in the scientists’ characteristics. Mobility in science is more dynamic and stronger in comparison with the other jobs and it continues to increase significantly.

There has always been professional mobility amongst the scientists. For example Mayer graduated medicine but he discovered the law of energy conservation; Pasteur is a chemist who started with crystallography and later he created classical microbiology, immunology and sets the basics of the classical biotechnologies [3]. But professional mobility in the past was not so popular. Its increase in the contemporary situation is determined by the fast differentiation of science and by the need of the scientists to regroup in order to solve certain

problems for a short time. The differentiation of science leads to the creation of new sciences and scientific branches on the borders between two or more existing sciences (interdisciplinary sciences and subjects).

Their formation and initial development is done by scientists from existing sciences and branches owing to the professional mobility of these scientists who change their subjects or specialty. More often this so called horizontal professional mobility is done by the change of the narrow specialty (for example a physiologist with basic medicine education becomes a biochemist, pharmacologist, immunologist or internist) but also it is not rare that they change the basic specialty (for example molecular biologists become scientists with different university education: biologists, medicals, physicists, chemists).

The broadened mobility of the scientific workers is dictated by the necessity to regroup in problem or program collectives in order to solve certain problems. This mobility is often connected with change of the work place and with the formation of new organizational structures. It can affect not only the single person but also whole collectives.

The scientists' mobility can also be done in vertical direction, in change of the position which the scientist occupies in the management hierarchy of the scientific research. The scientist can become scientific leader or scientific organizer or vice versa. The professional mobility of

the scientists is necessary for the contemporary science and it will go further and deeper with its future development. It creates favorable conditions for increasing the efficiency of the scientific research. But of course, not every mobility is justified and useful. One should not go into extremes and mobility should not be absolutized. Only the reasonable mobility of the scientists is beneficial and useful. The excessive and unnecessary mobility can lead to the opposite effect – decrease of efficiency of the scientific research and slowing down the scientific development.

Therefore an important moment in the scientists' characteristics is their ability and psychological attitude to professional mobility. It requires the contemporary scientists to combine their narrow preparation with general and broad fundamental knowledge. The preparation of scientists should be in compliance with the prognoses for development and differentiation of science and the advantage is being given to newly developing branches.

These are generally the characteristics of the contemporary scientists. The problem of the preparation of these scientists is not of less importance. It can be discussed in a different paper and here only some of the points will be mentioned.

The production of scientific workers becomes one of the basic problems of the contemporary society which is being regulated and solved in a scientific manner by the scientific organizations. A key moment in the

human resources policy is the selection of young people who had shown certain skills that are needed for scientific work. The process should begin from the university (diploma work) and with the active participation of professors in order to start the creative activity of these young people and to ensure possibilities for demonstration of their talents. The contestant principle when selecting young scientists should be introduced everywhere. It eliminates the chances of subjectiveness. The urge should be streamed towards elimination of the current weaknesses and disadvantages of the contestant system which has to be improved and not restricted or annulated. In order to increase the quality of the scientific workers and their effective use, all newly hired scientific associates, assistants and specialist with university education in the scientific organizations and organizations for scientific services and implementation, should be selected by a contest.

The limited volume of the paper does not allow the problems for postgraduation role, educational courses, the continuous seminars, youth schools, individual qualification, national and foreign specialization, language qualification, doctor's dissertation, scientific reviews and scientific discussions, etc. for the preparation of contemporary scientists, for intensive development of the scientific potential of the personnel. It is necessary to emphasize that highly qualified scientists are prepared basically in the

stationary scientific organizations. Many documents are right in emphasizing the importance of the quick professional and language qualification and long-term specializations with priority for the young scientific personnel. This is a leading principle in the human resources policy of the Bulgarian Academy of Sciences. The Academy developed and implemented a system for selection and qualification of young scientists and specialists with university education according to which all newly hired young people are given the conditions of qualification and evaluation which are very similar to these of the postgraduation conditions. It is a pity but it can be concluded that the situation with the young people in the Bulgarian science is not very satisfying. The percentage of young habilitated scientists is very small.

Science is a very dynamically developing system. Even the most qualified and knowledgeable scientists will fall behind if they do not make constant efforts for their improvement. Rendering the priority to the qualification of young scientists, this fact should not be oblivionized.

The talented scientists can demonstrate their abilities only when there is a high general scientific level of the collective. This is the reason why the differentiated fast qualification of the talented young scientists should be combined with the increase of the general scientific level of the whole collective.

However good and effective the system for selection and qualification of the scientists in the scientific organizations is, still there are a number of people who are not capable of scientific work. So the problem is what can be done to improve the effective selection system and to release the “plain masses” in science. Practice has shown that it is extremely difficult, especially with scientific workers with many years of work experience. There are many factors involved, including social ones. It is easier to get rid of incapable people at the beginning of their work. The system of attestation of the personnel provides a mechanism for releasing of incapable scientific workers even in later periods of their work experience. It is a pity that both regulated mechanisms for selection do not operate properly for the time being.

Of course, we can think of other methods for selection: periodical dismissal and redirecting of part of the personnel in every branch, economic forces by limiting the salary, etc. but according to the author the current mechanism are good as long as they are put into practice. The problem could be solved by working with these scientists (especially the managers) to change their psychological attitude and elimination of the possible subjectiveness when solving the problem. .

It can be concluded that striving for high quality and efficiency of the scientific research is impossible without the preparation of highly qualified and active personnel whose professional characteristics correspond to the requirements of the contemporary science.

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Original Contribution

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METHOD FOR SYNTHESIS OF LARGE FAMILIES OF SIGNALS WITH LOW CORRELATION

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Abstract: In the paper a new method for synthesis of large families of signals with low auto- and cross-correlation is presented. It is based on the known method for generation of Gold sets but is not related to a certain value of the decimation coefficient d . As a result it allows generating of families, consisting of p -ary M -sequences, for arbitrary values of p and the degree of their characteristic equation.

Key words: synthesis of signals, family of signals with low periodic correlation.

1. Introduction

Sequences with low periodic correlation (LPC) find many applications in radars and wireless communications for synchronization and for providing the simultaneous work of multiple users with low mutual interference. With regard methods for synthesis of families of signals with LPC have been researched from many authors for the last several decades [1] – [19].

In this paper a new method for creating of large sequence sets with LPC is presented. It is based on the known method for generation of the so-named *Gold sets* [1], [19], but is more general. The main advantage of the method is that it is not related to a certain value of the decimation coefficient d . Therefore it is applicable for all p -ary M -sequences independently of the values of p and the degree n of their characteristic equation.

The paper is organized as follows. First, the basics of the synthesis of the M -sequences are recalled in Section 2. After that in Section 3, a new general method for synthesis of phase manipulated (PM) signals, possessing both low level of the lobes of the periodic auto- and cross-correlation is suggested. Conclusions of the paper are summarized in Section 4.

2. Basics of the synthesis of the M -sequences

The linear recurring sequences (LRS) find wide implementation in many fields, especially for information protection and in communications [1], [2], [3], [11], [18], [19]. Due to this reason they have been extensively studied since 50th years of the 20th century.

LRSs are created by means of a linear recursive equation (LRE), which can be expressed as [19], [20]:

$$(1) \quad u(i) = a_{n-1}u(i-1) + a_{n-2}u(i-2) + \dots + a_0u(i-n)$$

where:

- $u(i)$ is the new i -th element of the LRS;

- $u(i-1), u(i-2), \dots, u(i-n)$ are elements of the considered LRS, obtained during the previous steps of the LRE (1) (the initial elements $u(0), u(1), \dots, u(n-1)$ should be known);

- $a_{n-1}, a_{n-2}, \dots, a_0$ are coefficients, belonging to a finite algebraic field (named *Galois Field* (GF)) and all algebraic operations in (1) are performed in $GF(p^m)$ (i.e. modulo p , where p can be an arbitrary prime integer).

After the substitution $u(i) = x^i, i = 0, 1, 2, \dots$, (1) is transformed into the so-named *characteristic equation* (noted often as *the connection polynomial* of the linear feedback shift registers (LFSRs), which are the hardware, realizing the LRE (1)):

$$(2) \quad x^n - d_{n-1}x^{n-1} - d_{n-2}x^{n-2} - \dots - d_0 = 0$$

If the left side of the characteristic equation is a primitive irreducible polynomial over $GF(p^m)$, then the period of the LRS is maximal, namely $N = (p^m)^n - 1$ and it is called *maximal length sequence* (M -sequence) [19], [20].

In communications the M -sequences are used for controlling

the phase modulation of the PM signals. Due to the symmetric connection the derivative PM signals are named M -sequences also. The main advantage of these signals is that their periodic autocorrelation function (PACF) is almost perfect, because the level of the side-lobes is constant and equal to -1 [19], i.e.:

$$(3) \quad P_{\zeta\zeta}(r) = \sum_{i=0}^{N-1} \zeta(i) \cdot \zeta^* \langle i+r \rangle = \begin{cases} N, & r = 0, \\ -1, & r \neq 0. \end{cases}$$

In (3) $P_{\zeta\zeta}(r)$ is the PACF of the M -sequence $\{\zeta(i)\}_{i=0}^{N-1}$, r is the time shift, the symbol “ $\langle \rangle$ ” means “summing modulo p ”, and symbol “ $*$ ” – “complex conjugation”.

The complex envelopes of the elementary phase impulses (chips) of the PM signal are described with the following equation (or *coding rule*):

$$(4) \quad \zeta(i) = \exp \left[j \frac{2\pi m}{p} u(i) \right], \quad j = \sqrt{-1}, \\ 1 \leq m \leq p-1, \quad i = 0, 1, 2, \dots, N-1, \dots$$

Here $u(i)$ are the elements of the M -sequence, controlling the phase modulation [18], [19].

Another important advantage of the PM signals, which are M -sequences, is that their length can be arbitrary long even though the size of the signal alphabet is small. This feature is essential if longer sequences are required.

3. Method for synthesis of large families of signals with low correlation

Key feature of the methods for synthesis of signals for the present communication systems is the possibility for synthesis of families (sets) of signals, possessing both periodic auto- and cross-correlation functions with small level of the side-lobes. These conditions can be mathematically described as follows. Let $\Phi(K, N, C)$ be a set of K signals with period N and with maximal level C of the auto- and cross-correlation lobes:

$$(5) \quad C \leq \eta \sqrt{N}$$

Here η is a coefficient with relatively low value. In this case $\Phi(K, N, C)$ is named *family of signals with low periodic correlation (LPC)* [19], [20], [21].

The known methods for generation of M - sequences with low cross-correlation are based on the principle of the permutation of a M -sequence or the so - named *decimation* [1]-[19]. Let we have a sequence $\{\xi(i)\}_{i=0}^{N-1}$ with ideal PACF, similar to a delta pulse. Then the derivative signals $\{\xi_k(i)\}_{i=0}^{N-1}$, obtained by the rule:

$$(6) \quad \xi_k(i) = \xi \langle d_k \cdot i \rangle_{\text{mod } N}, \\ i = 0, 1, 2, \dots, N-1, \dots$$

have also ideal PACF [1] - [19]. Here the decimation coefficients $d_k, k = 1, 2, \dots, N_t$ are the all possible

positive integers smaller than N and co-prime to N , and the symbol “ $\langle d_k \cdot i \rangle_{\text{mod } N}$ ” means “multiplication modulo p ”.

In the sequel we shall suggest a new method for synthesis of families of signals with LPC. It is a generalization of the so-named *Gold method* [1], [19], which can be described as follows. For $0 \leq l < 2^n - 1$ and n an arbitrary odd integer, let $s_l = \{s_l(i)\}_{i=0}^{2^n-2}$ be a binary sequence, whose elements are evaluated by the rule:

$$(7) \quad s_l(i) = \text{Tr}(\alpha^j \alpha^i + \alpha^{di}), \\ i = 0, 1, \dots, 2^n - 2.$$

Then s_l is called a *Gold-pair sequence* [19]. Here α is an arbitrary primitive element of $GF(2^n)$, $d, d = 2^k + 1, \text{gcd}(k, n) = 1, k \leq (n-1)/2$ is an integer co-prime with $N = 2^n - 1$ and $\text{Tr}(\alpha^l \cdot \alpha^i + \alpha^{di})$ denotes the trace function of the elements $\alpha^l \cdot \alpha^i + \alpha^{di}$ of $GF(2^n)$ to $GF(2)$. In this situation, the set, given by [19]:

$$(8) \quad S(d) = \{s_l \mid 0 \leq l \leq 2^n\},$$

is said to be a *Gold-pair (signal) set*.

Note, that $a = s_{2^n-1} = \left\{ \text{Tr}(\alpha^i) \right\}_{i=0}^{2^n-2}$ and $b = s_{2^n} = \left\{ \text{Tr}(\alpha^{di}) \right\}_{i=0}^{2^n-2}$, are M -sequences [19] and, consequently, they possess an almost ideal PACF, according to (3). Besides, it is easy to

see that the set (family) (8) is generated by the pair-wise summing modulo 2 of the sequences \mathbf{a} and \mathbf{b} :

$$(9) \quad s_l = L^l a + b, \quad 0 \leq l < N - 1.$$

Here $L^l a$ means “right rotation of the sequence \mathbf{a} at l steps”.

It is proven [1], [19] that the signal set (8) is a family $\Phi(K, N, C)$ of signals with LPC with parameters:

$$(10) \quad \begin{aligned} K &= 2^n + 1 = N + 1, \quad N = 2^n - 1, \\ C &= 2^{(n+1)/2} + 1 \end{aligned}$$

With regard to the described Gold method, since 1968 many authors (for example Kasami, Welch, No, Kumar, Niho, Hellesteth, Müller) have proposed different values of the decimation coefficients d that can be used in the construction (7) [2], [4], [5], [6], [7], [8], [10], [11], [13], [14], [15], [16], [17], [19]. It should be pointed out that despite of the all efforts there is no any general method, applicable for all values of n and p .

With regard below we shall prove a different approach for finding of decimation coefficients d for M -sequences over an arbitrary finite field $GF(p)$ so that the requirement (5) to be satisfied. The new method consists of the following steps.

1) For given p and n with a computer program all possible values of the decimation coefficients d , $\gcd(d, N = p^n - 1) = 1$, are calculated. Note that these

decimation coefficients d , applied in (6), transform every M -sequence over $GF(p)$ with a characteristic equation of degree n in a M -sequence of the same type [19], [20]. In this way an initial family (set) of M -sequences is obtained.

2) With the above computer program the initial set is filtered in order to retain only these pairs of M -sequences which periodic cross-correlation function (PCCF) satisfies the restriction (5).

3) The M -sequences from the all selected pairs are used in the Gold construction (7), which provides a large number of different families of signals with LPC.

The correctness of the proposed method is a consequence of the following facts. First of all, let \mathbf{a} be an arbitrary M -sequence over $GF(p)$ with characteristic equation of degree n . As known, it can be presented in the form [19]:

$$(11) \quad a = \left\{ \text{Tr}(\gamma \alpha^i) \right\}_{i=0}^{N-1}, \quad N = p^n - 1,$$

where α is a primitive element of $GF(p^n)$, $\gamma = \alpha^u$ for some u , $0 \leq u < N$ and $\text{Tr}(z)$ is the so-named trace function, which maps the elements of $GF(p^n)$ to $GF(p)$ [19], [20]:

$$(12) \quad \text{Tr}(z) = z^{p^0} + z^{p^1} + \dots + z^{p^{n-1}}.$$

According to the above method, let \mathbf{b} be another M -sequence, obtained by a decimation of \mathbf{a} , so that the maximal absolute level C of the lobes of PCCF of the sequences \mathbf{a} and \mathbf{b} does

not exceed the restriction (5). Consequently, \mathbf{a} and \mathbf{b} form a family $V(K, N, C)$ of signals with LPC, which parameters are:

$$(13) \quad K = 2, \quad N = p^n - 1, \quad C = \eta\sqrt{N}.$$

(Note that \mathbf{a} and \mathbf{b} are M -sequences and as a result the maximal level of the side-lobes of their PACF do not exceed -1).

It should be pointed out that \mathbf{b} can be presented in the form [19]:

$$(14) \quad b = \left\{ \text{Tr}(\delta\beta^i) \right\}_{i=0}^{N-1}, \quad N = p^n - 1,$$

where $\beta = \alpha^d$, $\text{gcd}(d, N) = 1$ is also a primitive element of $GF(p^n)$, $\delta = \beta^v$ for some v , $0 \leq v < N$.

Now, let this initial family be enlarged by the all sequences, generated by the rule (9). We shall show that the maximal absolute level of the lobes of the PACFs and PCCFs of the new family, consisting of $K = p^n + 1 = N + 2$ sequences, satisfy (5).

In order to prove the above proposition it is necessary to consider the following cases.

Case 1. The PACFs of the sequences \mathbf{a} and \mathbf{b} and their PCCF satisfy (5) due to the peculiarities of the initial family $V(K, N, C)$.

Case 2. Let $\omega = \exp(j\frac{2\pi mn}{p})$, $1 \leq m \leq p-1$ be an arbitrary p -th root of unity. Then the PCCF of an arbitrary pair s_l, s_k , $0 \leq l < k \leq N-1$ is:

$$(15) \quad \begin{aligned} P_{s_l s_k}(r) &= \\ &= \sum_{i=0}^{N-1} \left[\omega^{\text{Tr}(\gamma\alpha^l \alpha^i + \delta\beta^i)} \times \right. \\ &\quad \left. \times \omega^{\text{Tr}(\gamma\alpha^k \alpha^{i+r} + \delta\beta^{i+r})} \right] = \\ &= \sum_{i=0}^{N-1} \left[\omega^{\text{Tr}[\gamma(\alpha^l - \alpha^{k+r})\alpha^i]} \times \right. \\ &\quad \left. \times \omega^{\text{Tr}[\delta(1-\beta^r)\beta^i]} \right] = \\ &= P_{ab}(u'-v') \end{aligned}$$

Here $\alpha^{u'} = \alpha^l - \alpha^{k+r}$, $\beta^{v'} = 1 - \beta^r$ and u' and v' show the steps of the right rotations of \mathbf{a} and \mathbf{b} respectively.

Now it should be seen that the PCCF ($P_{ab}(u'-v')$) of the M -sequences \mathbf{a} and \mathbf{b} satisfy (5), according to their choice. Besides, if $r \equiv 0 \pmod{N}$ then

$$(16) \quad P_{s_l s_k}(0) = P_{aa}(l-k) = -1.$$

Case 3. The PACF of an arbitrary sequence s_l , $0 \leq l \leq N-1$ can be evaluated from (15) after the substitution $l = k$. The result is

$$(17) \quad P_{s_l s_l}(r) = \begin{cases} P_{ab}(u'-v'), & r \neq 0; \\ N, & r = 0. \end{cases}$$

Here $\alpha^{u'} = \alpha^l(1 - \alpha^r)$, $\beta^{v'} = 1 - \beta^r$.

Case 4. The PCCF of an arbitrary pair s_l, a , $0 \leq l \leq N-1$ is:

$$(18) \quad P_{s_l a}(r) = \begin{cases} P_{ab}(u'-v'), & r \neq 0; \\ -1, & r = 0. \end{cases}$$

Here $\alpha^{u'} = \alpha^l - \alpha^r$, $\beta^{v'} = -\beta^r$. In (18) it is accounted that if $r = 0$, then $P_{s_l a}(0) = \sum_{i=0}^{N-1} \omega^{Tr(\delta\beta^i)}$ and the sequence $\{Tr(\delta\beta^i)\}_{i=0}^{N-1}$ contains p^{n-1} times the elements $1, 2, \dots, p-1$ and $p^{n-1} - 1$ times the element 0 [19], [20].

Case 5. The PCCF of an arbitrary pair s_l, b , $0 \leq l \leq N-1$ is:

$$(19) \quad P_{s_l b}(r) = \begin{cases} P_{ab}(u'-v'), & r \neq 0; \\ -1, & r = 0. \end{cases}$$

Here $\alpha^{u'} = \alpha^l$, $\beta^{v'} = \beta^r - 1$. In (19) it is accounted that if $r = 0$, then

$P_{s_l b}(0) = \sum_{i=0}^{N-1} \omega^{Tr(\gamma\alpha^i)}$ and the sequence $\{Tr(\gamma\alpha^i)\}_{i=0}^{N-1}$ contains p^{n-1} times the elements $1, 2, \dots, p-1$ and $p^{n-1} - 1$ times the element 0.

This finishes the all possible variants.

The new method for synthesis of families of signals with LPC will be illustrated by the following examples.

Example 1: Let we consider a M -sequence over $GF(2^5)$ with length $N = 2^5 - 1 = 31$. The results of a survey of the all possible decimation coefficients d and the maximal absolute level of the PCCFs of the initial M -sequence and the decimated M -sequences, are shown in table 1.

Table 1: A Survey of the maximal values of the cross-correlation functions of the initial and the decimated M -sequences with length $N = 31$

d	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
C	31	9	31	9	9	9	31	9	9	9	9	9	9	11	31
d	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
C	9	9	9	9	9	9	11	9	9	9	11	9	11	11	

In table 2, a comparison of the known at present methods for synthesis of families of signals with low LPC is presented for the M -sequences over $GF(2^5)$ with length

$N = 2^5 - 1 = 31$, [2], [4], [5], [6], [7], [8], [10], [11], [13], [14], [15], [16], [17], [19].

Table 2: Comparison of the known methods for synthesis of families of signals with low LPC for $N = 31$

	Gold decimation $d=2^k+1,$ $k \leq (n-1)/2$	Kasami decimation $d=2^{2k}-2^k+1,$ $k \leq (n-1)/2$	Welch decimation $d=2^{(n-1)/2}+3$	Niho decimation $d=2^{2k}+2^k-1,$ $k=(n-1)/4$ or $(3n-1)/4$	Decimations, according to the new method
C=9	5	13	7	5	3, 5, 6, 7, 9, 10, 11, 12, 13, 14, 17, 18, 19, 20, 21, 22, 24, 25, 26, 28
C=11	-	-	-	-	15, 23, 27, 29, 30

Example 2: Let we consider a ternary (i.e. $p=3$) M - sequence with length $N=3^3-1=26$. The results of a survey of the all possible

decimation coefficients d and the corresponding M -sequences, are shown in table 3.

Table 3 A Survey of the maximal absolute values of the cross-correlation functions of the initial and the decimated M -sequences with length $N = 26$

d	3	5	7	9	11	15	17	19	21	23	25
C	26	10	10	26	10	10	10	10	10	10	10

As can be seen the decimation coefficients 5, 7, 11, 15, 17, 19, 21, 23 and 25 can be used in order to generate families of signals with maximal absolute level $C=10$ of the lobes of the PCCFs.

4. Conclusion

In the paper a general method for synthesis of families of signals with low periodic correlation is suggested. It is more general by the known at present methods and as a result it is

applicable for all possible values of p and n . These positive features are confirmed by the results, obtained by exhaustive computer surveys, shown in tables 1-3.

The proposed method can be successfully used in the process of development of perspective wireless communication system, providing both very high rate of information transmission and data protection.

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Original Contribution

COMPARATIVE ANALYSIS OF THE PROBABILITY IN DIGITAL WIRELESS COMMUNICATION SYSTEMS

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ABSTRACT: Digital signals dominate satellite communications systems. A measure the quality of digital signals is Bit Error Rate (BER) and Symbol Error Rate (SER). The main purpose of the paper is a comparison of the probability of error for various modulation and demodulation schemes used in digital communications systems (DCS) for transmitting information over channel. Error Rate parameters are resulting analytically, not experimentally.

KEYWORDS: the probability of error, modulation and demodulation schemes, wireless communication systems.

The purpose of Channel Coding is decreasing of errors when signals are transmitted by noisy channel. The capabilities of Channel Coding were investigated by Claude Elwood Shannon (30.04.1916–24.02.2001) and written in “A mathematical theory of communication” [3].

A measure the quality of digital signals is Bit Error Rate (BER). The bit error rate or bit error ratio is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unitless performance measure, often expressed as a percentage number. As the custom is the errors are slightly small if the BER values are 10^{-5} for the audio signals and 10^{-11} for the data. In cases when the states of signal information parameter are represented

by number of bits (the binary bit stream is combined into groups, called symbols) there is in use Symbol Error Rate (SER). The parameters P_b (BER) and P_s (SER) can be found by simulation, real experiment or analytically.

The BER is often expressed as a function of the E_b/N_0 , (energy per bit to noise power spectral density ratio):

$$(1) \quad BER = \frac{1}{2} \operatorname{erfc}(\sqrt{E_b/N_0}),$$

where erfc is a Complementary Error Function.

For transmission the digital information signal is gone to the modulator to form a radiosignal. The carrying of signal spectrum from low frequency to high frequency is doing by modulation. Modulation is

a process of transfer of information over sinusoidal microwave carrier. Thus, in transmitter enter two signals - information low frequency baseband signal $s_m(t)$ and continuous in time high frequency signal $s_c(t) = f(t; a_1, a_2, \dots, a_m)$. The combination of parameters $\{a_i\}$ determines a signal form. When the value of some of these parameters depend on the information signal $s_m(t)$ in time or other variable quantity, the form of high frequency signal is carrying an information that is identical with this in $s_m(t)$. Then the signal $s_c(t) = f(t; a_1, a_2, \dots, a_m)$ is called Carrier. The low frequency signal $s_m(t)$ is called Modulating Signal, the result of modulation - Modulated Signal. The general form of the carrier wave is harmonic:

(2)

$$s_c(t) = A_i \cdot \cos(2\pi \cdot f_0 \cdot t + \varphi) = A_i \cdot \cos(\omega_0 \cdot t + \varphi),$$

where A_i is an amplitude of carrier, $\omega_0 = 2\pi f_0$ is a radian frequency in rad/s , φ is the phase.

The digital modulation is a process whereby the amplitude, frequency, phase or combination of them is varied in accordance with the information. In this reason, the main digital modulation method are called Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK) and hybrid methods that are combination of them. The frequency and phase modulations are mutually connected and they are called Angle Modulations. When both the amplitude and phase simultaneously are changed the

modulation is called Quadrature Modulation.

The receiver process the modulated signal by transforming in low frequency signal (demodulation) and then make detection. The demodulation is used to recovery waveform, and detection is the process of symbol decision. There are known two types of detection: coherent and noncoherent detection. Coherent detection is a process when the receiver utilizes information about phase of RF carrier. When the receiver doesn't use information about phase of RF carrier it is called noncoherent detection, the phase estimation is not required. When the signal is transmitted there are two main causes for error performance degradation. The first of them is intersymbol interference (ISI) because of nonideal system transfer function. The second is electrical noise and interference produced by galaxy and atmospheric noise, intermodulation noise, switching transients and other sources. The additive white Gaussian noise (AWGN) is the most often used as model of the noise in the detection process. The detector has to retrieve the digital signal from the received waveform without of errors and maximum value of the ratio E_b/N_0 , if it is possible.

The transmitted signal in the limits of symbol interval $(0, T)$ is

$$(3) \quad s_i(t) = \begin{cases} s_1(t), & \text{where } 0 \leq t \leq T \text{ for binary 1;} \\ s_0(t), & \text{where } 0 \leq t \leq T \text{ for binary 0.} \end{cases}$$

The received signal $r(t)$ is degraded by noise $n(t)$ and can be represented by

$$(4) \quad r(t) = s_i(t) + n(t), \quad i = 0,1; \quad 0 \leq t \leq T,$$

where $n(t)$ represent a noise amplitude and it is changing from sample to sample.

Figure 1 shows the binary signal acted by random signal noise. The amplitude of received signal varies at each sample.

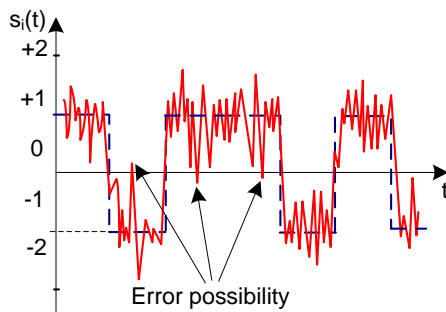


Figure 1. The binary signal acted by noise

The value of noise varies with time and it is assumed to be normally distributed with a zero mean and variance of quantity σ^2 , where σ is a standard deviation of the noise process. The receiver has to make a decision on the fluctuating values, shown in Fig. 1. There are two possibilities to make a mistake: first of them is when signal

$s_1(t)$ has been received, but because of the presence of noise the energy of the signal is not enough and the detector chooses the hypothesis H_2 : $z(T) < \gamma$, as it was received the signal $s_0(t)$. The quantity $z(T)$ is the sampler output at the end of each symbol duration, and it has a voltage value directly proportional to the energy of the received symbol and inversely proportional to the noise [1].

$$(5) \quad z(T) = a_i(T) + n_0(T), \quad i = 0,1,$$

where $a_i(T)$ is the desired signal component, $n_0(T)$ is the noise component.

The two error possibilities can be expressed as

$$(6) \quad p(e|s_1) = \int_{-\infty}^{\gamma_0} p(z|s_1) dz,$$

$$(7) \quad p(e|s_0) = \int_{\gamma_0}^{\infty} p(z|s_0) dz,$$

where

$$p(z|s_1) = \frac{1}{\sigma_0 \sqrt{2\pi}} \cdot \exp \left[-\frac{1}{2} \left(\frac{z - a_1}{\sigma_0} \right)^2 \right] \text{ and}$$

$$p(z|s_0) = \frac{1}{\sigma_0 \sqrt{2\pi}} \cdot \exp \left[-\frac{1}{2} \left(\frac{z - a_0}{\sigma_0} \right)^2 \right] \text{ are}$$

the conditional probability density functions, shown in Figure 2.

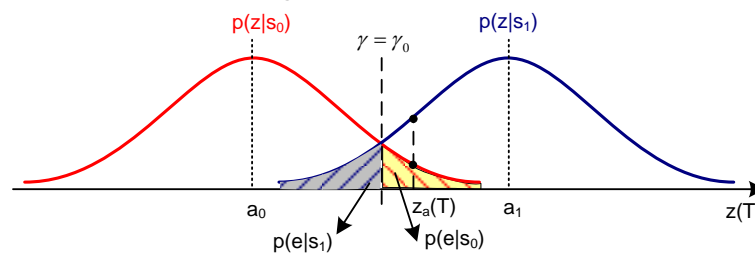


Figure 2. Conditional probability density functions

The function $p(z|s_1)$ shows the probability density of the random variable $z(T)$ if symbol s_1 was transmitted. Respectively, the function $p(z|s_0)$ shows the probability density of the random variable $z(T)$ if symbol s_0 was transmitted. The intervals are up to $\gamma_0 = \frac{a_1 + a_0}{2}$ symmetrically because of equal probability to receive 0 or 1 [10]. The Figure 2 illustrates the process of making decision. Choosing $z(T) > \gamma$ is equal decision that signal $s_1(t)$ was sent and a binary 1 was detected by the receiver. Respectively, choosing $z(T) < \gamma$ notes that signal $s_0(t)$ was sent and a binary 0 was detected.

Because of the symmetry of the probability density functions, and the equal of the priori probabilities the probability of bit error is

$$(8) \quad P_B = p(e|s_1) = p(e|s_0).$$

Therefore, the probability of bit error can be calculate by integrating of conditional probability $p(e|s_1)$ or $p(e|s_0)$ between their limits.

$$(9) \quad P_B = \int_{\frac{a_1+a_2}{2}}^{\infty} \frac{1}{\sigma_0 \sqrt{2\pi}} \exp\left[-\frac{1}{2} \left(\frac{z-a_2}{\sigma_0}\right)^2\right] dz = \\ = \int_{\frac{a_1+a_2}{2\sigma_0}}^{u=\infty} \frac{1}{\sqrt{2\pi}} \exp\left[-\frac{u^2}{2}\right] du = Q\left(\frac{a_1-a_2}{2\sigma_0}\right)$$

where $Q(x)$ is a tabular function, Gaussian error integral

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} \exp\left(-\frac{u^2}{2}\right) du$$

The purpose of each detector is to minimise the probability of error. Thus

the receiving filter has to be optimized by choosing the maximum argument of Q-function in Equation 9. It is known, that matched filter provides the maximum signal-to noise power ratio at its output at time $t = T$

$$(10) \quad \max\left(\frac{S}{N}\right)_T = \frac{(a_1 - a_2)^2}{\sigma_0^2} = \frac{2E}{N_0},$$

where E is a energy of the input signal, N_0 is a noise power spectral density.

Thus, by maximizing the signal-to noise power ratio at the output, matched filter achieves a maximum distance between two possible signals $s_1(t)$ or $s_0(t)$, and provides better performance to detect signal without errors.

There are work out an equations, that show the probability of error for the different types of modulation.

- Binary Phase Shift Keying and coherent detection:

$$(11) \quad P_B = Q\left(\sqrt{\frac{2E_b}{N_0}}\right);$$

- Differential Binary Phase Shift Keying and coherent detection:

$$(12) \quad P_B = \frac{1}{2} \exp\left\{-\frac{E_b}{N_0}\right\};$$

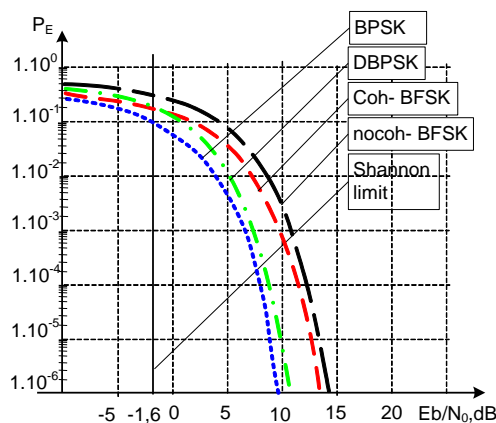
- Orthogonal Frequency Shift Keying and coherent detection:

$$(13) \quad P_B = Q\left(\sqrt{\frac{E_b}{N_0}}\right);$$

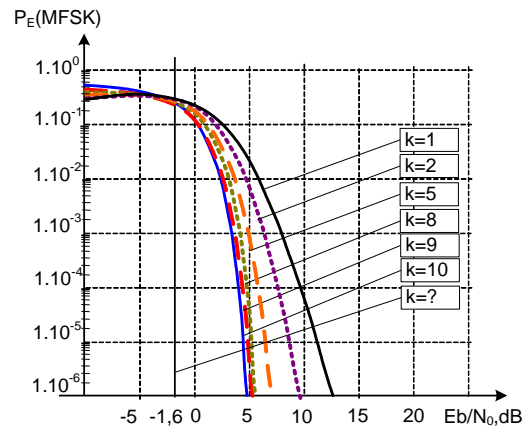
- Orthogonal Frequency Shift Keying and noncoherent detection:

$$(13) \quad P_B = \frac{1}{2} \exp\left\{-\frac{E_b}{2N_0}\right\}.$$

Figure 3a shows curves for various binary modulations.



a)



b)

Figure 3. Curves for various binary modulations (a) and M-ary frequency shift keying (b).

The less value of E_b/N_0 ratio achieves BPSK modulation, the maximum value - nocoh-BFSK with the equal probability of error. The difference between them is about $4dB$. The DBPSK lose $1dB$ from BPSK because of character - it redoubles incoming errors. Although DBPSK is less efficient than BPSK, sometimes it is preferred modulation because DBPSK receiver doesn't need phase synchronization. BPSK works with antipodal signals. The distance between antipodal signals is $2\sqrt{E_b}$. The distance between orthogonal signals (FSK) is less $\sqrt{2E_b}$, i.e. the distance squared between orthogonal signals is two less than distance squared between antipodal signals. This is the reason of higher probability of error when FSK is

detected. The comparison of coherent OFSK with noncoherent OFSK shows that noncoherent OFSK requires approximately $1dB$ more E_b/N_0 ratio. It is because the error performance of this type of modulation depends on bandpass filter bandwidth. The probability of error P_b becomes more when bandwidth increases [1]. The minimum bandwidth allowed is equal to bit rate.

Figure 3b shows curves of error probability depending on E_b/N_0 ratio for coherent M-ary Frequency Shift Keying and different symbol length. Figure 4a shows curves of error probability depending on E_b/N_0 ratio for M-ary Phase Shift Keying, Figure 4b - M-ary QAM.

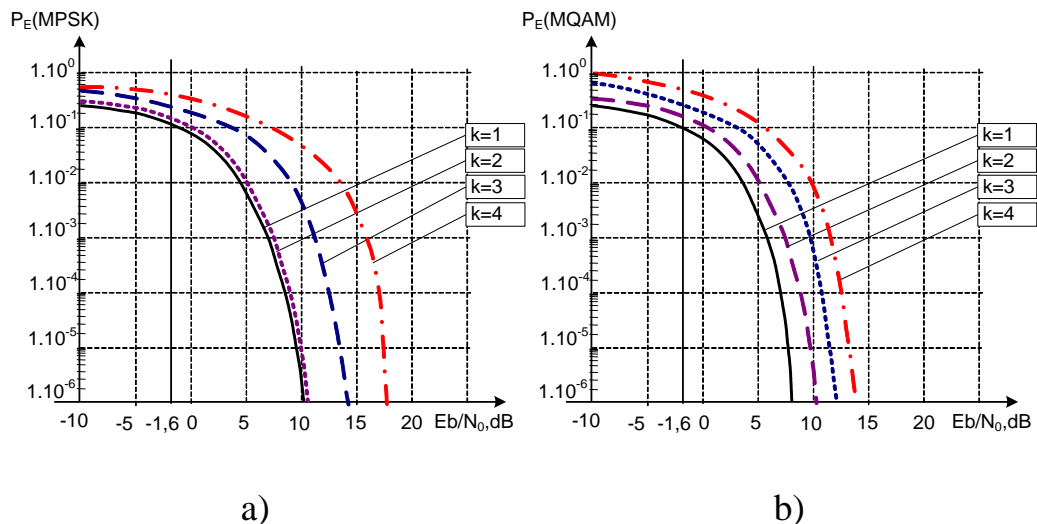


Figure 4. Curves for various M-ary modulations and different symbol length.

Figure 3b shows as number of bits k in symbol increases the error probability decreases. The required bandwidth also increases. For the M-ary phase curves in Fig. 4a as k increases the required bandwidth decreases if data rate is fixed, or if the bandwidth is fixed as k increases the data rate also increases. In this reason more length of symbol leads to less error performance. Therefore, M-ary

modulations can be utilize to achieve optimum in accordance to required performance of the link - more data rate in the same bandwidth and less error performance, or less error probability versus data rate and bandwidth.

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SPECIAL CHARACTERISTICS OF SPARE ELEMENTS INVENTORY MANAGEMENT

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***Abstract:** Some aspects in the problem of management inventory system for spare elements are presented in this paper. The life cycle management of spare elements and their special characteristics is considered in the inventory process. The machine time-down divided with partial weighing range is shown. Emphasis is on the delivery time of spare elements, as the main reason for a fast repair of the failing machine. It's therefore necessary to predict the demand for spare elements.*

***Key words:** inventory system, spare elements.*

I. Introduction.

Material resources are a basic company activity of a production plant; a trade company or a state institution. The effective management of the inventory and minimizing the stock materials together with guaranteed ensuring of the production process are warrant for the successful company functioning. The provision of inventory is a basic priority for every production or servicing structure from a technical and economical point of view.

A special part of the inventory is the spare elements and the system which ensures its timely supply in the storehouse. The management of the processes which are connected with the creation of stored spare elements is of basic importance for maximum efficiency of the machines and with

the use of optimal financial and material resource. [2].

The time when the machines stop because of lack of spare elements is unduly expensive and in some special cases when it's connected with the exploitation safety and the ecology of the work place: the lack is inadmissible. According to some authors the time when the industrial process stops due to lack of spare elements is 50% of the whole time for repairing the failed machines. [1, 5]. Another huge financial factor is the price of the spare elements which ensure the machines during the exploitation stage which is about 50% of their technical maintenance.

The problems connected with the production of spare elements require stable prognoses and insightful analyses. The extent to which the problem of ensuring the machines

during their whole life cycle with spare parts is connected with the idle time of the machines. The problem is of basic importance especially for the state institutions, for example the Ministry of Defense when they purchase new weapons. In this case a unilateral answer should be provided to the question what the financial and technical conditions are at which a certain inventory of spare elements will be maintained which will ensure unending exploitation of the systems during their whole life cycle until their utilization.

II. Process characteristics of the inventory management of spare elements.

The inventory management includes a few steps – definition of inventory policy (structuring and concentration of inventory) and development of short-term, mid-term and long-term prognosis for the necessity of elements. With the help of this prognosis we can plan the inventory (when and how many elements of a certain kind to be available); storing the inventory in different storages – this is especially important for the distribution storages; defining the strategy of the inventory management; choosing a management system and technology for inventory management.

The system of inventory management of spare elements functions effectively if there are adequate rules which allow minimization of the idle time of the machines from the moment the order is placed for the spare element up to

the moment the order is fulfilled and thus using a minimum recourse of material and non-material inventory.

When a suitable policy of inventory management for spare elements is being formed, the following basic stages of their life cycle should be considered: [6]:

- identification of spare elements;
- prognosis of searching for spare elements;
- analysis of the storage system;
- formulation of management policies for the different kinds of spare elements;
- developing the system of inventory management;
- policy for capital investment in spare elements;
- policy for inventory management of restorable elements or unit assemblies;
- policy for spare elements exchange;
- control of the spare elements;
- production of the spare elements;
- restoration of the spare elements;
- creating a data base of the spare elements;
- computer software for the spare elements management.

The spare elements are distinguished by most of the other inventory. They have specific characteristics which differentiate them from the elements and materials which are used in a production or service system. In connection with their necessity, their most important characteristic is the irregularity of

their demand which means that the quantity is different and the interval of time between the moments when the demand for elements emerged is different. These values are random and due to the insufficient statistic information it is difficult to find a theoretical law according to which they change in time.

Another distinctive characteristic of the spare elements is the specificity of their use. Usually they cannot be universally used. The purpose of their production is to function only for what they had been created. The stored quantity creates a risk of moral and physical aging, which is especially important when the company decides to change the equipment: the nomenclature of spare elements which is not used again in other systems is automatically transformed into obsolete.

The production of spare elements requires a big technical resource and this results in a high unit price. For the acquiring and

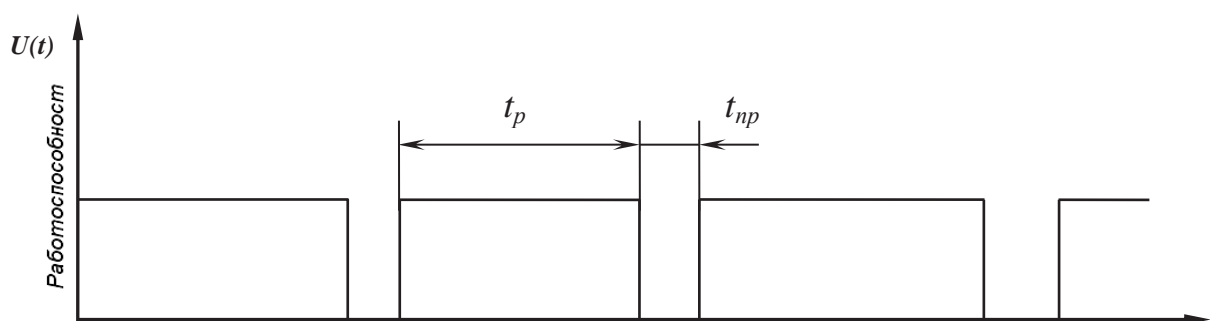
elements which parameters should be maintained in certain conditions: temperature, moisture, corrosion resistance, etc.

Whatever the characteristics, the basic problem with the inventory management of spare elements is the irregularity of the time when there is a demand for working spare elements and the quantity of the corresponding nomenclature.

III. System for maintenance of the machines' life cycle.

The stage of the life cycle of a machine in which it is used according to its function, is a process which represents a process containing intervals of normal functioning t_p , which are separated by unwanted pauses of the machine in result of failures of its elements or blocks (the process is presented as a scheme in Fig. 1)

The time interval t_{np} , during which the machine is not working can be divided into sub intervals which



maintenance besides the price for the purchase, substantial finances are required for subsequent technical servicing.

On the other hand, the storehouses for keeping the spare elements have certain requirements, especially when storing complex

include activities for:

- localization of the failure;
- preparation for dismounting;
- dismounting of the failed element;
- finding the reasons for the failure;
- supply of a working element;

- calibration;
- preparation for mounting;
- mounting;
- technical check;
- start of exploitation.

These activities of setting the machines to working mode are presented in the scheme in Fig. 2.

One of the basic economic and technical goals when leading the recovery process is minimizing the time during which the machine is not operating, i.e. $t_{np} \rightarrow 0$. From all sub intervals, which constitute the time for the repairing of the machine, the one that includes the activities of finding and supplying the spare element has the highest level of uncertainty. The deficit of the wanted spare elements in the storage of the servicing workshop blocks its operation and increases the financial losses both for the workshop and for the owner of the failed machine. The duration of the sub interval of supply of the spare element can vary from some minutes up to hours, days or weeks.

It's obvious that a considerable part of the stage of maintaining the exploitation reliability of the machines is connected with setting the parameters of two processes: appearance of the failures and supply of the spare elements.

The time for supplying the necessary spare element and for exchanging the failed one is a random process which depends on different factors, part of which are changing without any trend. Due to the necessity to ensure a continuous working cycle of the machine and

insufficient statistical data for prognosis of the supply time of a spare element, it is necessary to create an inventory. Depending on the type of the machine and the policy of the producing company, it is possible to have a set of spare elements for every item or group of items. The optimal maintenance of a certain nomenclature and quantity of spare elements requires the application of the theory of inventory management. By means of statistical analysis of the inventory, evaluations can be made for the condition of the equipment, for the stability of the production process of the company; the low effective equipment can be discovered by such criteria as material expenditures for a certain period, readiness coefficient, usage coefficient, storage time, etc.

The appearance of failures in the exploitation stage is also a random process and is a subject of research by the reliability theory. Failure emergence in the machine elements depends on different factors which is the reason for its random character. For example, the intensity of the wearing is a function of the precise design of the elements, the choice of proper materials and production technology. The basic parameter which is used and is a premise for prediction of the necessary quantity of spare elements is the intensity of the failures or the parameter of the sequence of the failures. Practice shows that the calculated quantity spare elements by the methods of the reliability theory do not correspond to the real needs [3]. The reasons are different and are a function of the

machine work regime, the exploitation conditions, etc. but the dominating reason is the improper machine exploitation [4] which includes not conforming to the instruction manuals for the proper use, the time and volume of the servicing work.

In conclusion, to increase the precision evaluation of the planned nomenclature and quantity of spare elements, mathematical methods

should be applied which should take into consideration a greater number of factors and their influence on the need of working elements which to replace the failed elements. This is the reason for the use of the methods for the prognosis of the spare elements inventory which application is a complex process which requires sometimes non-stereotypical solutions.

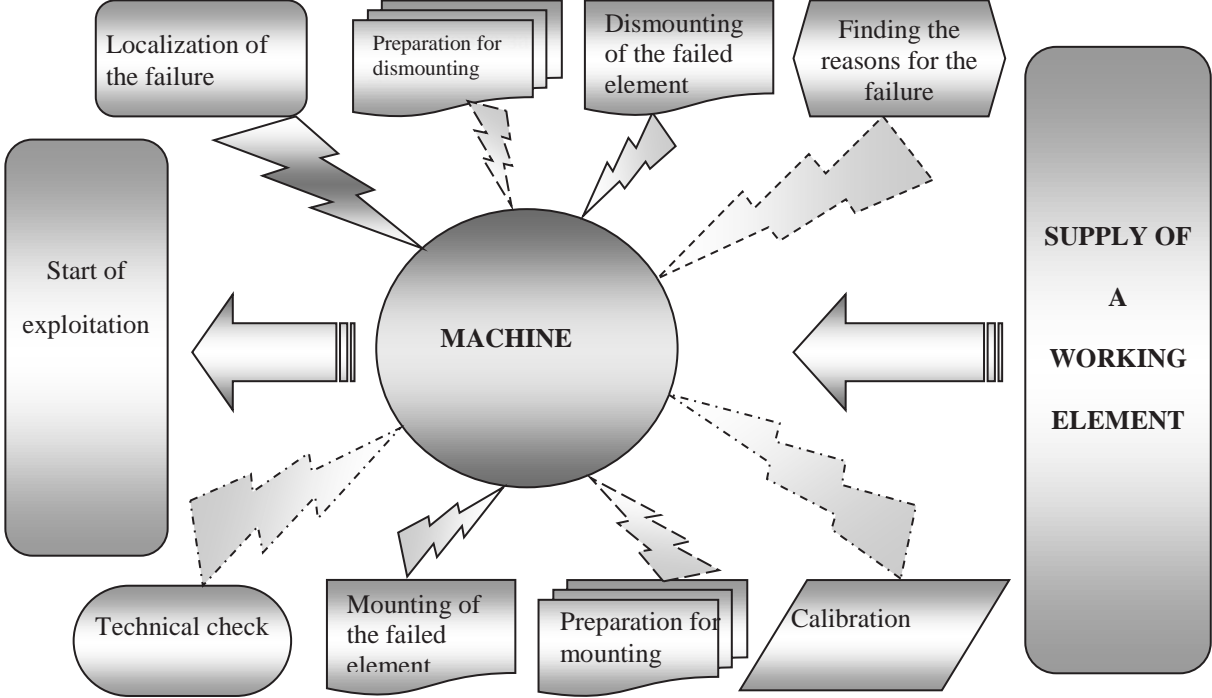


Fig. 2.

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APPLICATION OF STATISTICAL METHODS IN FORECASTING FOR SPARE ELEMENTS DEMAND

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Abstract: *The problem of predicting the demand for spare elements is extremely important for continuous operation of machines. It is necessary to know when and how much to order. To calculate and ensure the availability of spare elements, appropriate mathematical models should be applied. The statistical method for predicting spare elements demand is considered in this paper. The study shows how to use a demand forecasting technique for determining the expected number of spare elements. Some of the results are given by engineering software.*

Key words: *statistical calculations, spare elements.*

I. Introduction.

The maintenance of exploitation reliability of the machines requires conducting of technical diagnosis, prevention and repair work in order to restore the efficiency. Conducting an effective and timely repair work is only possible when the proper nomenclature and quantity of spare elements are available. It's a fact that the basic reliable parameter of the machines is the intensity of failures flow [2]. The process of failure appearance which is a function of the machine flawlessness, from the point of view of the inventory management theory can be presented as a process of searching spare elements. Because the spare elements are a specific kind of spare inventory, the process of searching for them is being characterized with some specific traits such as: the intervals of time between

two consecutive moments of searching for spare elements are random; the searched for quantity of the corresponding nomenclature spare elements is a random value; the intervals of the supply time are a function of random values, etc.

Usually, when the parameters of the search process of spare elements are defined, the results from the machine reliability tests are being used. Since these tests are conducted in laboratories, it is not always possible to consider the influence of every exploitation factor on the machine flawlessness. This is the reason why if the variability law of changes in the demand for spare elements for a certain machine is not known in advance, the provision of the necessary nomenclature and quantity can be done by means of

statistical methods of the search prognosis.

II. Statistical modeling of the search for spare elements.

The prognosis procedure includes several stages. During the first one the data for the demand for spare elements with similar characteristics in the past is processed and the reliability of the gathered information is being evaluated. During the second stage the proper mathematical model is being selected considering the demand for spare elements of similar machines and on the basis of analysis from the point of view of the reliability theory and having in mind the processed a priori statistical information. The last stage includes evaluating the parameters of the selected mathematical model.

On the basis of the method of the least squares, and by using the program product MATLAB [6], a method is developed for the search prognosis of the spare elements which are necessary to exchange the failed elements as a result of mechanical wearing.

The variable values are the quantity of spare elements R and the intensity U with which the elements are worn out. They are statistically interrelated.

Data base with volume n is examined. The results from the experiment (u_i, r_{ij}) are described where $i=1, 2, 3, \dots, n$ and $j=1, 2, 3, \dots, m$ in points of a Decartes' coordinate system and the graphic form of systematization of statistical data (correlation field) is received. On

the basis of the volume n of the statistical data sample, the function of the model should be evaluated and the mathematical expectation of the variable R . In order to evaluate the function of the model, an approximate empirical function is being used which is close to the unknown model by means of a selected criteria.

To select the class of the empirical functions which describe the process of searching the spare elements, it is necessary to perform the following activities:

- 1) analysis of the experiment and the research connected with the problem;
- 2) evaluation of the coordinates of the statistical results from the measuring in the correlation field;
- 3) analysis of the results (u_i, r_{ij}) considering the specific conditions.

Considering the accumulated experience and the character of the wearing process, the mathematical modeling of the search for spare elements by means of functions of a higher order is considerably more realistic in comparison with the linear approximation. On the basis of experience and expert analysis [1, 3, 7, 8] a polynomial of the kind was selected:

$$(1) \quad R_u = a.e^{bu} + c.e^{du} .$$

To find the coefficients of the polynomial, a system of four regular linear equations is created:

(2)

$$\begin{cases} \sum_i^n u_i \ln r_i = \ln a \sum_i^n u_i + \ln b \sum_i^n u_i^2 + \ln c \sum_i^n u_i + \ln d \sum_i^n u_i^2 \\ \sum_i^n u_i^2 \ln r_i = \ln a \sum_i^n u_i^2 + \ln b \sum_i^n u_i^3 + \ln c \sum_i^n u_i^4 + \ln d \sum_i^n u_i^3 \\ \sum_i^n u_i^3 \ln r_i = \ln a \sum_i^n u_i^3 + \ln b \sum_i^n u_i^4 + \ln c \sum_i^n u_i^3 + \ln d \sum_i^n u_i^4 \\ \sum_i^n u_i^4 \ln r_i = \ln a \sum_i^n u_i^4 + \ln b \sum_i^n u_i^5 + \ln c \sum_i^n u_i^4 + \ln d \sum_i^n u_i^5 \end{cases}$$

These systems are always defined and incompatible and they allow finding the polynomial coefficients.

After the coefficient evaluations are defined, a statistical analysis should be done on the equation. Procedures to check hypotheses, such as the hypothesis test for equation adequacy, hypothesis test of the equation coefficients significance, defining the confidence intervals, etc. are being performed [5]. To receive precise results and to decrease the time of the problem solution, the following procedures are performed by "Statistics Toolbox" of "Matlab":

- Definition of the sum of the squares of the deviation of every r_{ij} from the predicted \hat{r}_u

$$(3) \quad g_{ij} = \sum_{j=1}^n (u_{ij} - \hat{u}_r)^2,$$

Evaluation of the residual dispersion

$$(4) \quad s_R^2 = \frac{1}{n - (k + 1)} \sum_{j=1}^n (u_{ij} - \hat{u}_r)^2,$$

where: $k+1$ is the coefficient number of the model.

The closer to zero values of g_{ij} show a better approximation of the model.

Defining the sum of the squares of the deviations of the mean values for the groups \bar{u}_i from the total value

$$(5) \quad w_{ij} = \sum_{j=1}^n (\hat{u}_r - \bar{u}_i)^2$$

where $\bar{u}_i = \frac{1}{n} \sum_j^n u_{ij}$,

dispersion evaluation by the factors

$$(6) \quad s_A^2 = \frac{1}{k - 1} \sum_{j=1}^n (\hat{u}_r - \bar{u}_i)^2.$$

Defining the squares sum by the deviation of their mean value

$$(7) \quad h_{ij} = \sum_{j=1}^n (u_{ij} - \bar{u}_i)^2,$$

The total dispersion evaluation

$$(8) \quad s_T^2 = \frac{1}{kn - 1} \sum_{j=1}^n (u_{ij} - \bar{u}_i)^2.$$

Evaluation of the approximation extent of the data variables by means of the correlation square N^2 .

N^2 can be defined as a relation of the squares sum of the deviations of every measurement from the predicted value and the total sum of the squares of all the measurements.

It is known that the total sum of the squares of the differences from all the data is equal to the sum of the squares and the residuals [4]

Then N^2 is

(9)

$$N_{\text{square}} = N^2 = \frac{\sum_{j=1}^n (\hat{u}_r - \bar{u}_i)^2}{\sum_{j=1}^n (u_{ij} - \bar{u}_i)^2} = 1 - \frac{\sum_{j=1}^n (u_{ij} - \hat{u}_r)^2}{\sum_{j=1}^n (u_{ij} - \bar{u}_i)^2}$$

N^2 can have values only in the interval from 0 to 1. The closer the value is to 1, the better approximation with the selected empirical equation.

Defining the degrees of freedom of the “residuals” ($u_{ij} - \hat{u}_r$),

(10) $D=n-k,$

where: n – levels of the factor;

k – the coefficient number in the model equation.

The adjusted correlation coefficient is:

(11)

$$\text{adjusted } N_{\text{square}} = \frac{n-1}{k-1} \frac{\sum_{j=1}^n (\hat{u}_r - \bar{u}_i)^2}{\sum_{j=1}^n (u_{ij} - \bar{u}_i)^2} = 1 - \frac{n-1}{n-k} \frac{\sum_{j=1}^n (u_{ij} - \hat{u}_r)^2}{\sum_{j=1}^n (u_{ij} - \bar{u}_i)^2}$$

It can have every value which is smaller or equal to 1 and the closer these values are to one, the greater is the parity of the chosen model with the results.

Calculation of the statistical mean squared error

(12) $M_{se} = \frac{1}{n-k} \sum_{j=1}^n (u_{ij} - \hat{u}_r)^2 .$

It’s obvious that when the values of the standard error are closer to

zero, the results from the model are closer to the experimental ones.

Calculation of the confidence intervals for the significance coefficients

$$b_j - t_k s_b(b_j) < C < b_j + t_k s_b(b_j)$$

where: t_k is a statistics which has the Student’s distribution [5];

s_b – characteristics of the coefficient dispersion [4].

Depending on the accepted significance level, the size of the confidence interval is defined.

Part of the experimental data is presented on fig. 1.

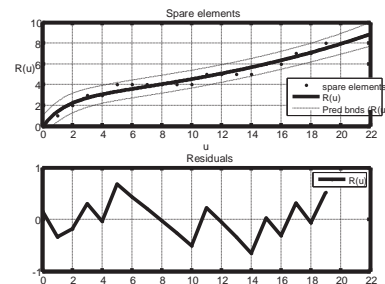


Fig. 1.

The used method for forecasting the quantity of spare elements with the calculation by means of a program product creates opportunities to elect a proper mathematical model in the search process in the conditions of limited statistical information. Using similar kind of method leads to decreasing the time for managing the statistical data and a better economic effect with the inventory management.

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ECONOMIC ASPECTS FOR EVALUATION OF LOGISTIC SYSTEMS

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Abstract: The economic aspects of evaluation of logistic systems are presented in the paper and factors for differentiated evaluation of the financial state, purchasing power, the population with its number and ethnicity and specific preferences, the mass consumption in the region, the trade in the country and abroad, variety, quality and the corresponding competitive price.

Key words: economic aspects, logistic systems

Technical and technological environment is of great importance for the development of technical advancement. It is envisaged acceleration of the creation, implementation and dissemination of scientific and technical innovations [1,2]. More innovative ideas are developed and time gap between the emergence of an idea and its successful implementation in practice is decreasing rapidly. Significantly shortens the time from introduction of the idea until it reaches maximum possible production rate.

Over the past two years there has been a slight increase in the relative spending on acquiring new machinery and equipment. The largest share of expenditure is for acquisition of tangible fixed assets in industrial activities. Of particular interest are logistics systems associated with the renovation of the technology [3]. Higher spendings on machines are mostly aimed to maintain existing production capacities rather than to

create new production. This is generally a threat because of the lack of investment in new technology.

Analyzing logistics system as part of financial analysis of company X based in N-town, we determine huge production capacity of the company. Operating at full production capacity, the company can meet 70% of the national consumer demand. This is due to the fact that technology in the enterprise is new and provides great manufacturing opportunities. As a result, there is an opportunity for N-town based Company X, operating at full production capacity, to produce significant amounts and to profit from the scale of production. Another opportunity for the company is the growing number of highly skilled professionals that are preferred for hiring. They improve and advance the technique and work on creating new and high quality products.

To analyze the logistics system company must be evaluated in the

branch environment and be given due weight to the meat as food. It is a rich source of biologically complete protein. The nutritional value of meat and meat products are mainly determined by their morphology and chemical composition, as well as their biological value and digestibility of the substances that compose it. Therefore, meat from different types of domestic animals has specific properties that make it a favorite of various categories of consumers. For example, bovine has a number of advantages as flavor, nutritional and dietary character. Its consumption is not subject to seasonal preferences.

Pork outperforms other types in terms of calorific value, the content of calcium, phosphorus, iron, vitamin B1 and B2. Meats of sheep and caprine have higher protein content than pork and almost as much as beef, but higher dry matter content and calorific value than beef. Company X operates a processing plant with a completed cycle of live animals processing: pigs, cattle, sheep and caprine to meat, sausages, canned food and waste management in pink slime and bone meal. Logistics system for economic analysis is defined by the scheme (Fig. 1).

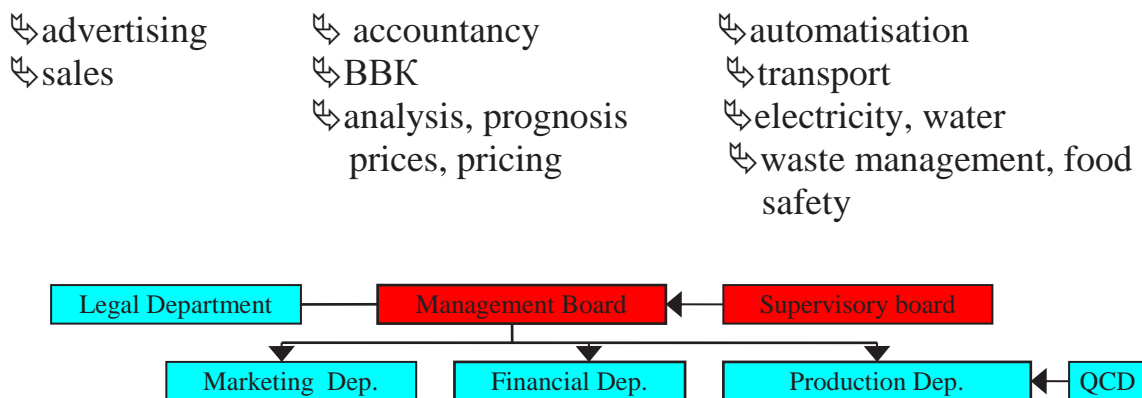


Fig. 1. Logistics system for economic analysis

Analysis and evaluation of consumer behavior is an important and fundamental goal of marketing - to identify and meet the needs of consumers. Key point in the analysis is the complexity of consumer behavior conditioned by many factors that partially counteract. Furthermore, consumers often act impulsively, intuitively or simply by habit without rational basis of their behavior.

In logistical terms users are divided into two main groups: mainstream and industrial. For **mainstream users** include individual users of products for mass consumption. In this analysis, potential mass consumers of Company X is the population of Region of City of N, and the neighboring towns of V and H (Table 1).

Table 1

Region of N			
Municipalities	total	men	women
X ₁	21844	10945	10899
X ₂	22004	10919	11085
X ₃	28468	14203	14265
X ₄	17931	8816	9115
X ₅	7021	3646	3375
X ₆	21683	10868	10815
X ₇	103532	50661	52871
X ₈	6951	3430	3521

Patterns of consumer behavior upon purchase of products of the Company X can be combined into two main groups:

- logistic patterns based on the postulates of positive psychology / cognitive /;

- logistic patterns based on the concept of stimulus-response.

Cognitive logistic patterns consider the process of user behavior as a sequence of three phases: cognitive, emotional and volitional. Consumers go through the three phases in a different sequence, depending on the nature of the product and on consumer decision. According to the sequence of the three phases is determined what marketing influences can be applied in each of the phases.

Stimulus-response models are based on the idea that the consumer is exposed to various marketing and other stimuli inducing consumer response and purchase decision. The

main factors influencing the behavior of consumers of the products of the company X is scaled by cultural, social and psychological behavior.

Cultural factors have the strongest impact on the consumer's behavior because they are the determining factor in the formation of personal desires and behaviors. Culture includes personal values and a wide range of behaviors, which are acceptable in a certain society. The concepts, values and behavior which compose culture are learned and passed on from generation to generation. Our culture determines what we eat and how to eat it and when and how to buy it. The culture has an impact on our choice and the usage of products and influences our satisfaction with them. According to human traits like age and ethnicity, culture is divided into subcultures (Table 2).

Table 2

Ethnic composition of the population in region - V	
Total	916070
Bulgarians	720218
Turks	133104
Gypsies	50253
Others	13391
Not-stated	101

In this case it must be taken into account that the majority of the Turk population is under religious influence and because of it doesn't buy pork products and any kind of sausage made from it. Another aspect of the cultural factors is the social class.

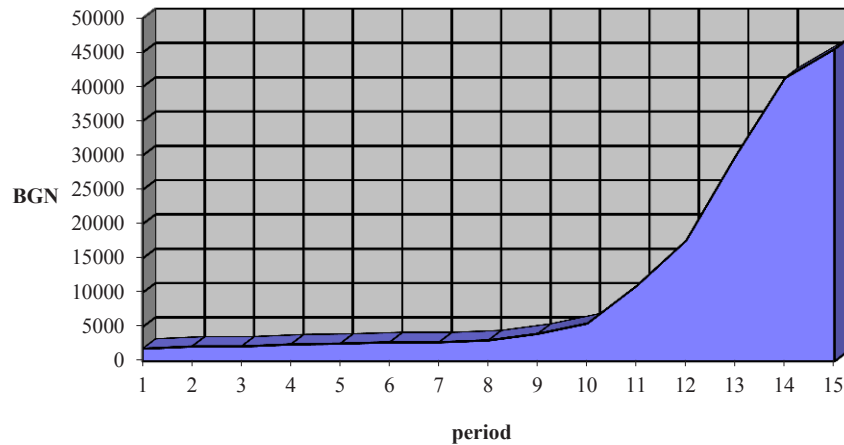
Social factors include reference groups – families, social roles and statuses. The family is the most influential primary reference group. There are two families in one's life – his parents' family and his own. That is so, because it's quite possible that the inherited habits from the first family may transfer to the other. For example – If there had been a certain type of sausage included in one 25 year old men's usual meal then most probably it would still be included in his meals after he has created a new family.

Social Roles and Statuses. As people occupy numerous positions in their careers, they have many roles. For example – A male can be a

husband and a father, but he can also be a worker, an employee or trainer. There are some sets of expectations for the behavior of every person. The roles of the individual influence not only the general behavior, but also the shopping behavior. The requirements of the different roles one has can be inconsistent and confusing. For example – let's assume a father wants to buy fillet "E". His wife wants it bought tomorrow. His kids want him to buy ham "D". His college recommends him pork "T", which is famous for its high quality. So the shopping behavior is partially influenced by the input and the opinion of others.

Personal Factors: include age, stage of life, career, economic environment, lifestyle, personality and self-perception. The economic environment has a strong impact on the customer's decision which product from the company X's assortment to buy. (Figure 2)

Distribution of wages



Graphic 2 - Distribution of Wages

Individuality and self-perception are important factors of the personality which include special psychological characteristics which lead to a fairly consequent and unchanging reaction towards surrounding environment. Self-perception is a part of the person's view of himself or his attitude towards marketing – whether the product or brand are positioned so that they meet the perception of the target market. Self-perception is made of two types:

- Ideal – or how the person sees himself in his own eyes;
- Through others – or how a person is seen by the others.

Psychological factors include motivation, perception, knowledge, beliefs and attitude. *Motives* are necessities big enough to cause action. The main theories of human motivation are the theories of Freud, Maslow and Hertzberg. According to Freud the psychological motives

forming the human behavior are mainly subconscious. According to Maslow the human needs are hierarchically arranged – Maslow's pyramid. According to Herzberg motivation is influenced by two types of factors – the first one causes feeling of satisfaction – and the second type causes feelings of dissatisfaction. Our goal here is to remove the influence of the second type of factors. Increasing the feeling of satisfaction leads to differentiation of the brand and product.

Perception as a psychological factor influences the human choice, organizes and interprets the available data in order to construct an idea of the world or the situation. There are three processes:

- Selective attention – it means that the people perceive only a part of the stimuli. The stimuli of the company X should ensure attracting and keeping of the consumer's attention;

- Selective distortion – it reflects the tendency of people to perceive the received data while not dismiss their predisposition;

- Selective memory – People permanently hold back the information which supports their views and beliefs.

Learning describes the change in attitude due to gaining experience. Learning is a result of the interaction of motives, stimulus, motivation and reinforcement effects.

Beliefs and predisposition are formed in the process of human activity. Beliefs are thoughts which support a certain statement. Beliefs construct the views of brands and products. Predisposition is a permanent evaluation, feeling and eventual action regarding a certain object or an idea. Predisposition puts the objects in a certain thought frame – positive or negative.

Industrial user is a term that includes user organizations forming the business market as well as different social structures. Their thought process preceding a purchase are different than that of the mainstream user. That is so because their purchasing decisions depend mostly on the economic benefits of the purchase.

Competitive analysis is one of the key points in analyzing the presence of a company on the market. Considering that importance, the logistic analysis has the purpose of making a most accurate assessment of the current and potential competitors. It is important to point the source of the data we have used. First is the

register of the Privatization agency for companies subject to mass privatization, annual accounting reports published in the media, the business plan of one of the competitors. We haven't had a direct contact with the companies themselves due to physical and material limitations of the research. We'll fix on three main competitors of the company X from the town N. The criteria according to which the competitors are chosen are the following:

- Company structure;
- Company size;
- The company's way of working;
- The location of the company;
- Membership in a particular system.

The scope of activity and the production structure of the competitors overlap because of the similarity of the companies. In general the all three companies stated in the competitor analysis have as main activity producing and processing meat into a variety of meat products and selling them on the market. The focus of the products is for the internal market due to the setting in the country. The production structure is also similar. In both of the stated competitor companies and in company X in town N had been noted a tendency of updating the equipment inherited from the state structures.

In conclusion it must be noted that the differential assessment of the economical aspects of evaluation of the logistic systems has great

importance on the company's profits. The mass demand in the region, sales in the country and abroad, the

assortment, quality and the competitive price all have a significant influence as well.

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THE REMOVAL OF EXCESSIVE MOISTURE ON SPACESHIPS AND SATELLITES THROUGH LYOPHILIZED FOODS AND OTHER LYOPHILIZED PRODUCTS

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Abstract The moisture in the spaceships and satellites is one big problem disturbing the normal functioning of number of devices and worsening crew's conditions of life. Lyophilized products are extremely hygroscopic. Foods for astronauts are conserved through lyophilization. That means, lyophilized products, including and lyophilized food products, in principle could be used to eliminate the excess of water.

Key words: lyophilization, lyophilized blood products, lyophilized foods, spaceships, moisture, gas mask, absorption, submarine

Lyophilization is a process of extracting water from food and other products (e.g. erythrocyte mass, plasma proteins, blood serum, collagen from pigskin and others), so that food or products stay stable, easier to keep under room temperature [1, 2].

Lyophilization is being done using a simple physical principle, called sublimation. Sublimation is the transition of a substance from solid to gaseous condition, without going through intermediate phase liquid [3]. Lyophilization as a method presents drying of some products in low temperature, in vacuum. Temperature of water boiling depends on external pressure. In low pressure it goes down, which creates possibility products to get dried. In sublimational

drying are combined two ways of conserving – freezing and drying in vacuum, in temperatures, not over the critical ones, in other words, temperatures in which micro- and macrostructure of the product is being impaired. Sublimational drying consists in separating the water substance from solid matrix of the product, in environmental pressure lower than the triple point of water. In its own nature dryness is an equal process, leading through moisture- and warmth-transfer, to a certain constant physicochemical parameters of product and before everything, to a certain residual moisture content. Process should be done in a way that secures the required decreasing of moisture, without worsening the

biological value of the food product and its quality indicators.

Lyophilization is multi-stage process that includes:

- 1) Freezing of the products to low temperatures, so that the water in food (not nutrient respectively product) becomes ice; under vacuum, ice sublimates directly in steam.
- 2) Primary drying, where the new-formed, during the freezing, icy crystals sublimate under the influence of initial intensive, and after that moderate heating, in conditions of high vacuum;
- 3) Secondary drying, where residual moisture is being desorbed, in positive temperatures and conditions of higher vacuum;
- 4) Completing the process, by reaching a specific final residual moisture of the product, where the vacuum, in the sublimational chamber, is being impaired with dry inert gas, product is being packed up and stored [4].

Subject of sublimational drying are all kind of foods, except for foods with fats. The technology of sublimational drying is suitable for production of mass-consumed food, as well as a specific dietetic and functional foods, including and foods for astronauts. The consistence of moisture in the product and the character of its connection with the material, influence over the continuance of drying and its speed. In sublimational drying is imperative 70-90% of moisture in the product, to be exuded in negative temperatures, so that to be

guaranteed its high quality. Part from the left, the most closely related water, could be exuded only in positive temperature, in the phase of desorbtion [5].

Sublimational dried products are lean, dry, light with porous structure. They keep their original form, structure, color, smell, taste, vitamin consistence, mineral substances, amino- and fat acids, proteins and etc. The residual moisture content is practically equal distributed over the entire volume of the product, e.g for lyophilized blood products it is from 3 to 6 % [6]. For most of the vegetables and fruits it is in within the boundary of 2-3%, for meat and eggs – 4-5%, and in rich of starch potatoes, corn, beans, - 6% [7]. In a correctly performed sublimational drying, the final product is with low values of water activity (a_w is within the boundary of 0.3-0.5). Water activity parameter gives information about the water condition in the material and accounts that part, which could be exchanged with the environment and it is available for chemical and biological interactions. Water activity is fermentational stability of lyophilized products [8].

Sublimational dried foods usually are highly hygroscopic. The absorbed water vapors from the air, which leads to sharp increase of moisture content of the product and worsening its qualities. The selection of suitable wrapping is necessary condition for effective and long-term storage of lyophilized products [8]. In hermetic closed wrapping (of materials impermeable to gases and vapors)

they could be stored for a continuous period of time – 5-10 years, without changing their qualities. That way dried products could be quickly restored through re-hydration, where most of their basic physico-chemical, organoleptic and nutrient qualities are restored.

Lyophilization has many advantages compared to other technics of conserving. Lyophilization retains quality of food, because during the process of sublimation, food stays at temperature, which is below the temperature of freezing. Lyophilized foods usually could be stored without cooling, and that leads to significant reduce of expenses for storage and transport. Lyophilization significantly reduces the weight and that makes the products easier to transport, e.g. many foods consist over 90% water. These foods are about 10 times lighter after lyophilization.

So that lyophilized foods and products are porous, most of them could be easily re-hydrated. Lyophilization does not reduce the volume significant, and because of that, water returns its place in

molecule structure of the food, so quickly. That makes lyophilized foods suitable for astronauts' food (well conserved, with retained nutrient qualities, and in the same time very light), because for exporting of each gram payload into space are needful large amounts of fuel, respectively the price grows significant.

In the same time lyophilized products are highly hygroscopic. They absorb large amount of moisture, if they are left free in air [9]. Moisture is a big problem on the spaceships.

Perhaps it is possible lyophilized products to be used (e.g. collagen sponges, derived from pigskin) or even foods for absorption of excess of moisture. That way re-hydration with water in liquid condition will not be needed, and it could be saved. It is enough only to break the package of the food and to wait for a while, before consuming.

Lyophilized products could absorb toxic gases and vapor of many different toxic compounds [10]. Perhaps their quality could find some practical application in space or in submarines?

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MODELING OF THE RIVER SYSTEM OF GOLIAMA KAMCHIA

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Abstract: The present study is based on an integrated approach for assessing the conditions and the relations between environmental factors that determine the extent of flooding danger in the researched area. Meteorological and hydrological factors come first, as well as geo-morphological factors, landscape factors and the management of flood risks. For the purposes of the study a wide range of statistical, cartographic, geodesic, remote and inquiry methods, and field observations are used.

Key words: GIS, ESRI MAIK 11, ETK, ДГМ, ДGPSM, ГММП, РГО, ERDAS, Singlet CAM

1. General information about River Kamchia

Kamchia River's former name was Ticha. Its water catchment area has the following coordinates: B1 = 42 ° 45 ', L1 = 26 ° 20' and B2 = 43 ° 25 ',

L2 = 27 ° 55'. The river and its tributaries flow in the eastern part of Stara Planina. Their position is shown on the hydrographic pattern on (Fig. 1).

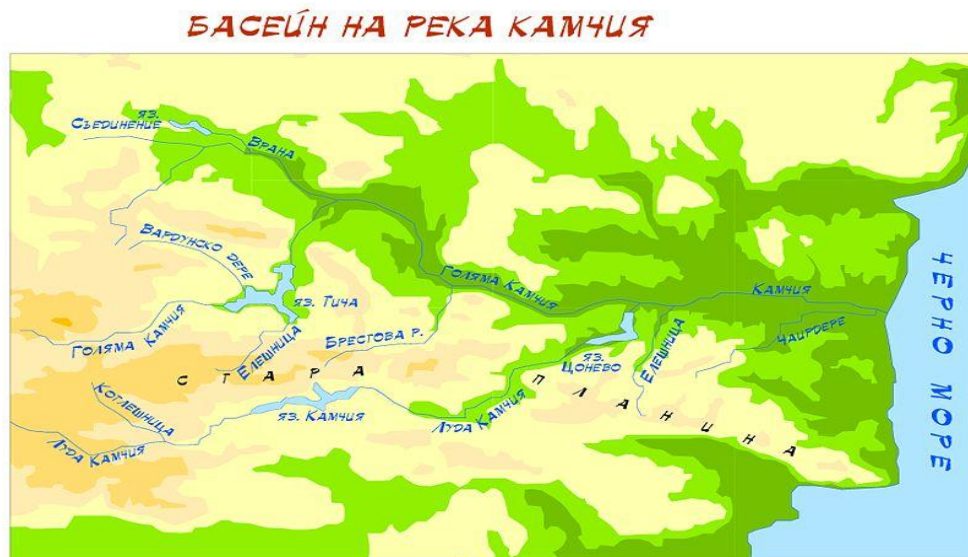


Fig. 1 river system of goliama kamchia

River Kamchia is formed by the rivers Goliama Kamchia (Big Kamchia) and Luda Kamchia (Overflowing Kamchia); Goliama Kamchia is conditionally accepted as its starting

point. The total water catchment area of the basin is 5358 km². River Kamchia begins from Lisa Mountain. The coordinates of its source are C = 42 ° 59'40 "and L = 26 ° 16'40" in

height $H = 710$ m. The river flows northeast, towards the town of Shumen to the village of Khan Krum. At this location, the river makes a big turn to the south, and from the town of Smiadovo it flows eastwards, keeping that direction until its flow into the Black Sea. The coordinates of its mouth are $B = 43^{\circ} 01'30''$ and $L = 27^{\circ} 53'30''$. River Kamchia is 245 km long, with an average slope of 2.9° . Despite the many tributaries (27 in all) the density of its river system is too low – 0.7 km/km². The largest tributary of Kamchia is Luda Kamchia – its length is 201 km and its catchment area is 1612 km², with an average gradient of the river 5.3° . The second largest tributary is Vrana River – having length of 68 km and catchment area of 938 km². The average slope for all feeders is between 3.7° to Kerizbunar River (a tributary of River Vrana (the name means ‘crow’)), and 4.1° to Black River, a tributary of River Kamchia. The average altitude of the river basin of Kamchia is $H = 327$ m.

2. Overview of the modeling

A river system can be modeled using the following methods [5],[10],[11]:

- Hydrological modeling;
- Hydraulic modeling;
- Geo-information modeling.

Hydrological modeling is applied in river basins where rainfall has to be conducted into runoff of water discharges at special river posts.

Hydrological processes are quite complex, as rain or snow do not

go directly into the riverbed, and follow a conceptually different path, passing through various transformations until reaching the outflow of the pool [9],[11].

There are different ways of modeling these processes of water transfer from rain to a runoff of rivers: hydrological models can be generalized (where a pool is considered as one whole), or distributed (the pool is shredded into small connected segments (1ha), in which the modeling of processes is held, and then combined with the others).

Usually, practical hydrology makes use of generalized models. Thus is the approach in the present experiment.

Hydrological modeling allows for tracking the movement of the high wave along the river current, by setting also the elevation of the water surface. Individual items can be 1D (one-dimensional) or 2D (two-dimensional) planes.

The following table shows the watershed of River Kamchia. The river is modeled in two parts: from Ticha Dam – near the village of Cherny Vrah (Black Peak), Shumen District, and from the village of Cherny Vrah to the Black Sea (Varna). After completing the modeling of each part, the two models are merged and validated as a general model. The length is measured in kilometers.

Tabl. 1 First part of Goliama Kamchia River

Name – hydrodynamic model	CRS	Length
Kamchia	50	40 km
Vrana	1	68 km
Poroyna	1	19 km
Brestova	1	15 km
Total	53	142 km

Tabl.2 Second part of Goliama Kamchia River

Name – hydrodynamic model	CRS	Length
Kamchia	50	63 km
Luda Kamchia	1	5 km
Eleshnitsa	1	5 km
Total	51	73 km

A) Creating a hydrological model

Hydrological model could be created by using the specialized program of ESRI MAIK 11[13],[14].

Each hydrological model in the system is defined on a conceptual level first, by splitting the river basin into sub-basins. The models are constructed from GIS of the river basin and its sub-basins. Their definition (i.e. the first calculation of parameters) before calibration is based on various features provided by GIS: surface and shape of the basin, vegetation, soil characteristics, geological information, incline, slope, etc.

The calibration of a hydrological model consists of specifying the parameters that form each model. For the present model, data of past observations have been used. At the start of the model, with real recorded data input into the

system (rain, snow, temperature, excessive intake of water, etc.) and at the end comparing them to the observed water quantities, the various parameters are optimized to minimize the differences between the results at the end and the observed data in several measured periods characterized by high waves.

B) Creation of a hydraulic model

Hydraulic models are created using the exact details of the gutters, the ratio of total runoff, storage mechanisms on floodplains, as well as major facilities such as bridges, dams, dikes, terraces, and drained swamps. Detailed topography is required – of the areas endangered of flooding, to the intersection of the slope, to the terraces or to the hills – to form and shape the hydraulic system.

Hydraulic modeling is based on points that are connected in a topology network. For the connected

points in the main channel and the nearest left and right side of the flood plain.

For points in the flood plain associated with the topographic structures such as dams, roads, railways, whose borders of water retention are defined. In addition, floods can be modeled through equations using water overflowing quantities.

Since a detailed topographical description is used, the water level is the main variable controlling the modeling of currents in the spill. Thus, the topographic information must be accurate enough, so that the model is effective in its forecast. Accuracy of ± 10 cm of the topographic structure as a whole is desirable for these models.

Depending on the topographical variations of the riverbed and fortifications, the distance between the cross sections can vary from 2-3 kilometers to 500 meters.

When the area of the spill and the slope of the riverbed are in planes (as is the case with the lower river current of Kamchia), the hydraulic models are very sensitive to errors in the topography. This means that variations in the water level (which may be the result of a not so good topographic survey) between real data and simulation data will spread downstream and upstream, which will generally lead to a bad result.

The main disadvantage of the hydraulic models is in the quality of geo-information used for designing topology.

The creation of a hydraulic model contains the following steps:

- Gathering and processing information for cross-sectional and topographic data.
- Assessment of the terrain in which water discharges, and of the ground on which water retains, in the cross sections and spills.
- Collection and processing of measurements for the level and the quantity of water flow of hydrological stations situated on the tributaries of the rivers from the first order.
- Collection of data for the constructed river structures and ways of managing them.

Building of the model by recording data on:

- The borders of the rivers and their tributaries with relevant significance;
- The cross sections;
- The side and border flow;

Calibration and validation of the hydraulic model through testing it with data from the past, leads to minimization of model deviations (as compared to the ones reported by the stations) in water levels and quantities.

One should have in mind that the calibration and validation of the model can be started only when all necessary information is collected, analyzed and processed; the steps before checking the model do not depend on each other and can be executed separately.

C. Creation of Geo-information models [1-3],[7]

As the hydrological and hydraulic models show, a central role in their building takes the credibility of the geo-information model.

1. Geo-information model, created using the method of digitalization of topographic maps

For the development of a geo-information model using the method of digitizing topographic information from topographic maps, the following materials are collected and analyzed:

- Topographic maps at a scale of 1:25000;
- Large-scale topographic maps (ETC) at scale 1:5000;
- Cadastral maps in digital form;
- Coordinate lists, catalogs and registers of geodesic points SGN, DGPSM, GNLI, BER etc..

ETK in scale 1:5000 of the Nomenclature line-wide river Kamchia (84), as well as topographic maps in scale 1:25000 (25), are scanned. The scanned images are in raster format, with JPEG extension. In an MKAD medium, the raster images are geo-referenced in coordinate system year 1970 K-7. A series of related ETK throughout the valley is obtained. In an MKAD medium, a transformation of the image coordinate system of the 1970 K-7 in the coordinate system UTM - WGS 84 Zone 35N is performed. Based on the resulting image, vectorization is performed. A “relief” layer is created first, and then main, additional, and auxiliary horizontals are vectorized in base section 5 m (1 m). The vectorization is held in an AutoCAD medium map. Data for the metrics and semantics are saved in files with

DXF and DWG extensions, by creating also files for ESRI medium with SHP extension. The objects (the horizontals) in the “relief” layer are obtained discretely using the graphics primitive POLYLINE. Data for objects are stored in object-oriented relational table of the layer (the topic). The correctness of the data in the table is checked and, if necessary, corrections are made. In an ESRI medium - ArcGIS (ArcView) theme “relief” is added. The coordinate list of points from SGN, GNLI, DGPSM, BER are introduced, in the form of TXT or DBF format tables, which enriches the information about the landscape. The result theme is of points. To obtain a model of the surface of the research area, based on the information from linear and point themes “relief”, an irregular network of triangles (TIN) is created. Based on the created TIN model, a GRID model and a raster DTM models are made [4],[15].

Following the “relief” theme, a “hydrography” theme is created. Goliama Kamchia River is vectorized, part of the larger tributaries - Vrana River and Luda Kamchia River, Ticha Dam, Tsonevo Dam, and part of the Black Sea. The vectorization is done in an AutoCAD medium map. Data for the metrics and semantics are saved in files with DXF and DWG extension, by creating files for an ESRI medium – with SHP extension. Objects in the “hydrographic” layer (rivers, dams, the sea) are discretely obtained by using graphical primitives POLYLINE. Then Polyline is edited and presented as a polygon.

Exporting “hydrographic” layer from AutoCAD map in ESRI - ArcGIS (ArcView) is performed as a polygon theme with the SHP file. Consecutive topics are created, such as: “roads”, “vegetation”, and “settlements”. With the last topic, “settlements”, data from the cadastral maps is used, in CAD and ZEM formats. All files are

converted into coordinate system UTM – WGS84 – zone 35N in advance.

All topics are supplemented with attribute information and stored in the database as “Kamchia” Project. The developed model is shown in (Figure 2).

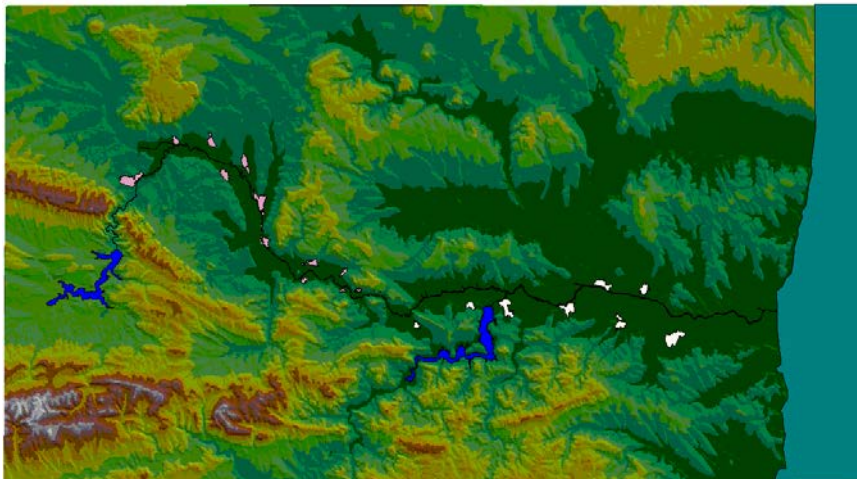


Fig. 2 The developed TIN model

2. *Geo-information model established by photogrammetric methods*

A). *Introduction of raster data* - of ortorectificated aerial photographs, is realized by the following technology: Scan of the source materials with precision photogrammetric scanner ULTRA SCAN 5000; Creation of project in ERDAS; Defining the sensor model; Determination of control (anchor) points and their measurement with GPS or reporting from topographic maps, Automatic generation of interconnection points; Block alignment (including aero-triangulation); Ortorectification; Quality Control; Alignment of brightness (and color) of the images; Creating of mosaics (pooling of

individual grid lines and aerial photographs of map sheets); Entering metadata.

B). *Input of data for the relief by photogrammetric method* includes: Creating a project in ERDAS; Defining the sensor model; Determination of control (anchor) points and their measurement with GPS or reporting from topographic maps; Automatic generation of interconnection points; Block alignment (including aero-triangulation); Extracting digital elevation model of the relief; Editing the digital elevation model of the relief; Quality control; Import of raster data for the terrain in geo-base data;

In the accomplishment of the photogrammetric methods, data from aerial photographs in the period 2000 - 2011 are used, by courtesy of the company Geodetect Bulgaria and CI. (Fig. 3)

Company Geodetect provided an UAV - Swinglet CAM of the Swiss company SeneseFly, for the experimental research of the section of the village Khan Krum near the village Salmanovo. Swinglet CAM is an innovative mini airplane. Swinglet CAM has a 12-megapixel camera

with a focus length of 24 mm. When flying at an altitude of 50 m, the pixel size of the pitch is 2 cm. The altitude can reach up to 1500 m, which corresponds to 60 cm pixel size.

Despite the small area (about 15 km), data from the measurements and their processing show that this modern method is economical and the precision achieved is within the standard photogrammetric method - (0.3 - 0.5 m) in both horizontal and vertical position.

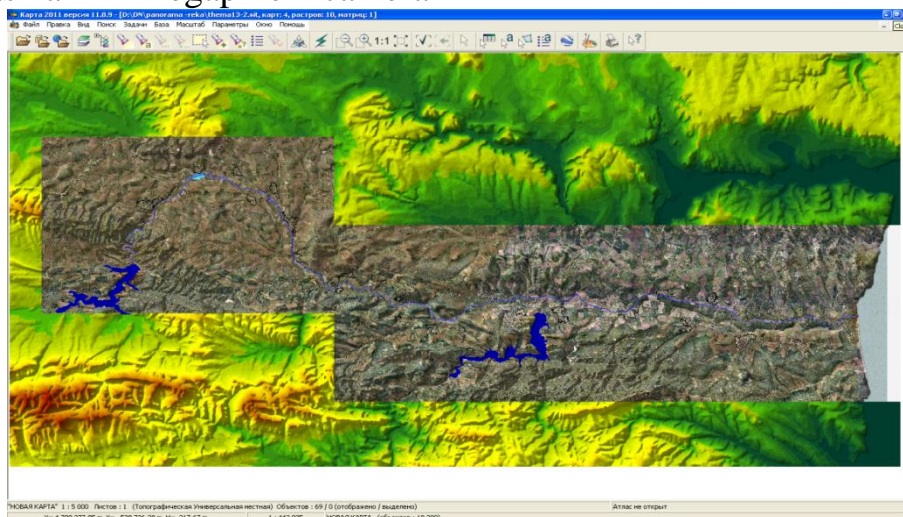


Fig. 3 the photogrammetric methods

The models created by these two methods were tested (validated) in previously developed concept and methodology. This is done through geodesic surveying of the terrain, which is considered a standard. Due to the large size of the studied area and the limited resources available, impressive part of the whole territory is tested. The obtained results are positive and the models' reliability is proven, which allows for their implementation into practice. Some minor omissions and inaccuracies in modeling are detected

in the process of validation, and after analyzing the discrepancies between model and reality, the model parameters are adjusted and changed. Comparative analysis of the models is performed, using methodology specially created for the purpose. In the evaluation of the geo-information models by using the two methods, accuracy and reliability are accepted as main criteria. The data are shown in Figure 4 [6]. The accuracy of the geo- information model, created by using the digitizing of topographic maps, is $m_{ETK} = \pm 3.66$

m, while with the model, established by photogrammetric method, it is $m_{A\Phi C} = \pm 0.51$ m.

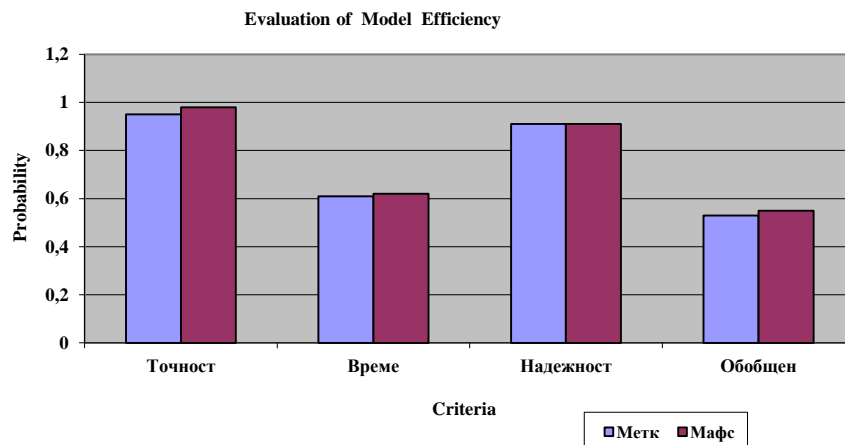


Fig. 4 the evaluation of the geo-information models by using the two methods

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TETRAHEDRAL COMPLEX OF Cr^{3+} AND Cr^{4+} IONS IN $\text{Bi}_{12}\text{SiO}_{20}$

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ABSTRACT Absorption measurement is taken in the visible spectral region (650 – 1300 nm). The dopants Cr^{3+} and Cr^{4+} ions occupy the tetrahedral sites in the crystal lattice of doped sillenite. The energy level structure of these ions in $\text{Bi}_{12}\text{SiO}_{20}:\text{Cr}$ (BSO:Cr) are presented. The Dq -, B - and C -parameters of the crystal field theory for the Cr^{3+} and Cr^{4+} ions were obtained. The spin-coupling energy is also calculated for the chromium ions.

KEY WORDS: absorption spectrum, 3d transition metals, Racah parameters, energy of the spin pairing

INTRODUCTION

Bismuth oxide compounds such as the sillenite-type $\text{Bi}_{12}\text{MO}_{20}$ (BMO, where $M = \text{Si}, \text{Ge}, \text{Ti}$) crystals are being extensively studied because of their potential applications including dynamic holography, optical information processing, optical phase conjugation and real-time interferometry [1–5]. The defect identification, including the dopant ions involved, their valence and local symmetry is essential because this information may guide the efforts for optimization of the synthesis conditions to obtain the intended material properties. In this paper, we present a detailed optical study of Cr^{3+} and Cr^{4+} ions which are in the tetrahedral coordination.

MATERIALS AND SAMPLES PREPARATION

$\text{Bi}_{12}\text{SiO}_{20}$ crystals belong to the sillenite family of materials with the space symmetry $I23$ with a body

centered cubic unit cell ($a = 10.102 \text{ \AA}$), which contains 24 Bi^{3+} ions, 2 Si^{4+} ions and 40 O^{2-} ions (nominal valences). Two structural elements can be distinguished, the SiO_4 regular tetrahedron and the BiO_7 polyhedron [6]. The former exists at the corners and at the center of the cubic unit cell. In the BiO_7 polyhedron, each of the Bi^{3+} ions is surrounded by 7 oxygen atoms and is coordinated in a pseudo-octahedral configuration, in which the oxygen atom at one corner is replaced by two atoms at somewhat larger distance. BSO single crystals were grown in air by the Czochralski method from a melt containing a mixture of high purity (99.9999%) oxides including Bi_2O_3 and SiO_2 in a 6:1 molar ratio [7]. Platinum crucibles of 60 mm in diameter and 80 mm in height were used as containers. The crystals were grown in a $\langle 001 \rangle$ direction under conditions of low temperature gradient over the solution ($5\text{--}7 \text{ }^\circ\text{C}/\text{cm}$), at a growth rate of 0.7

mm/h and a rotation rate of 20 rpm. Fully faceted and optically homogeneous crystals of 35 mm in diameter and 50 mm in height were obtained. The starting chromium dopant was introduced into the melt solution in the form of the oxide Cr_2O_3 . The analysis by atomic absorption spectrometry shows that they are present in the crystal at concentration of $[\text{Cr}] = 4.9 \times 10^{18} \text{ cm}^{-3}$. This corresponds to relative concentration $[\text{Cr}]/[\text{Si}] = 0.25\%$.

EXPERIMENTAL RESULTS AND DISCUSSION

The electron paramagnetic resonance (EPR) identifies a chromium ion in the unusual Cr^{3+} valence replacing a substitutional Si^{4+} in tetrahedral oxygen coordination [8]. Evidence is found that the symmetry lowering from tetrahedral (T_d) to trigonal (C_{3v}) is not spontaneous, but induced by an associated defect. It has been previously reported that chromium in BSO and $\text{Bi}_{12}\text{GeO}_{20}$ (BGO) crystals occupies the tetrahedral metal M^{4+} sites in the oxidation states Cr^{5+} and Cr^{4+} and that both reduction under vacuum annealing and illumination pushes the balance toward Cr^{4+} [9–11]. The aim of this work is to explain the appearance of $3d^3$ transitions (Cr^{3+}) in the spectral region 650-900 nm and the observation of $3d^2$ transitions (Cr^{4+}) in the spectral region 900-1300 nm.

The experimental set up for measurement of the absorption coefficient in the visible and near IR region consists of the following: a halogen lamp with a stabilized 3H-7

rectifier, a SPM-2 monochromator, a system of quartz lenses, a polarizer, a crystal sample holder, and a Hamamatsu S2281-01 detector.

The absorption coefficient of the investigated samples has been measured to be between 650 and 1300 nm (Figs.1a and 2a). The first derivative of the absorption coefficient at photon energy is calculated to be in the 680-1300 nm spectral region. The $[d\alpha/d(h\nu)]$ determines only the number of electron transitions in a Cr^{3+} and Cr^{4+} ions and it does not give an exact information about the energy position of these transitions. This is the reason for the calculation of the second derivative of the absorption coefficient $[d^2\alpha/d(h\nu)^2]$.

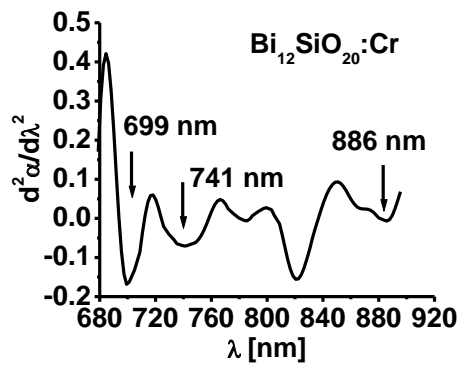
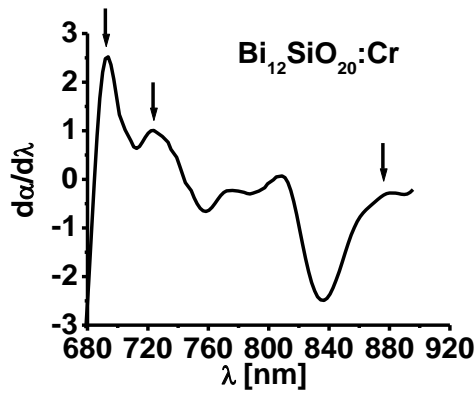
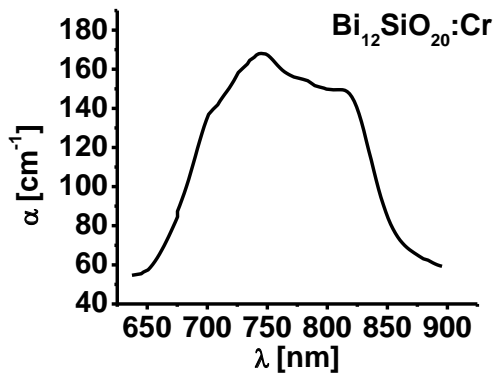


Figure 1 a) Absorption spectrum of Bi₁₂SiO₂₀:Cr³⁺ in the spectral region 650 – 900 nm; b) first derivative of absorption coefficient; c) second derivative of absorption coefficient.

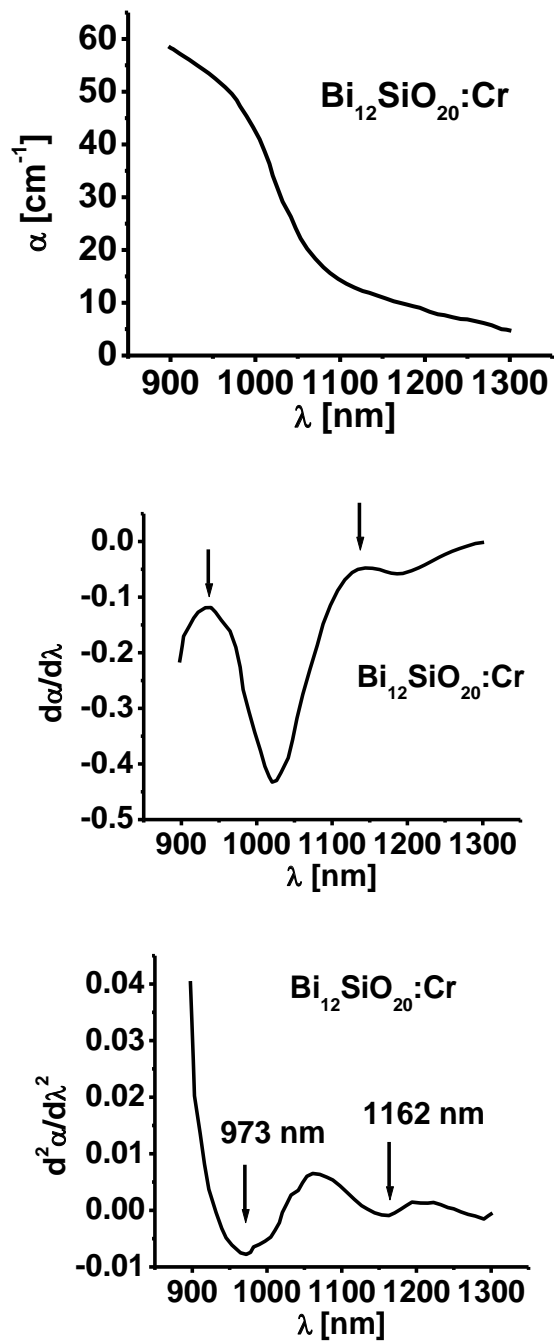


Figure 2 a) Absorption spectrum of $\text{Bi}_{12}\text{SiO}_{20}:\text{Cr}^{4+}$ in the spectral region 900 – 1300 nm; b) first derivative of absorption coefficient; c) second derivative of absorption coefficient.

The absorption coefficient is calculated using the formula: (1) $\alpha = (1/d)\ln(I_0/I)$, where I_0 is the intensity of the incident light, I is the intensity of the passing light and d is the sample thickness.

The components of the Cr^{3+} structure that are connected with the electron transitions are ${}^4\text{A}_2({}^4\text{T}_1({}^4\text{F})) \rightarrow {}^2\text{E}({}^2\text{G})$ (1.4 eV), ${}^4\text{A}_2({}^4\text{T}_1({}^4\text{F})) \rightarrow {}^4\text{A}_1({}^4\text{T}_2({}^4\text{F}))$ (1.67 eV) and ${}^4\text{A}_2({}^4\text{T}_1({}^4\text{F})) \rightarrow {}^2\text{E}({}^2\text{T}_1({}^2\text{G}))$ (1.77 eV) (Fig. 3). The absorption structure of Cr^{4+} includes the next two electron transitions ${}^3\text{A}_{2g}({}^3\text{F}) \rightarrow {}^3\text{T}_{2g}({}^3\text{F})$ (1.07 and 1.27 eV) (Fig. 4). The crystal field parameter D_q and the Racah parameters B and C are calculated for Cr^{3+} and Cr^{4+} . The values of B are 910 cm^{-1} and 944 cm^{-1} . The values of the parameter C are 4213 cm^{-1} and 4446 cm^{-1} . The values of the crystal field parameter D_q are 1365 cm^{-1} and 944 cm^{-1} .

If the electron transitions are realized between the basic and the closest low energy excited states, then they are connected with the manifestation of the dynamical Jahn-Teller effect (Fig. 3). This effect is manifested as the deformation of the chromium tetrahedron and the T_d symmetry transforms into the C_{3v} symmetry. The ionic radii of Si^{4+} , Cr^{3+} and Cr^{4+} are as follows 40 \AA , 75.5 \AA and 69 \AA . Thus it can be observed the tetrahedral distortion. The final result is expressed by the great influence of the Jahn-Teller effect on the energy values of the observed impurity absorption bands (Fig. 3) and the chromium complex becomes stable

under the influence of the spin-orbit interaction.

After the spin-orbit interaction the total angular momentum J becomes equal to $1/2$ and $3/2$. The EPR of chromium doped $\text{Bi}_{12}\text{SiO}_{20}$ gives information that the total spin angular momentum S is $3/2$ [8]. In this connection, there are two possibilities for the total orbital angular momentum $L = 0$ and $L = 1$. The case when $L = 1$ is very interesting, because the orbital quantum number $l = \pm 1$. The ligand gives one electron to the metal ion when the charge transfer is observed [12]. This electron becomes indistinguishable from the other electrons of the metal ion. Thus we can change the value of the exchange energy and it can increase or decrease. Thereby the spin-coupling energy (SCE) corrects. This energy is presented by the formula:

$$(2) E_{\text{SCE}} = P[3/4q - [3q(q-1)]/(16l+4) - S(S+1)],$$

where P is a parameter of spin coupling and it depends on the parameters B and C and q is the number of the electrons of the metal ion. When the charge transfer from ligand to the metal ion is observed, the parameter P is calculated using the formula:

$$(3) P = 7/6[(5/6)B+C].$$

The final result is that $E_{\text{SCE}} = 13\,920 \text{ cm}^{-1}$ for Cr^{3+} ion and $E_{\text{SCE}} = 6410 \text{ cm}^{-1}$ for Cr^{4+} .

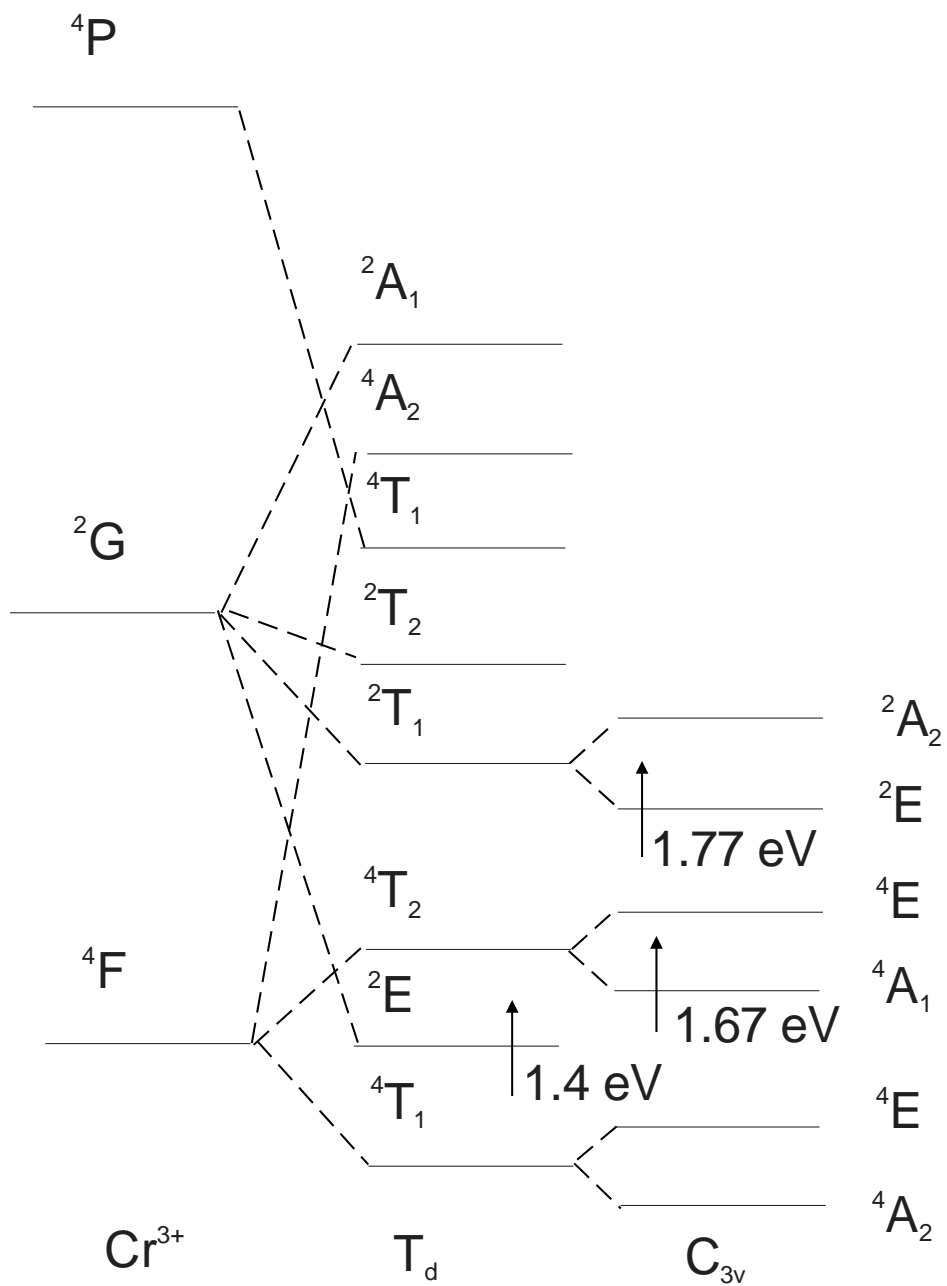


Figure 3 Energetic diagram of Cr^{3+} ion in C_{3v} symmetry.

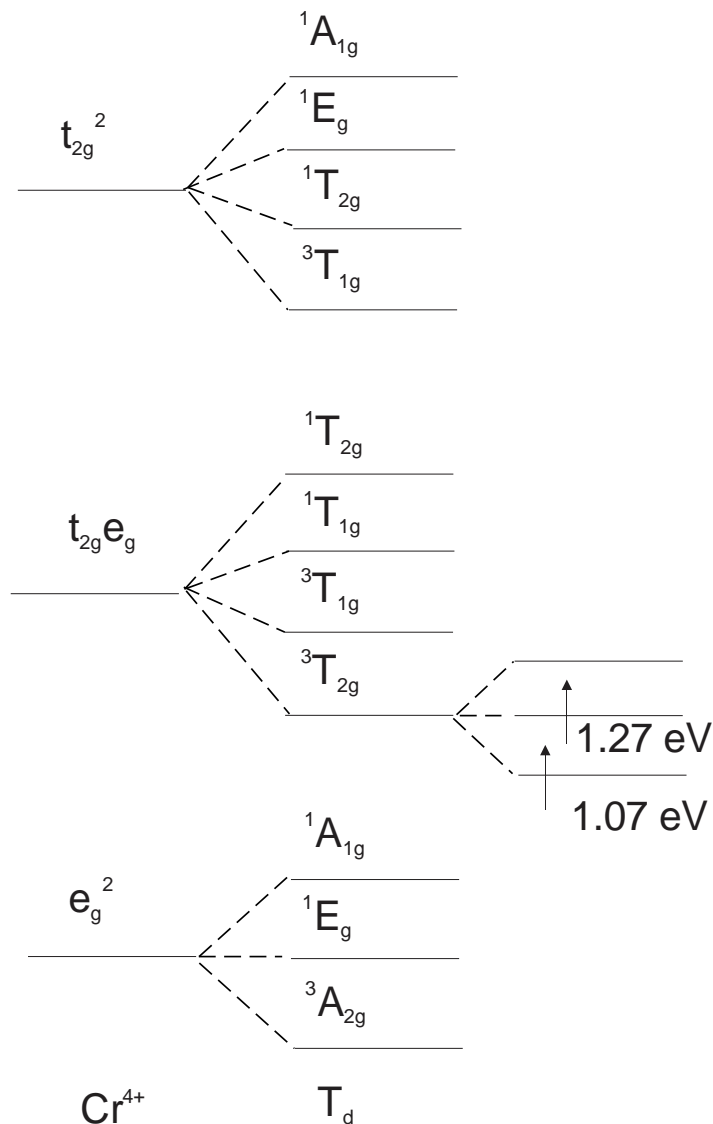


Figure 4 Energetic diagram of Cr^{4+} ion in T_d symmetry.

CONCLUSIONS

In this work, the interesting fact is that the impurity absorption structure in the visible spectral region is a combination between the structure of Cr^{3+} and Cr^{4+} ions.

The tetrahedral complex of Cr^{3+} manifests stronger Jahn-Teller effect

and the tetrahedral complex of Cr^{4+} appears stronger spin-orbit interaction.

The charge transfer for $\text{O}^{2-} \rightarrow \text{Cr}^{3+}$ is realized at bigger spin-coupling energy in comparison with the value of the spin-coupling energy for $\text{O}^{2-} \rightarrow \text{Cr}^{4+}$.

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SYNTHESIS OF AMINO DERIVATIVES OF MONOTHIO- AND DITHIO- ANALOGUES OF CYCLOHEXANESPIRO-5-HYDANTOIN

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Abstract: This article presents methods for synthesis of 3-amino derivatives of cyclohexanespiro-5-(2-thiohydantoin) and cyclohexanespiro-5-(2,4-dithiohydantoin). It was found out that the treatment of cyclohexanespiro-5-(2-thiohydantoin) with hydrazine hydrate under different reaction conditions led to obtaining of 3-amino derivative and 2-hydrazone of the initial compound. As a result of thionation of 3-aminocyclohexanespiro-5-hydantoin with P_4S_{10} or Lawesson's reagent, the corresponding dithio-analogue was synthesized. The structures of the products obtained were verified by IR, 1H NMR, ^{13}C NMR and mass spectral data.

Key words: cyclohexanespiro-5-hydantoin, amino derivatives, thio-analogues, thionation

I. Introduction

It is well known that the refluxing of cycloalkanespiro-5-hydantoins with hydrazine hydrate lead to obtaining of the relevant 3-amino derivatives [1].

Conducting the reaction between spirodithiohydantoins and hydrazine hydrate at normal conditions resulted in formation of the corresponding 4-hydrazones of the initial compounds [2].

The aim of this paper is to examine the implementation of the above said interactions on spiro-monothiohydantoins, as well as to present two effective thionation techniques for obtaining of dithio-analogues of 3-aminocycloalkanespiro-5-hydantoins.

For this purpose, studies on the treatment of cyclohexanespiro-5-(2-

thiohydantoin) with hydrazine hydrate at different reaction conditions were conducted.

The thionation of 3-aminocyclohexanespiro-5-hydantoin was performed by using P_4S_{10} and Lawesson's reagent (LR) as thionation reagents.

II. Experimental

II.1. Materials and methods

All chemicals used were purchased from Merck and Sigma-Aldrich.

The cyclohexanespiro-5-hydantoin (compound **1**, Scheme 1) was synthesized *via* the Bucherer-Lieb method [3]. The cyclohexanespiro-5-(2,4-dithiohydantoin) (compound **2**, Scheme 1), the 4-(2-hydroxyethylimino)-cyclohexanespiro-5-(2-thiohydantoin) (com-pound

3, Scheme 1) and the cyclohexanespiro-5-(2-thiohydantoin) (compound **4**, Scheme 1) were obtained in accordance with Marinov et al. [4]. The 3-aminocyclohexanespiro-5-hydantoin (compound **6**, Scheme 1) was synthesized in accordance with Naydenova et. al. [1]. Lawesson's reagent (2,4-bis(4-methoxyphenyl)-1,3,2,4-dithiadiphosphetane-2,4-disulfide) was prepared in accordance to Ref. 5.

Melting points were determined with a digital melting point apparatus SMP 10. IR spectra were taken on spectrometer Specord – IR75 VEB Carl – Zeiss in Nujol suspension. NMR spectra were taken on a Bruker DRX-250 spectrometer, operating at 250.13 and 62.90 MHz for ^1H and ^{13}C , respectively, using the standard Bruker software. Chemical shifts were referenced to tetramethylsilane (TMS). Measurements were carried out at ambient temperature. Mass spectra were recorded using LCQ-DUO LCMS2 System Electrospray Interface on CH-5 Varian MAT spectrometer at 70 eV. The purity of the compounds was checked by thin layer chromatography on Kieselgel 60 F₂₅₄, 0.2 mm Merck plates, eluent systems (vol/vol ratio):

- (a) chloroform : methanol = 9 : 1;
- (b) ethylacetate : petroleum ether = 1 : 2;
- (c) ethylacetate : petroleum ether = 1 : 5;
- (d) chloroform : acetone = 9 : 1.

All known products obtained (**2**, **3**, **4**, **5** and **6**) were characterized by physicochemical parameters, IR and NMR spectral data. The results

obtained from these analyses are identical with the previously published in the literature [1, 4, 6].

II.2. Synthetic procedures

II.2.1. Synthesis of 3-amino-cyclohexanespiro-5-(2-thiohydantoin) (compound **5**, Scheme 1)

1.00 g (0.005 mol) of cyclohexanespiro-5-(2-thiohydantoin) (compound **4**, Scheme 1) and 2 ml of 95 % hydrazine hydrate were refluxed for 4.5 hours. The reaction mixture was cooled down to room temperature and a small amount of crushed ice was added to it. The product obtained was recrystallized from ethanol.

Yield: 0.90 g (83 %);

M.p.: 239-240 °C;

Rf_a = 0.64; Rf_b = 0.14;

IR (Nujol suspension, cm⁻¹): 3347, 3167, 3080 (NH, NH₂), 1720 (C=O), 1640, 1180 (C=S);

^1H NMR (δ , ppm, DMSO-d₆): 1.34-1.82 (m, 10H, CH₂), 6.20 (s, 2H, NH₂), 9.60 (s, 1H, N¹-H);

^{13}C NMR (δ , ppm, DMSO-d₆): 20.2 (C⁹), 24.9 (C⁷), 31.2 (C⁸), 53.8 (C¹⁰), 60.4 (C⁶), 72.3 (C⁵), 167.2 (C²), 177.1 (C⁴);

MS: m/z 197, calculated for C₈H₁₃N₃OS (M)⁺ 199.

II.2.2. Synthesis of 2-hydrazone (compound **8**, Scheme 1) of cyclohexanespiro-5-(2-thiohydantoin)

0.6 ml of 95 % hydrazine hydrate was added to 0.20 g (0.001 mol) cyclohexanespiro-5-(2-thiohydantoin) (compound **4**, Scheme 1). The target product crystallized after 24 hours staying at room temperature.

The compound obtained was recrystallized from ethanol.

Yield: 0.19 g (95%);

M.p.: 181-182 °C;

Rf_a = 0.86; Rf_c = 0.53;

IR (Nujol suspension, cm⁻¹): 3560, 3487, 3147, 3080 (NH, NH₂), 1731 (C=O), 1620 (C=N);

¹H NMR (δ, ppm, DMSO-d₆): 1.25-1.73 (m, 10H, CH₂), 10.21 (s, 1H, N³-H), 11.43 (s, 1H, N¹-H);

¹³C NMR (δ, ppm, DMSO-d₆): 20.4 (C⁹), 24.2 (C⁷), 33.5 (C⁸), 60.2 (C¹⁰), 65.1 (C⁶), 72.2 (C⁵), 178.6 (C²), 180.7 (C⁴);

MS: m/z 184, calculated for C₈H₁₄N₄O (M)⁺ 182.

II.2.3. Synthesis of 3-aminocyclohexanespiro-5-(2,4-dithiohydantoin) (compound 7, Scheme 1)

Method a: Thionation of compound 6 with LR

A suspension of 3.66 g (0.02 mol) of 3-aminocyclohexanespiro-5-hydantoin (compound 6, Scheme 1) and 16.18 g (0.04 mol) of LR in 40 ml toluene was refluxed for 6 hours. The solvent was decanted, then cooled down to room temperature and extracted with methylene chloride / water. The methylene chloride layer was dried over anhydrous sodium sulphate and then was evaporated to dryness. The product obtained was recrystallized from methylene chloride / petroleum ether.

Yield: 2.92 g (68 %);

M.p.: 162-163 °C;

Rf_d = 0.73; Rf_c = 0.39;

¹H NMR (δ, ppm, DMSO-d₆): 1.23-1.84 (m, 10H, CH₂), 7.80 (s, 2H, NH₂), 12.50 (s, 1H, N¹-H);

¹³C NMR (δ, ppm, DMSO-d₆): 20.3-60.6 (CH₂), 72.4 (C⁵), 175.4 (C²), 206.7 (C⁴);

MS: m/z 215, calculated for C₈H₁₃N₃S₂ (M)⁺ 215.

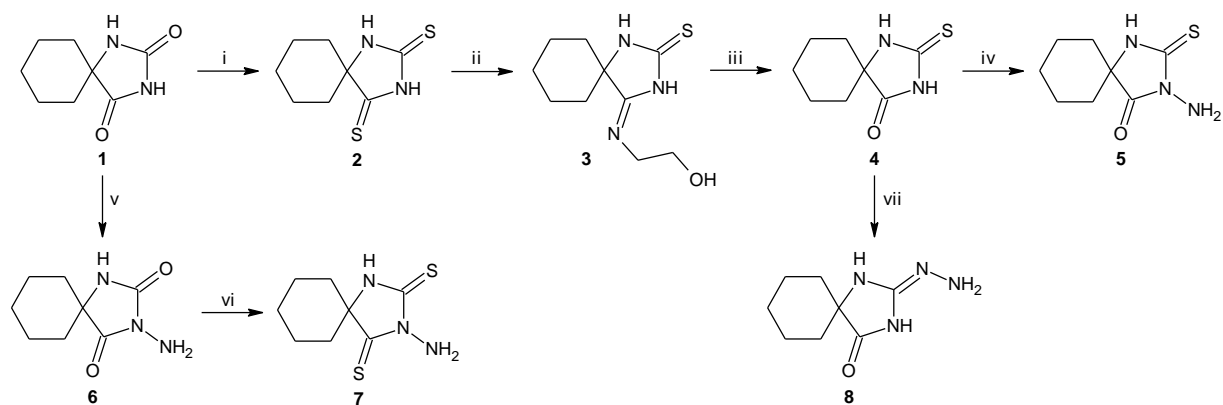
Method b: Thionation of compound 6 with P₄S₁₀

The reaction was carried out in a similar manner to the above mentioned procedure (Method a), except that in this case the reactants (mole ratio of compound 6 and P₄S₁₀ = 1 : 1) were refluxed in a media of xylene for 5 hours. As a result of this interaction, product 7 was obtained with 43 % yield.

III. Results and discussion

The synthesis of the target compounds (5, 7 and 8) was performed in accordance to Scheme 1.

The initial cyclohexanespiro-5-hydantoin (compound 1, Scheme 1) was prepared *via* the Bucherer-Lieb method [3]. In this case the cyclohexanone was subjected to an interaction with sodium cyanide, ammonium carbonate and ethanol. Thus product obtained was converted to its 2-thioanalogue (compound 4, Scheme 1) in accordance with Marinov et al. [4].



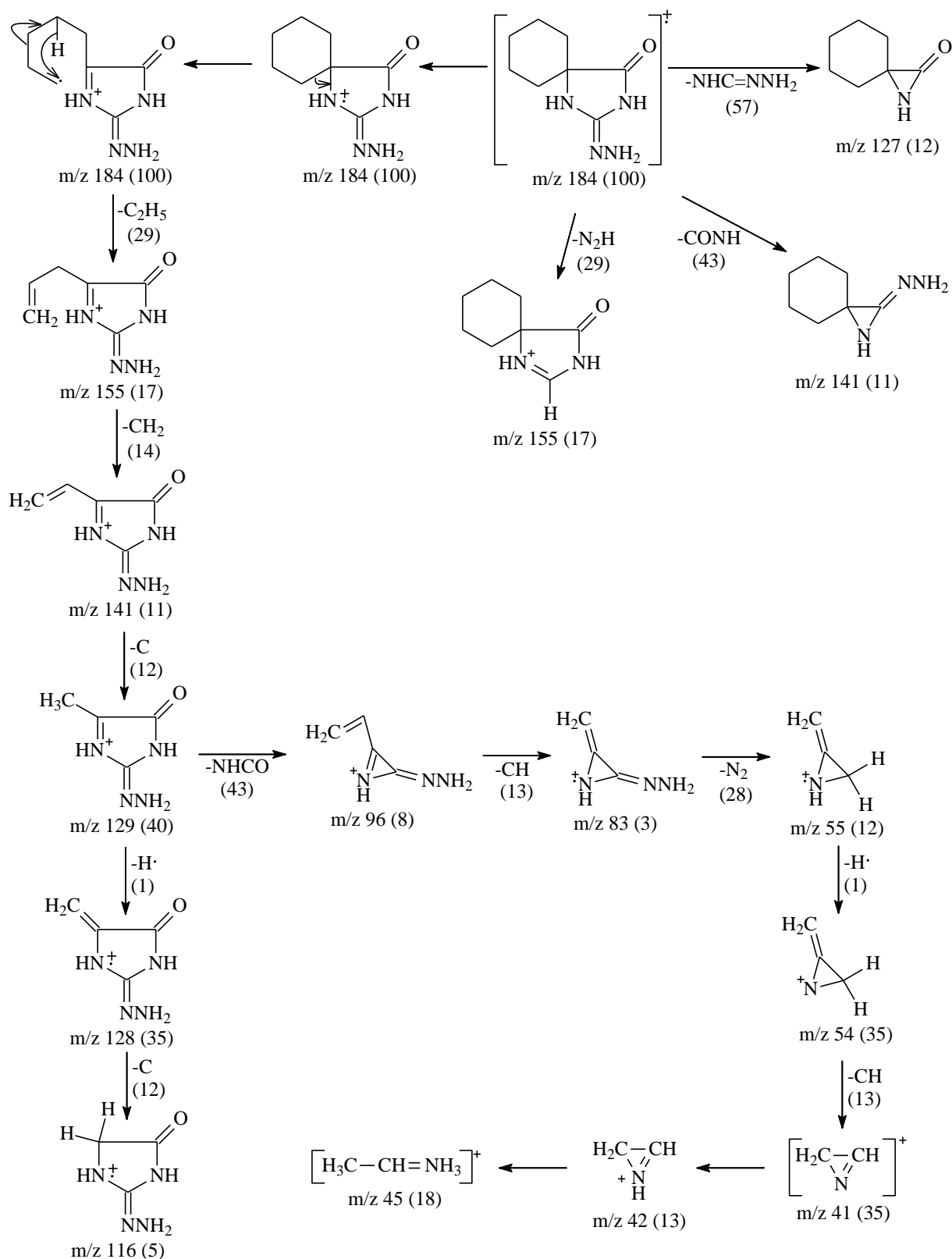
Scheme 1. Reagents and conditions: (i) P_4S_{10} or LR, xylene or toluene, reflux [4]; (ii) 2-aminoethanol, reflux [4]; (iii) hydrochloric acid, reflux [4]; (iv) hydrazine hydrate, reflux; (v) hydrazine hydrate, reflux [1]; (vi) P_4S_{10} or LR, xylene or toluene, reflux; (vii) hydrazine hydrate, room temperature

The method of obtaining of cyclohexanespiro-5-(2-thiohydantoin) (compound **4**, Scheme 1) is based on the interaction of cyclohexanespiro-5-(2,4-dithiohydantoin) (compound **2**, Scheme 1) with 2-aminoethanol, followed by a hydrolysis of the 4-(2-hydroxyethylimino)- derivative obtained (compound **3**, Scheme 1) with hydrochloric acid [4].

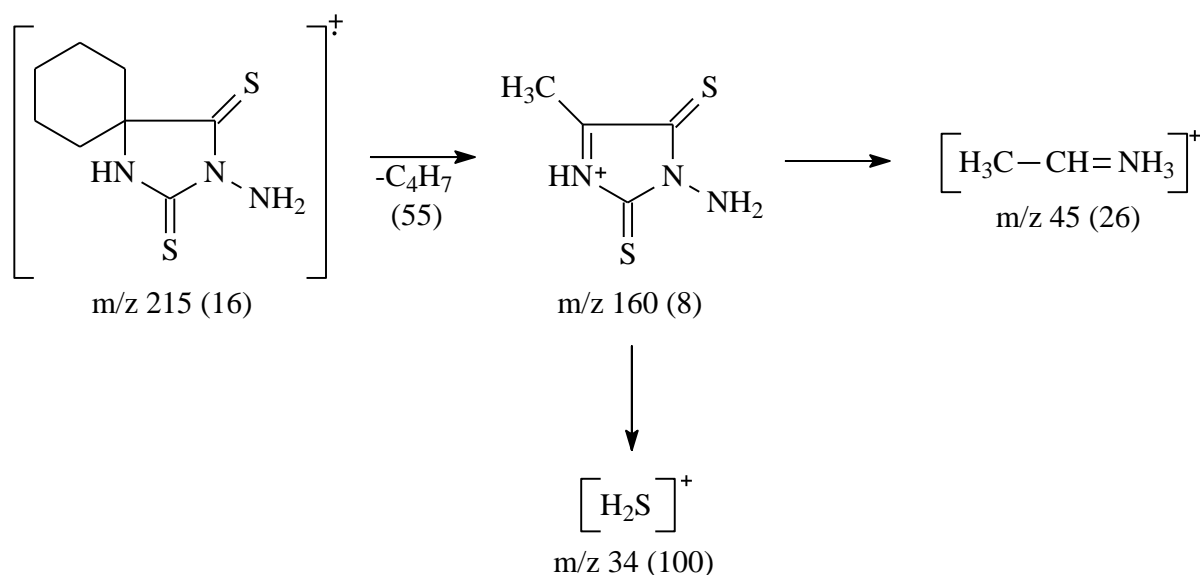
The interaction of cyclohexanespiro-5-(2-thiohydantoin) (**4**) with hydrazine hydrate was examined at different reaction conditions. First, compound **4** was refluxed with 50 % hydrazine hydrate for an hour and a half. As a result of this interaction the relevant 3-amino derivative (**5**) was obtained with 59 % yield. When the treatment of compound **4** was done with 95 % hydrazine hydrate at refluxing for 4.5 hours, the yield of product **5** increased to 83 %. The structure of compound **5** was confirmed by IR, NMR and mass spectral data (see the experimental part). The fragmentation of 3-

aminocyclo-hexanespiro-5-(2-thiohydantoin) [also named as 3-amino-2-thioxo-1,3-diazaspiro[4.5]decan-4-one] (compound **5**) is presented in Scheme 2. Unlike the above-mentioned case, conducting the interaction between compound **4** and 95 % hydrazine hydrate at normal conditions led to obtaining the corresponding 2-hydrazone [also named as 2-hydrazinylidene-1,3-diazaspiro[4.5]decan-4-one] (compound **8**). The structure of compound **8** was confirmed by IR, NMR and mass spectral data (see the experimental part). Its fragmentation is shown in Scheme 3.

As already mentioned, one of the tasks of this study is the obtaining of 3-aminocyclohexane-spiro-5-(2,4-dithiohydantoin). For this purpose, at first 3-aminocyclohexanespiro-5-hydantoin (compound **6**, Scheme 1) was prepared. The synthesis was carried out in accordance with Naydenova et al. [1].



Scheme 3. Fragmentation of compound 8



Scheme 4. Fragmentation of compound 7

Compound **6** was converted to its dithioanalogue 3-aminocyclohexanespiro-5-(2,4-dithiohydantoin) (compound **7**, Scheme 1) by applying two different pathways. When LR was used as thionation reagent (see Method a, experimental part), product **7** was prepared with 68 % yield. The thionation of compound **6** with P_4S_{10} (see Method b, experimental part) led to obtaining of product **7** with 43 % yield.

The spectral data of 3-aminocyclohexanespiro-5-(2,4-dithiohydantoin) [also named as 3-amino-1,3-

diazaspiro[4.5]decane-2,4-dithi-one] (compound **7**) are listed in the experimental part. Its fragmentation is presented in Scheme 4.

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ECOTOXICOLOGICAL EXAMINATION OF ACUTE TOXICITY OF SOME SPIROHYDANTOINS AND THEIR DERIVATIVES TOWARDS SEA LETTUCE (*ULVA LACTUCA*)

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Abstract: This article presents an ecotoxicological study of acute toxicity deleterious effect of cyclopentanespiro-5-hydantoin, cyclohexanespiro-5-hydantoin, cyclopentanespiro-5-(2,4-dithiohydantoin) and 1-aminocyclopentanecarboxylic acid towards Sea lettuce (*Ulva lactuca*) conducted in accordance with international standards adopted by the Organisation for Economic Co-operation and Development (OECD). Dose-response modeling was carried out by R language for Statistical Computing, *drc* package.

Key words: spirohydantoin, Sea lettuce, *Ulva lactuca*, toxicity, *drc*, R language

I. Introduction

It is well known that the hydantoin (imidazolidine) and their derivatives have application in the medicine and the clinical practice as aldose reductase inhibitors [1, 2]. They also possess antitumor [3], anticonvulsant, antiepileptic [4] and antiarrhythmic action [5].

Sea lettuce (*Ulva lactuca*) is bright green algae which is a common inhabitant of seas. The plant can be found attached to rocks and shells by a holdfast, but it is also commonly found free floating. Large volumes of sea lettuce often indicate high levels of nutrient pollution. It is often found

in areas where sewage runoff is heavy. That's why sea lettuce is used as a standard indicator species to monitor pollution trends for indication of large amounts of nutrients [6].

During recent years there even are projects for using *Ulva lactuca* as human and animal food source which makes this plant potentially significant for agricultural economy.

As a common sea macroalga sea lettuce is a typical organism for ecotoxicological research of eventual deleterious action of

chemical substances according to the marine plants [7-9].

During this study we examine the presence or lack of acute toxic action of cyclopentane-spiro-5-hydantoin, cyclohexane-spiro-5-hydantoin, cyclopentane-spiro-5-(2,4-dithiohydantoin) and 1-aminocyclopentanecarboxylic acid towards sea lettuce which is one of the most common and widely spread alga for the region of the Bulgaria Black Sea Coast and Aquatoria.

II. Materials and methods

II.1. Synthetic compounds

All chemicals used were purchased from Merck and Sigma-Aldrich. The cyclopentanespiro-5-hydantoin (CPSH, Fig. 1a) and cyclohexanespiro-5-hydantoin (CHSH, Fig. 1b) were synthesized *via* the Bucherer-Lieb method [10]. The cyclopentanespiro-5-(2,4-dithiohydantoin) (CPSDTH, Fig. 1c) was synthesized in accordance with Marinov et. al. [11]. The 1-aminocyclopentanecarboxylic acid (ACPCA, Fig. 1d) was obtained in accordance with Stoyanov and Marinov [12]. Melting points were determined with a Koffler apparatus and with a digital melting point apparatus SMP 10. Elemental analysis data were obtained with an automatic analyzer Carlo Erba 1106. IR spectra were taken on spectrometers Bruker-113 and Perkin-Elmer FTIR-1600 in KBr discs. NMR spectra were taken on a Bruker DRX-250 spectrometer, operating at 250.13 and 62.90 MHz for ^1H and ^{13}C , respectively, and on a Bruker Avance II + 600 MHz

spectrometer, operating at 600.130 and 150.903 MHz for ^1H and ^{13}C , respectively, using the standard Bruker software. Chemical shifts were referenced to tetramethylsilane (TMS). Measurements were carried out at ambient temperature.

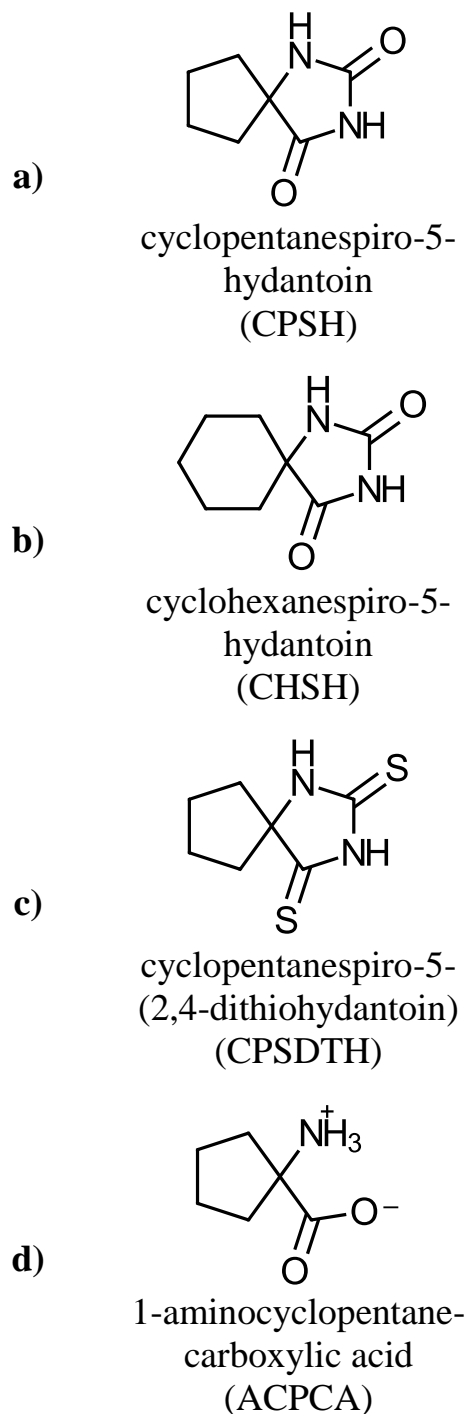


Fig. 1. Structures of the compounds

All products obtained were characterized by physicochemical parameters, IR and NMR spectral data. The results obtained from these analyses are identical with the previously published in the literature [11-13].

In addition, in this paper we present Raman and DRIFT spectral data for the compounds. The Raman spectra of the compounds (the stirred crystals placed in aluminium disc) were measured on RAM II (Bruker Optics) with a focused laser beam of 200 mW (for CPSH, CHSH and ACPCA) and 100 mW (for CPSDTH) power of Nd:YAG laser (1064 nm) from 4000 cm^{-1} to 51 cm^{-1} at resolution 2 cm^{-1} with 25 scans. Their Diffuse Reflectance FTIR (DRIFT) spectra were recorded with a VERTEX 70 FT-IR spectrometer (Bruker Optics). DRIFT accessory used is Praying Mantis™ (Harrick Scientific). Crystals of the compounds were stirred with KBr; the spectra are from 4000 cm^{-1} to 400 cm^{-1} at resolution 2 cm^{-1} with 49 scans. The spectral data obtained are presented in Table 1 below.

II.2. Ecotoxicological tests

Conduction of ecotoxicological tests was in accordance with OECD Standard № 201 – Freshwater Alga and Cyanobacteria, Growth Inhibition Test [14].

Natural occurring *Ulva lactuca* algae were collected from the Bulgarian Black Sea Coast, the Burgas beach region.

Ten concentrations using natural sea water of each compound were

prepared for the purpose of the test. Saturated concentrations of the compounds in water were as follows:

- CPSH – 1 %;
- CHSH – 0.1 %;
- CPSDTH – 0.025 %;
- ACPCA – 0.1 %.

The test design included three replicates at each test concentration plus control variant.

The duration of test was 72 h (3 days). At the end of the test, tested plants were visually observed for phytotoxicological manifestations as whitening, discoloring, deformations, necrosis and other signs. Plant biomass was measured before and after test. Based on this, a dose-response modeling was conducted for determination of NOAEC (LD_{05}), LOAEC (LD_{25}) and LD_{50} via R language for statistical computing (R Development Core Team (2011). R: A language and environment for statistical computing [15] and R packages drc [16].

Physical/chemical properties of tested compounds, required for such ecotoxicological studies, were estimated by using the US EPA EPI (Estimation Programs Interface) Suite™ – Windows®-based suite of physical/chemical property and environmental fate estimation programs developed by the EPA's Office of Pollution Prevention Toxics and Syracuse Research Corporation (SRC) [17].

Table 1. Raman and DRIFT spectral data for the compounds

Compound	Raman spectral bands, cm⁻¹	DRIFT spectral bands, cm⁻¹
CPSH	3011, 2962, 2924, 2878, 2641, 1731, 1703, 1479, 1454, 1446, 1434, 1420, 1317, 1249, 1207, 1180, 1105, 1075, 1037, 1020, 1007, 948, 919, 890, 834, 776, 725, 642, 455, 350, 329, 204	3899, 3439, 3413, 3207, 2961, 2877, 2761, 2490, 2351, 2051, 1776, 1734, 1680, 1446, 1415, 1314, 1245, 1177, 1073, 1046, 1023, 1004, 949, 917, 888, 790, 750, 717, 645, 471, 445, 411
CHSH	3072, 2996, 2936, 2878, 2520, 1754, 1600, 1582, 1452, 1401, 1358, 1233, 1195, 1157, 1106, 1071, 1028, 1018, 1000, 912, 877, 788, 764, 752, 675, 640, 618, 536, 484, 350, 243	3955, 3869, 3722, 3656, 3477, 3205, 3067, 2990, 2937, 2811, 2706, 2514, 2471, 2421, 2375, 2320, 2116, 2033, 1983, 1952, 1883, 1769, 1720, 1599, 1539, 1496, 1444, 1400, 1367, 1317, 1291, 1231, 1191, 1161, 1106, 1072, 1018, 1000, 983, 961, 915, 876, 852, 786, 766, 752, 735, 696, 668, 640, 629, 537, 482, 453, 448, 411
CPSDTH	3147, 2939, 2925, 2845, 2677, 2098, 1529, 1437, 1397, 1357, 1300, 1268, 1232, 1214, 1162, 1130, 1111, 1091, 1042, 1021, 981, 950, 921, 852, 773, 665, 628, 585, 525, 458, 442, 351, 324, 271, 241, 220	3882, 3848, 3808, 3772, 3693, 3148, 3058, 2934, 2924, 2845, 2798, 2696, 2660, 2555, 2487, 2434, 2348, 2320, 2285, 2253, 2219, 2192, 2112, 2075, 1967, 1881, 1788, 1654, 1543, 1478, 1453, 1446, 1428, 1384, 1350, 1328, 1306, 1285, 1270, 1260, 1232, 1217, 1203, 1161, 1128, 1109, 1090, 1048, 1019, 981, 959, 921, 892, 851, 842, 803, 772, 733, 665, 652, 628, 584, 527, 496, 465, 443, 421, 406
ACPCA	2962, 2948, 2877, 2541, 2159, 1710, 1591, 1448, 1391, 1295, 1263, 1223, 1149, 1038, 1017, 954, 884, 788, 719, 557, 496, 435, 407, 353, 304	3855, 3745, 3467, 2961, 2541, 2079, 1740, 1673, 1577, 1527, 1475, 1447, 1403, 1331, 1229, 1196, 1035, 1013, 960, 882, 770, 579, 555, 511, 470, 438, 419, 413, 406

III. Results and discussions

All tested compounds, except CPSH, did not manifest any phytotoxic signs at their saturated concentrations in water. ANOVA analysis conducted with R language for statistical computing in respect to plant biomass did not show significant differences ($p > 0.05$ at 95 % confidence level) between tested variants and control.

However, the CPSH substance showed extremely high deleterious effect on plants at the saturated concentration in water – 1 %, at the form of completely discoloring and whitening of the plants – Fig . 2.



a)

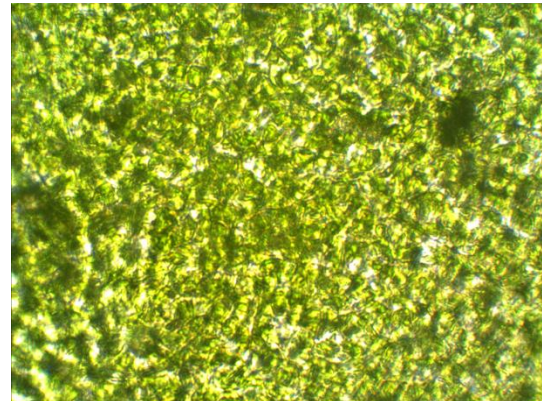


b)

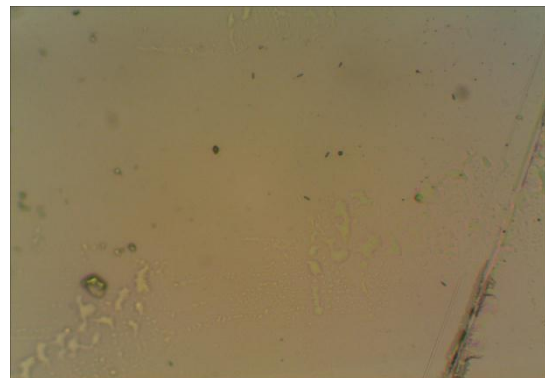
Fig. 2. Pictures taken with Chronos USB 2.0 digital microscope (150x):

- a) control variant;
- b) CPSH (1 %) treated variant

Fig. 3. shows control variant and CPSH variant at 1 % concentration under light inverter microscope (400x) magnification:



a)



b)

Fig. 3. Pictures taken with light inverter microscope (400x) – Boeco BIB-100:

- a) control variant;
- b) CPSH (1 %) treatment variant

A dose-response curve describing the acute toxic action of CPSH compound is presented on Fig. 4.

Calculated values of NOAEC (LD_{05}), LOAEC (LD_{25}) and LD_{50} are as follows:

- NOAEC (LD_{05}) = 0.165 %;
- LOAEC (LD_{25}) = 0.427 %;
- LD_{50} = 0.750 %.

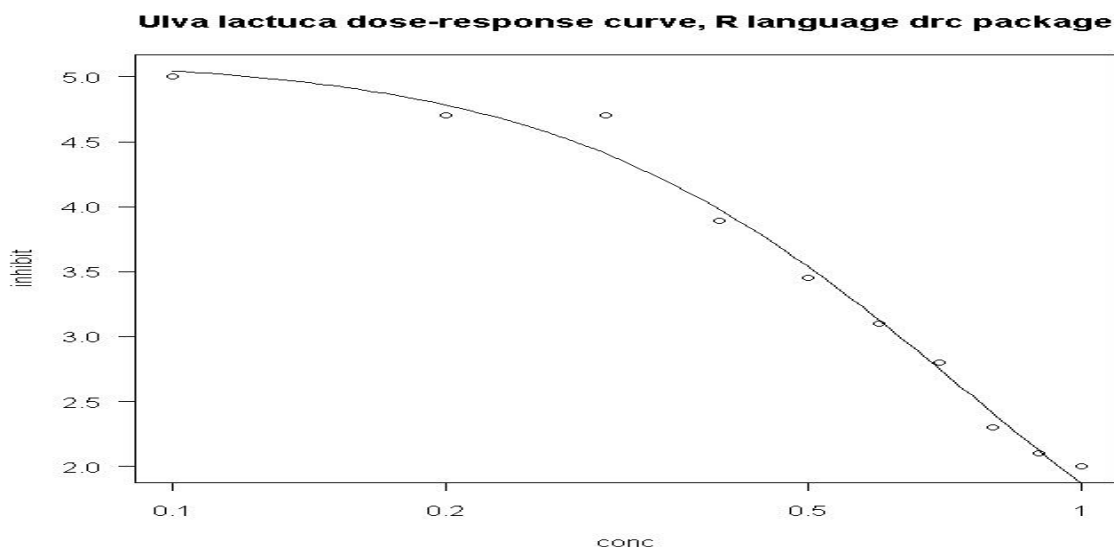


Fig. 4. Dose-response curve described the acute toxic action of CPSH

It is obvious from these results that relatively high levels of CPSH compound concentration will be able to produce acute deleterious effect on populations of Sea lettuce ($LD_{50} = 0.750\% = 7500\text{ ppm}$).

Physical/chemical properties of compounds tested as calculated by EPI Suite are presented in Table 2: According to the Regulation (EC) No 1107/2009 of The European Parliament and the Council dated 21 October 2009, concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC, the persistence criterion for half-life (DT_{50}) in marine water is higher than 60 days – 1440 hours.

All compounds can be characterized as non-persistent based on predicted values as calculated by EPI Suite.

Future research of tested compounds is necessary in order to further reveal their behavior in the environment in terms of PECs (Predicted Environmental Concentrations) by FOCUS ecotoxicological software models as adopted by the European Parliament and the Council [18] based on field tests of selected synthetic compounds.

Acknowledgements

Financial support by the Agricultural University – Plovdiv, Bulgaria (Contract 06-12) is gratefully acknowledged.

We are grateful also to Mr. G. Marinov, Sofia and Mr. V. Gergov, Burgas, for stimulating discussions.

Table 2. Physical/chemical properties of tested compounds calculated by EPI Suite

physical/chemical properties	CPSH	CHSH	CPSDTH	ACPCA
Log Kow	0.60	1.09	0.12	-1.67
Vapour Pressure P(mm Hg,25 deg C)	3.78e-007	1.59e-007	4.74e-007	9.49e-010
Water Solubility at 25 deg C (mg/L)	2.245e+004	7371	1987	6.982e+004
DT ₅₀ Water (hours)	900	900	900	360

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Original Contribution

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IN VIVO PHYTOTOXICOLOGICAL STUDY OF CYCLOPENTANESPIRO-5-HYDANTOIN AND ITS DERIVATIVES TOWARDS SOME CULTURAL AND NON-CULTURAL PLANTS

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Abstract: *This paper represents ecotoxicological study about phytotoxic action of cyclopentanespiro-5-hydantoin, cyclopentanespiro-5-(2,4-dithiohydantoin) and 1-aminocyclopentanecarboxylic acid towards cultural and non-cultural plants conducted in accordance of Organisation for Economic Co-operation and Development standards for such kind investigation. The dose-response modeling was conducted with R language for Statistical Computing and drc package.*

Key words: *spirohydantoin, phytotoxic, drc, R language*

I. Introduction

Ecotoxicological research of phytotoxic action of toxicants has a key role in their characterization and adoption in practice. Studies of this type are used to reveal eventual deleterious action of toxicants with regard to aquatic and terrestrial plants and to prevent possible damages on cultural and non-cultural plants.

In the present study, examination of acute phytotoxic action of cyclopentanespiro-5-hydantoin, cyclopentanespiro-5-(2,4-dithiohydantoin) and 1-aminocyclopentanecarboxylic acid was conducted towards cultural and non-cultural terrestrial plants in

accordance with international standards for such studies.

II. Materials and methods

II.1. Synthetic compounds

All chemicals used were purchased from Merck and Sigma-Aldrich. The cyclopentanespiro-5-hydantoin (CPSH, Fig. 1) was synthesized *via* the Bucherer-Lieb method [1]. The cyclopentanespiro-5-(2,4-dithiohydantoin) (CPSDTH, Fig. 2) was synthesized in accordance with Marinov et. al. [2]. The 1-aminocyclopentanecarboxylic acid (ACPCA, Fig. 3) was obtained in accordance with Stoyanov and Marinov [3]. Melting points were

determined with a Koffler apparatus and with a digital melting point apparatus SMP 10. Elemental analysis data were obtained with an automatic analyzer Carlo Erba 1106. IR spectra were taken on spectrometers Bruker-113 and Perkin-Elmer FTIR-1600 in KBr discs. NMR spectra were taken on a Bruker DRX-250 spectrometer, operating at 250.13 and 62.90 MHz for ^1H and ^{13}C , respectively, and on a Bruker Avance II + 600 MHz spectrometer, operating at 600.130 and 150.903 MHz for ^1H and ^{13}C , respectively, using the standard Bruker software. Chemical shifts were referenced to tetramethylsilane (TMS). Measurements were carried out at ambient temperature.

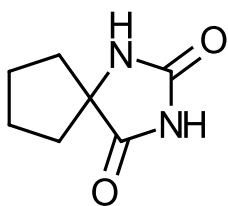


Fig. 1. Cyclopentanespiro-5-hydantoin (CPSH)

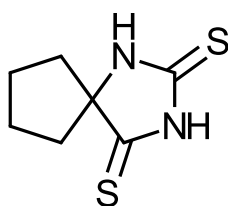


Fig. 2. Cyclopentanespiro-5-(2,4-dithiohydantoin) (CPSDTH)

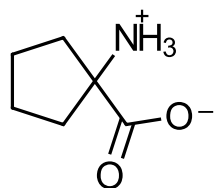


Fig. 3. 1-Aminocyclopentane-

carboxylic acid (ACPCA)

All products obtained were characterized by physicochemical parameters, IR and NMR spectral data. The results obtained from these analyses are identical with the previously published in the literature [2-4].

II.2. Phytotoxicological tests

Three cultural and three non-cultural plants and their growth stages [5] were used as follows:

• Cultural plants:

- Oil yielding rose (*Rosa damascena*), BBCH growth stage 19;
- Plum tree (*Prunus cerasifera*), BBCH growth stage 75;
- Grape (*Vitis vinifera*) variety Muller-Thurgau, BBCH growth stage 19.

• Non-cultural plants:

- Lime-tree (*Tilia platyphyllos*), BBCH growth stage 19;
- Chestnut (*Aesculus hippocastanum*), BBCH growth stage 19;

- Oval-leaved privet (*Ligustrum ovalifolium*), BBCH growth stage 19.

Standard phytotoxicity tests were conducted in accordance with OECD Guide 227 - Terrestrial Plant Test: Vegetative Vigour Test [6]. Test substances were sprayed on the plant and leaf surfaces with ten tested concentrations to the point of runoff. Ten concentrations of each compound were tested, with the saturated concentration of the given compound in distilled water.

Saturated concentrations of the compounds in water were as follows:

- CPSH – 1 %;
- CPSDTH – 0.025 %;
- ACPCA – 0.1 %.

Each test variant was set in five replicates. The test period was 21 days. The plants were weekly observed for visual phytotoxicity and mortality manifestation and Percentage Disease Indexes (PDIs) were calculated based on a 5-grade scale [7]. Based on PDI values, dose-response modeling was conducted by using R language for statistical computing [8] and R language drc package [9] in order to describe phytotoxic action of the compounds. Physical/chemical properties of tested chemicals, required for such ecotoxicological studies, were estimated by using The EPI (Estimation Programs Interface)

Suite™ - Windows®-based suite of physical/chemical property and environmental fate estimation programs developed by the EPA's Office of Pollution Prevention Toxics and Syracuse Research Corporation (SRC) [10].

III. Results and Discussion

The test results revealed that at the saturated concentration of the compounds in distilled water they do not cause any phytotoxic manifestations on Oil yielding rose (*Rosa damascena*), Plum tree (*Prunus cerasifera*), Grape (*Vitis vinifera*) variety Muller-Thurgau, i.e. examined cultural plants, as well as Oval-leaved privet (*Ligustrum ovalifolium*) from the non-cultural species.

However, all tested compounds were able to cause phytotoxic damages to Lime-tree (*Tilia platyphyllos*) in different concentration. CPSH substance showed deleterious effect on Chestnut (*Aesculus hippocastanum*). The rest of the compounds were not toxic at the saturated concentration in distilled water with regard to this plant species.

Fig. 4 shows acute phytotoxic manifestation of Lime-tree caused by CPSH compound at 1 % concentration with regard to the active substance.



Fig. 4. Lime-tree, CPSH treated variant (1 % active substance)

Fig. 5 shows the action of the same compound at 1 % concentration with regard to the active substance but on Chestnut tree.



Fig. 5. Chestnut tree, CPSH treated variant (1 % active substance)

The results from dose-response modeling, conducted with regard to the Lime-Tree, are as follows:

CPSH compound:

- NOAEC (LD₀₅) = 0.73 %;
- LOAEC (LD₂₅) = 0.85 %;
- LD₅₀ = 0.94 %.

CPSDTH compound:

- NOAEC (LD₀₅) = 0.02 %;
- LOAEC (LD₂₅) = 0.05 %;

- LD₅₀ = 0.10 %.

ACPCA compound:

- NOAEC (LD₀₅) = 0.060 %;
- LOAEC (LD₂₅) = 0.073 %;
- LD₅₀ = 0.082 %.

Dose-response curves, created by drc package, are presented on Fig. 6, Fig. 7 and Fig. 8.

With regard to the Chestnut tree, only CPSH compound revealed an insignificant phytotoxic effect (Fig. 5) at the saturated concentration in distilled water (1%).

Values calculated by the drc package of NOAEC (LD₀₅), LOAEC (LD₂₅) and LD₅₀ are as follows:

- NOAEC (LD₀₅) = 0.90 %;
- LOAEC (LD₂₅) = 2.56 %;
- LD₅₀ = 4.56 %.

It is obvious from the dose-response modeling results presented that, regarding its phytotoxic action towards lime-tree and chestnut-tree, LD₅₀ of CPSDTH compound is much higher than the saturated concentrations of substance in distilled water. This proves the relative safeness of these compounds towards selected terrestrial plants.

However, the CPSH and ACPCA substances revealed serious deleterious effect (especially CPSH) at the saturated concentrations in water which makes them potentially dangerous to plants.

CHSH compound did not manifest any phytotoxic signs on plants treated in saturated concentration in distilled water.

Physical/chemical and ecotoxicological properties of compounds, as calculated by EPI Suite software, are presented on Table 1 below.

Future research of CPSH and ACPCA compounds will be

conducted in order to determine Predicted Environmental Concentrations, as well as to evaluate Toxicity Exposure Ratios (TERs) of chemicals towards terrestrial ecosystems and respective safeguards.

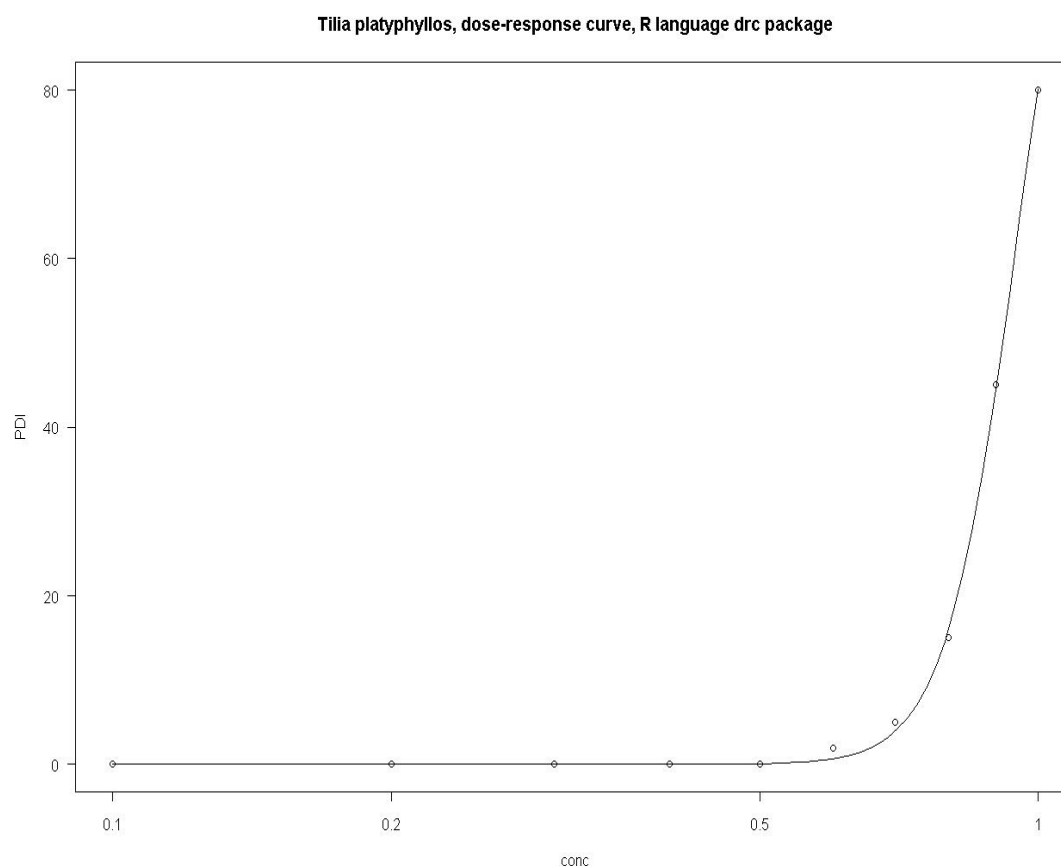


Fig. 6. *Tilia platyphyllos*, CPSH compound Dose-Response Curve

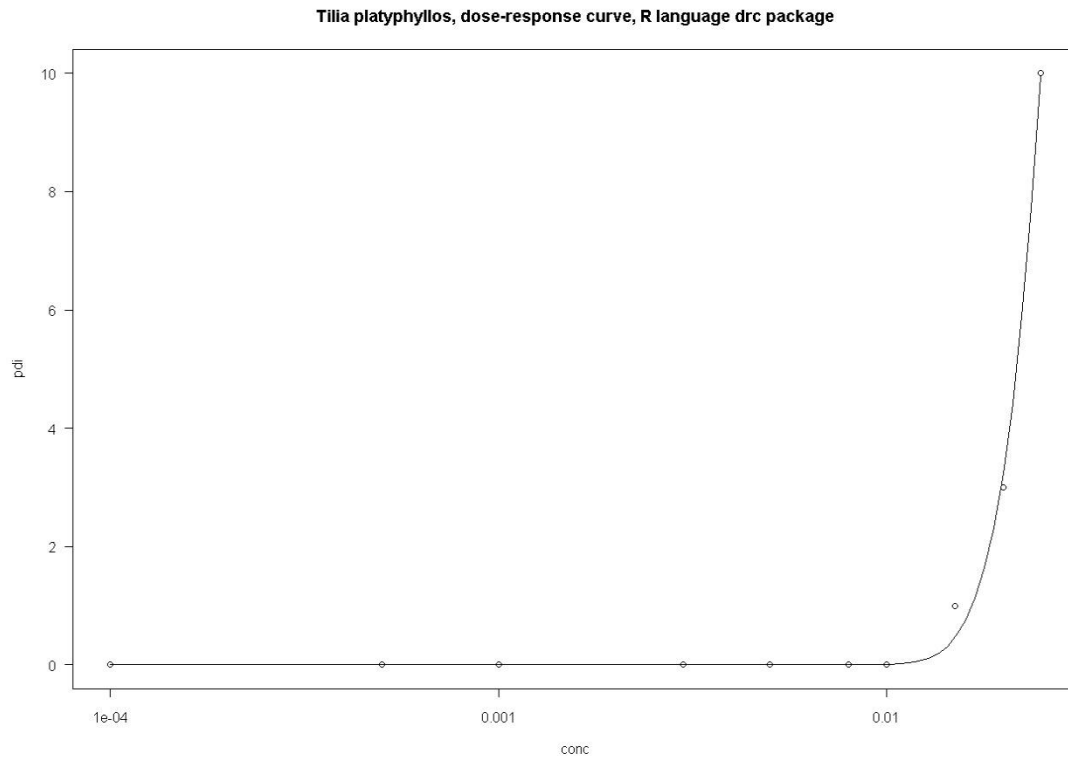


Fig.7. *Tilia platyphyllos*, CPSDTH compound Dose-Response Curve

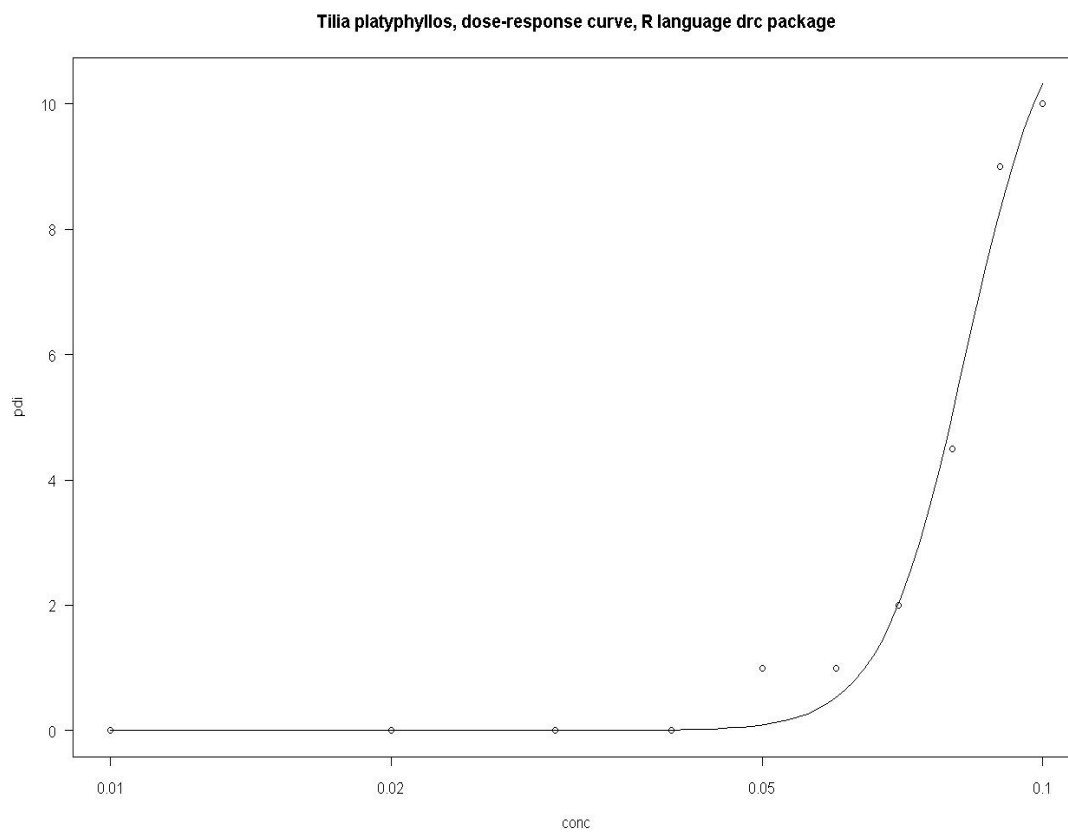


Fig. 8. *Tilia platyphyllos*, ACPCA compound Dose-response curve

Table 1. Physical/chemical properties of tested compounds calculated by EPI Suite

physical/chemical properties	CPSH	CPSDTH	ACPCA
Log Kow	0.60	0.12	-1.67
Vapour Pressure P (mm Hg,25 deg C)	3.78e-007	4.74e-007	9.49e-010
Melting Point (deg C):	164.17	158.29	330
Water Solubility at 25 deg C (mg/L)	2.245e+004	1987	6.982e+004
Henry's Law Constant (25 deg C) - atm-m ³ /mole	2.15e-009	2.94e-007	1.54e-009
Soil Adsorption Coefficient (Koc)	10	10	1.808
DT ₅₀ Air (hours)	26.9	1.98	10.2
DT ₅₀ Water (hours)	900	900	360
DT ₅₀ Soil (hours)	1.8e+003	1.8e+003	720
DT ₅₀ Sediment (hours)	8.1e+003	8.1e+003	3.24e+003
Persistence Time (hours)	994	566	551

Acknowledgements

Financial support by the Agricultural University – Plovdiv, Bulgaria (Contract 06-12) is gratefully acknowledged.

We are grateful also to Mr. G. Marinov, Sofia, for stimulating discussions.

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RESEARCH OF THE VARIATIONS OF THE ATMOSPHERIC OZONE AND CHANGE OF THE ULTRAVIOLET SUN RADIATION OVER NORTHEASTERN BULGARIA

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Abstract

The atmospheric total ozone content variations over the North-eastern region of Bulgaria have been observed during the May-August period of 2011. The measurements are conducted above the hydro-meteorological station in the Kaliakra peninsula using a ground-based ozonometer M-124. The experimental data for the total ozone content distribution have undergone processing and the mean month values have been calculated. A distribution anomaly has been observed during the second half of July, when the trend is negative.

Keywords: total ozone content

1. INTRODUCTION

The problem of the periodic variations of the total ozone content is a question of present interest. The results of the interpretation of these data for the northern hemisphere show decreasing of the ozone layer with 30-50 Dobson units [1].

In 1986 a spring negative anomaly of the ozone trend has been detected in Greece [2]. In 1987 a considerable decrease of total ozone content was detected in the town of Belsk, Poland [2].

The anomalies of the ozone trend are similar (the coefficient of the correlation is +0,44) in Europe: from 1982-1983 in

Moscow [6]; from 1984-1985 in Southern Europe – Vina del Vale and Lisbon [4]. From 1986-1987 in Northern Europe [4]. These data are received from ground ozonometric stations and their processing shows a negative linear trend of the total ozone content in the Northern hemisphere – 1,4% and respectively there is a considerable variation of the average total ozone content [5,6].

2. THE RESEARCH

The goal of the research is to study the variations of the total ozone content in Northeastern Bulgaria for the period May – August 2011, which were measured by means of a ground

ozonemeter in the hydro meteorological station in Kaliakra. Kaliakra station is situated at 59,12 m altitude. Its geographic coordinates are 28°28' eastern longitude and 43°22' northern latitude. Having in mind the conservative meridional stratospheric circulation at altitude 20-22 km in northeastern Bulgaria and the comparative remoteness of Kaliakra from big industrial contaminators, it can be considered that the received experimental results are representative for a larger equable zonal structure, such as Northeastern Bulgaria.

The total ozone content is being researched by 4-month

results: May, June, July and August. The data are in table 1. The days with unfavorable weather are less than 4 per month and they are not taken into consideration because they are within the limits of for the determination of the total ozone content variations.

The goal of the research is to check whether the values of the total ozone content X for the four months are commensurable and to examine for possible variations. Since the number of the days, in which the experimental value X is received, is different for the single months, the Barlet criterion is used [3].

Table 1. Average values of the total ozone content X in Dobson units, Kaliakra, 09.05. – 18.08. 2008

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
May									437			365	345	360	388
June	340	400	490	348	375				390	394	359	383	360	421	454
July	385	331	341	384	360	369	337	343	349	356	342	339	302	302	333
August	236	256	297	243	242	181	220	199	227	273	260	176	179	223	191

Month	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
May	388	304	341	335	402	384			414	437	412	414	397	380	408	384
June	383	344	428	403	389		385	389	395	324	376	364	341	330	334	
July	372	349	368	317	350	305	305	326	185	231	264	232	223	222	236	246
August	196	211	201													

The evaluations for every dispersion are calculated $S_1^2, S_2^2, S_3^2, S_4^2$

$$(1) \quad S_1^2 = \frac{1}{n_i - 1} \sum_{j=1}^{n_i} (X_{ij} - \bar{X})^2$$

and the formula

$$(2) \quad \bar{X}_i = \frac{1}{n_i} \sum_{j=1}^{n_i} X_{ij}$$

is used to get the average values for the total ozone content for the separate months:

$\bar{X}_1=384$ Dobson units, $\bar{X}_2=375$ this case:
 Dobson units, $\bar{X}_3=313$ Dobson units, $\bar{X}_4=223$ Dobson units

$$(6) \chi^2 = \frac{1}{C} \sum_{i=1}^4 \ln \frac{S_i^2}{S^2} = 9,659,$$

The dispersions are as follows:

$$S_1^2 = 1245,94; S_2^2 = 1153,96; S_3^2 = 3060,37; S_4^2 = 1191,47$$

The zero hypothesis H_0 is checked that

$$S_1^2 = S_2^2 = S_3^2 = S_4^2 \text{ as an assumption that}$$

The number of degrees of freedom is:

$$Y_1 = 19 - 1 = 18; Y_2 = 27 - 1 = 26; Y_3 = 31 - 3 = 30; Y_4 = 18 - 1 = 17$$

In this case

$$(3) Y = \sum_{i=1}^4 Y_i = 91.$$

On the other hand,

$$(4) S^2 = \frac{1}{Y} \sum_{i=1}^4 Y_i S_i^2 = \frac{1}{91} 164 495,98 = 1807,5$$

To calculate the value χ^2 , the following values are determined:

$$(5) C = 1 + \frac{1}{3(n-1)} \left(\sum_{i=1}^n \frac{1}{Y_i} - \frac{1}{Y} \right) = 1,0158,$$

$$Y_1 = \ln \frac{S_1^2}{S^2} = -0,3722,$$

$$Y_2 = \ln \frac{S_2^2}{S^2} = -0,4488,$$

$$Y_3 = \ln \frac{S_3^2}{S^2} = 0,5265,$$

$$Y_4 = \ln \frac{S_4^2}{S^2} = 0,4168,$$

At a level of importance

from the tables of χ^2 the

distribution of the degrees of freedom $4-1=3$ is given: $(0,05; 3)=7,815$.

4. CONCLUZION

Because $\chi^2=9,659 > 7,815 = \chi^2(0,05; 3)$, the conclusion is that there are reasons to reject the zero hypothesis, which means that the four dispersions are different. Since they cannot be considered equal, there are distinct variations of the examined values of total ozone content for the given months. Since the dispersion $S_3^2 = 3060,37$ is maximum, the conclusion should be that the observed anomaly in the total ozone contents values is the biggest in July when the trend is negative during the second half of the month and the total ozone content reaches 185 Dobson units. Similar explanation can be given for the maximum values within the range 176-181 Dobson units in the beginning of August. A registered sudden transition towards anomalous values of the total ozone content can be observed at the end of July.

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DETERMINATION OF INTEGRATED ENVIRONMENTAL INDICATORS OF THE IMPACT OF POLLUTANTS INTO WATER BODIES

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***Abstract:** The advantages and disadvantages of the current limit concentrations (PDC) have been analysed as they do not fully reflect the impact of alien substances on water in aquatic ecosystems. A relatively simple method for determining integral doses in multifactorial contamination of water bodies has been proposed.*

***Key words:** limit concentrations, integral dose, water pollution*

Introduction

Currently, water bodies are characterized by multifactorial contamination, suggesting diverse content of mineral and organic substances, mixtures and/or elements. The hydrosphere has turned into a collector of waste generated by people and businesses. Its vulnerability to chemical contamination is determined by the continuous circulation of water in nature (precipitation, evaporation, cross-border movement, surface and underground flows) where any pollutant into the atmosphere or in the soil, eventually gets into water bodies. Pollution affects mainly fresh water bodies such as rivers, lakes, reservoirs, inland seas etc. This requires a specific methodological approach through which diverse hydrochemical information to

quantify a single dose effects on living organisms. It is complicated to take into account both direct and indirect effects, interactions between technogenic substances imported into the aquatic environment, which form the hazardous properties of water. Water pollution is the most complex. It is associated with eutrophication and changes in the salt regime. Acidification of water accompanies leaching of toxic elements from substances and mixtures. This process is especially dangerous for hydrobiontic species at low pH values.

At present the core dimension of ecological standardization of harmful chemicals in the environment components is the concentration limit. It is a harmful substance which practically does not affect human health and does not cause adverse

changes to the progeny. Its effect on animals, plants, microorganisms, and natural communities as a whole is considered in determining its values.

Limit concentrations are contingent variables that differ significantly in the countries, despite the attempts for standardization of the methods for their estimation.

They do not take into account the natural conditions of the water body in which the toxic substance is spread and acts [1,2,3]. Moreover, they do not consider the interaction between the elements in the complex water pollution, in which case it is possible the toxic properties of the substances to be mutually reinforced (synergism) [4].

The modern system of limit concentration does not take into account the effects of the joint action of mixtures of chemical substances or other toxic compounds of the same chemical element with different concentrations. The effects caused separately by each of them are known in most cases, but it is not possible to identify all possible combinations of the joint action of substances, particularly when they are in different concentrations [5]. It has been practically proved that the effects of many types of pollution occur decades after the contact with them. There are genotoxic substances causing somatic mutations that occur as inherited mutations later in the years or in the next generations. In recent decades, there has been stronger influence of the chemical compounds of technogenic origin,

which have no natural analogues (xenobiotics).

For the majority of them neither the toxicity, nor the time required for its development are not completely developed. Limit concentrations cannot be used as a means of assessing the late effects (gonadotropic, embryotropic allergic, teratogenic, mutagenic, carcinogenic) to the human and warm-blooded animals caused by the influence of xenobiotics on them.

The effects of increased toxicity and bioaccumulation of contaminants in the transition from one trophic state to another are not studied in detail. We should not ignore the fact that water bodies, like terrestrial ecosystems, have the ability of self-purification.

This would imply that the system of limit concentration should be considered as one of the possible indicators and even as a way of predicting and evaluating the rapid impact of xenobiotics on living organisms [5]. In any case, specific physical and chemical characteristics of natural water should be considered in the standardization of contaminants' content.

The integral index of water pollution can be determined depending on the type of contaminants identified.

When these contaminants have similar toxicological indicators for the degree of harm they cause (i.e. they are from the same Toxicology group), the integrated index can be easily represented as a sum of the concentrations measured for all toxic

chemicals normalised to LC (limit concentration).

$$I_{t1} = \sum(C_i / LC_i)$$

Notwithstanding all the reserves given above, LC provides a real picture of LC the relative risk of various substances and allows for standardisation of components and substances according to the degree of danger for the living organisms. When two or more highly toxic elements such as lead, cadmium, chromium and uranium are found in the water, their total concentration, calculated using the appropriate formula, should be less than or at most equal to one [5]

$$\frac{C_1}{C_1^{LC}} + \frac{C_2}{C_2^{LC}} + \frac{C_3}{C_3^{LC}} + \frac{C_4}{C_4^{LC}} = 1 \quad (1)$$

where: C_1 , C_2 , C_3 , C_4 - the concentration of the components in the test water in mg/l,

More correct would be the summation of concentrations exceeding the thresholds to their Cp influence on aquatic organisms.

$$I_{t2} = \sum(C_i / C_{pi}) \quad (2)$$

However, such data is available in the scientific literature only for some of the substances. Most often it is assumed that toxic substances have additive effect. You can introduce Coefficients for synergism or

antagonism can be introduced, if there is evidence of such effects.

When a body of water is contaminated with a large group of metals, which are imported by flow of wastewater, their toxicity, to a large greatest extent, depends on the metal ion forms. In this case one should take into account the ratio of labile and unlabile forms (associated with organic ligands) in the water body. Based on the studies of Rodyushkin (1995), Moiseenko (1999) for complex-forming ability of water, some quantitative data has been obtained on the ability of natural dissolved organic matter, which can deactivate different metal ions. Their position has been determined in the competitive order of connecting organic ligands.

$$I_{t3} = \sum(C_{Ni^{2+}} / LC_{Ni^{2+}} + C_{Hg^{2+}} / LC_{Hg^{2+}} + \dots) \quad (3)$$

$$I_t = I_{t1} + I_{t2} + I_{t3} \quad (4)$$

Assuming that the toxic properties of the aquatic environment are the result of metal ion mixtures, then the normalization according to the toxicity may be carried out according to PDC (limit concentration). Toxic properties of water can be different in the presence of the same metals depending on their origin. When they are the result of human activities, most often they are found in the form of ions, while in natural acidified water metals are deactivated by humic acids. Similar phenomena have been observed in the small lakes of Kola North. [6]. The greatest risk is posed by heavy metals, which have high biological activity.

Their action depends on the nature of the metal, the type of compound, under which it exists in the aquatic environment and of course its concentration. On Figure 1 the arrow

shows the direction of decreasing toxicity of the forms in which metals are found in the aquatic environment. [6]

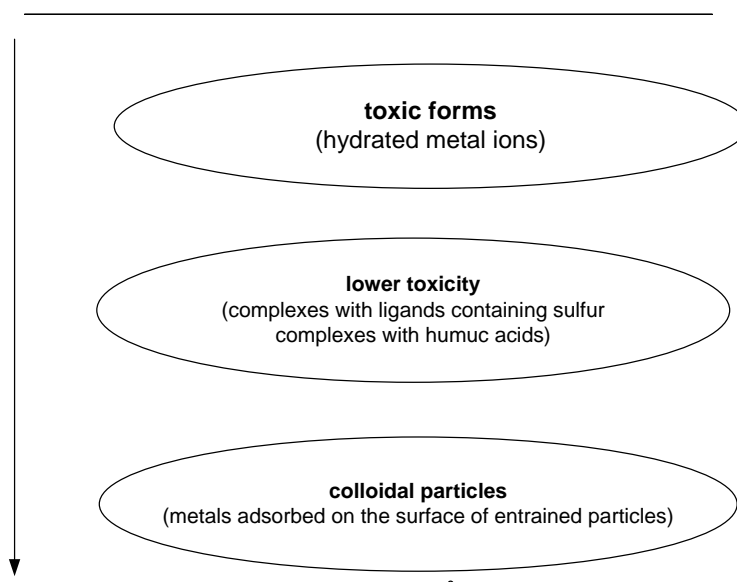


Fig.1. Different forms of metals in water bodies

Like all other values of LC (limit concentrations), the values for the metals are quite different in the different countries (Table 1). The ratio between the maximum and

minimum value ranges from 56 for arsenic to 160 for copper. This is due to different methodological approaches in establishing the LC.

Table 1. LC for surface water of some heavy metals

Country	Hg	Cd	Pb	Cu	As
Bulgaria	0,2	5	20	50	20
United Kingdom	-	-	4-25	0,5-12	50
Germany	0,8	1,2	100	80	-
Denmark	1	5	3,2	12	4
Russia	0,01	5	6	1	50
the Netherlands	0,23	0,34	11	1,1	24
Czech Republic	0,5	5	50	50	50
Sweden	-	0,09	1,2	2,1	0,9
Japan	0,5	10	50	3	10
PDC _{max} /PDC _{min}	100	111	100	160	56

In those cases when water bodies are contaminated by many toxic

substances and eutrophication is observed, a change occurs in their

physical and chemical characteristics - turbidity, salt composition, pH. etc. If several processes with different ecological significance run simultaneously in the aquatic environment, determination of the cumulative index of contamination is much more difficult.

In eutrophication inactivation of metals is observed due to their biological uptake, associated with turbulent growth of algae. At the same time, however, release of metals can be performed from bottom sediments.

Criterion for this process may be the degree of excess phosphorus above background values (C_p). The ratio of total nitrogen to total phosphorus in a water body characterises the degree of eutrophication of the aquatic ecosystem. For highly humificated inland reservoirs $N_{total}/P_{total} \geq 100$, clean oligotrophic and mesotrophic lakes - 30-40, for eutrophic reservoirs (under strong anthropogenic influence) 15-25, while for hypertrophic reservoirs - from 18 to 3.

Therefore trophic status of the reservoir should be considered. In mesotrophic state eutrophication index doubles, and in eutrophic state it triples:

$$I_e = (C_p / C_{P_{background}} - 1) \times 2 \quad (5)$$

$$I_e = (C_p / C_{P_{background}} - 1) \times 3 \quad (6)$$

Concentration of chlorophyll a ($C_{35}H_{72}N_4Mg$) is most often used as a direct indicator of trophic status. It is a major photosynthetic pigment and therefore the values of its concentration in water samples are representative indicator of algal

biomass. The pigment is an accurate and useful measure of the degree of eutrophication of water bodies.

The main criteria characterizing the process of eutrophication of water bodies are the following:

- Decrease in the concentration of dissolved oxygen in depth;
- Increase in the concentration of nutrients;
- Increase in the number of involved particles, especially of organic origin;
- Reduced penetration of light (self-darkening, increased water turbidity);
- Increase in the concentration of phosphorus in bottom sediments;
- Continuous change of the algae populations with priority of blue-green and green algae;
- Significant increase in the mass of phytoplankton, while simultaneously reducing species.

The main components of the aquatic biota are reducers, which decay organic matter, phytoplankton, zooplankton, benthos, microvials, amphibians and more. Phytoplankton activity decreases at $pH \leq 6$, but serious adverse effects are observed at $pH \leq 5$, including sharp decrease in the population of fish [7].

The indexes of other physical and chemical parameters of water can be similarly determined. Those indexes, which have the largest contribution to the changing conditions of the aquatic organisms'

habitat, are reported. The integrated index of physical and chemical contamination can be represented as follows:

$$I_{fiz-him} = \sum (C_i / C_{backgroundmax} - 1) \quad (7)$$

The total integral indicator of water contamination is defined as the sum of partial derivatives:

$$I_i = I_t + I_e + I_{fiz-him} \quad (8)$$

In the methodological scheme for the study of pollutants, which enter water bodies, besides all of the studies mentioned above and the values of environmental and hygiene regulations, studies should be conducted to assess the health of the population living in areas with potential adverse effects of the studied compounds in water bodies.

This is related to:

- development of harm criteria in the assessment of toxicity and danger of chemical water pollution;

Conclusions:

LC (limit concentrations), which are currently used, do not fully reflect the impact of extrinsic water substances in the aquatic ecosystems. It is necessary to develop ecological PDC. Furthermore, assessment of natural water should be made reporting not only the organoleptic, chemical, hygiene and sanitation indicators, but also the biochemical and microbiological indicators that reflect the status of hydrobiontic species.

- development of accelerated methods for toxicological justification of PDC (limit concentrations) of harmful substances in the water;

- forecasting the individual effects of water contaminants;

- development of principles and methods for establishing regulations for substances causing mutagenic, carcinogenic, allergenic, embryotoxic and gonade toxic late effects;

- development of methodological practices for environmental and hygienic evaluation and forecasting of transformation products of chemical reagents in water;

- improvement of the quantitative methods for assessment of the combined effect of the substances.

The method for determining the integral dose index in multifactorial water contamination is relatively simple, but it quite adequately reflects the hazardous properties of water. In the absence of contaminating substances I_i should be zero. Moreover, this method can identify the leading factor in the formation of dose effects and to consider its environmental hazard.

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Original Contribution

RISK OF THE IGNITION OF FLUID FUELS AND SOAKED MATERIALS DURING OXYACETYLENE CUTTING OF METALS

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Abstract: *The purpose of this study is to establish the regularities of the process of firing of liquid fuels and materials, soaked with liquid fuels, during oxyacetylene cutting. By means of suitable methods and a plant, we studied the firing of petrol and diesel fuel and paper, textile and wood chips, soaked with fuel. Three basic tasks have been solved – physical modeling of dangerous event and dangerous action, determination of danger indexes and assessment of firing in the zone of distribution of waste metal spatters. Regression models of probability and time of firing depending on the distance, height and materials subject to cutting and other factors have been formulated.*

Keywords: *risk, ignition, liquid fuels, oxyacetylene cutting.*

Introduction

Fire hazard of the process of oxyacetylene cutting has not been studied enough. Some studies [4,5] are dedicated only to the problem of generation and distribution of melted and heated metal drops. They make a limited number and insufficiently substantiated experiments. Authors do not study the ignition of materials.

The above, as well as our statistical analyses of probability of fire occurrence due to fire works show that the problem is very topical. It should be analyzed for the various conditions and characteristics of cutting – parts, cutting length, gas pressure, working height, effect of reflecting surfaces, combustible materials and surface distribution.

The purpose of this study is to establish the risk and regularities of variation of the ignition of gasoline

and diesel fuel and materials soaked with fuel during oxyacetylene cutting of metals.

To achieve that purpose the following tasks shall be solved:

- 1) Physical modeling of the process of ignition of materials;
- 2) Parameters of ignition are defined;
- 3) Multi-factor and single-factor models of the parameters of ignition of liquid fuels and materials soaked with them - paper, textile, wooden chips, located in the zone of distribution of waste metal pearls from gas cutting;
- 4) Assessment of risk for ignition.

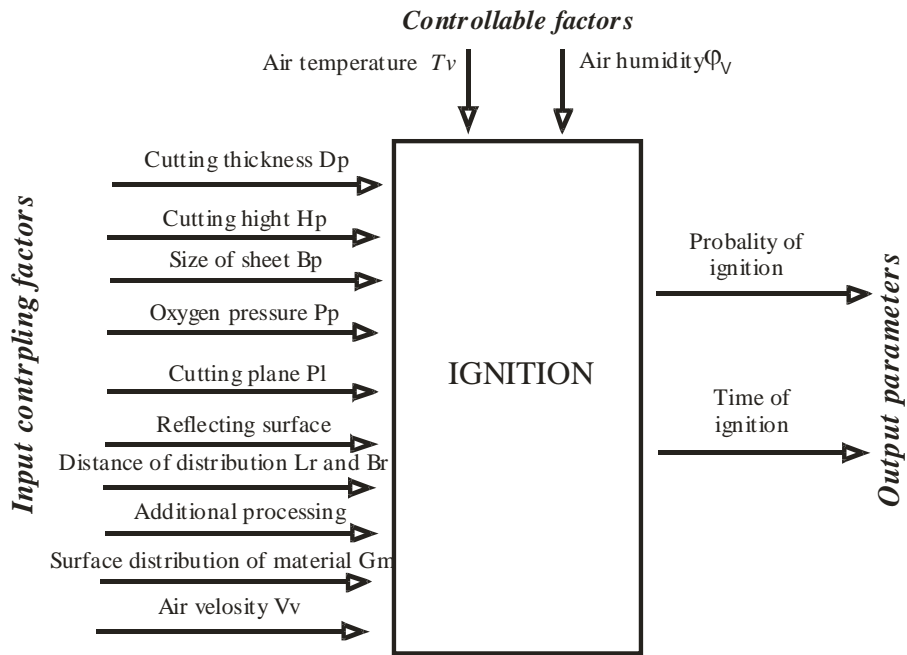


Fig. 1. Model of research

Methods of research

The objects affected by the cutting pearls are gasoline and diesel fuel, as well as the above-specified materials. They have been selected because of their availability everywhere, which makes them frequent objects, affected by cutting pearls. Once ignited they may initiate fire.

The study is carried out according to the model, presented on figure 1.

Controllable input factors are (fig.1): Cutting thickness $D_p=10,15$ and 20 mm ; Cutting height $H_p=2,4$ and 6 m ; Size of metal sheet $B_p=300\times300$; 400×400 and $500\times500\text{ mm}$; Oxygen pressure $P_p=300$, 500 and 700 kPa ; Cutting plane P_L -vertical and horizontal; Availability of reflecting surfaces 2 and 6 (fig.2); Type of surface distribution G_{MAT} of paper, textile and wooden chips -1; $1,5$ and 2 kg/m^2 ; Additional

processing, consisting of soaking Om with gasoline and diesel fuel on level - 25 ml , 75 ml , $125\text{ ml}/100\text{ g}$

The controlled factors are the temperature T_V and humidity φ_V of atmospheric air. Experiments have been carried out at temperature from $21,2$ to $29,4^\circ\text{C}$ and relative air humidity $69,4\text{-}84,2\%$. When experiments are carried out outdoor the air velocity V_V has been subject to control. It is within the range $0,3\text{-}1,6\text{ m/s}$.

Output parameters of the risk of ignition are the probability P_z and the time T_z of occurrence of ignition after the start of oxyacetylene cutting (fig. 1).

The method of physical modeling is used in the research.

Physical modeling is made on a plant, shown on fig. 2 – in production premises and outdoor. For simulation of the manufacturing technological process oxyacetylene

cutting was carried out of hot-rolled sheet metal (according to BDS 3992-84) with the above-specified size B_p , from carbon steel – ordinary grade CT0 and CT1 with thickness 10, 15 and 20 mm.

Horizontal and vertical cuts were made at the specified height.

Standard oxyacetylene generator and manual cutter have been used.

Opportunity was provided to study the effect of vertical and horizontal reflecting surfaces (2 and 6 - fig.2) with different width, length and height, located in the zone of the first phase of gravitational falling of cutting pearls. For that purpose metal construction panels with standard sizes were used. The horizontal panels are installed at height 1 m from the floor.

When modeling the dangerous effect imissions of cutting pearls were monitored and analyzed in the phases of gravitational falling, flying after hitting the floor and rolling on the floor surface. These phases of movement are observed and distances of flying and rolling are approximately established. Then, based on them, were selected the distances of study of the ignition of materials. For the purpose of identifying the surface and the distance of distribution, the floor was divided into elementary sections.

Experimental research was carried out in two phases.

In the first phase the imissions of cutting pearls were analyzed.

During the second phase the dependence of the parameters of the process of ignition on the controllable

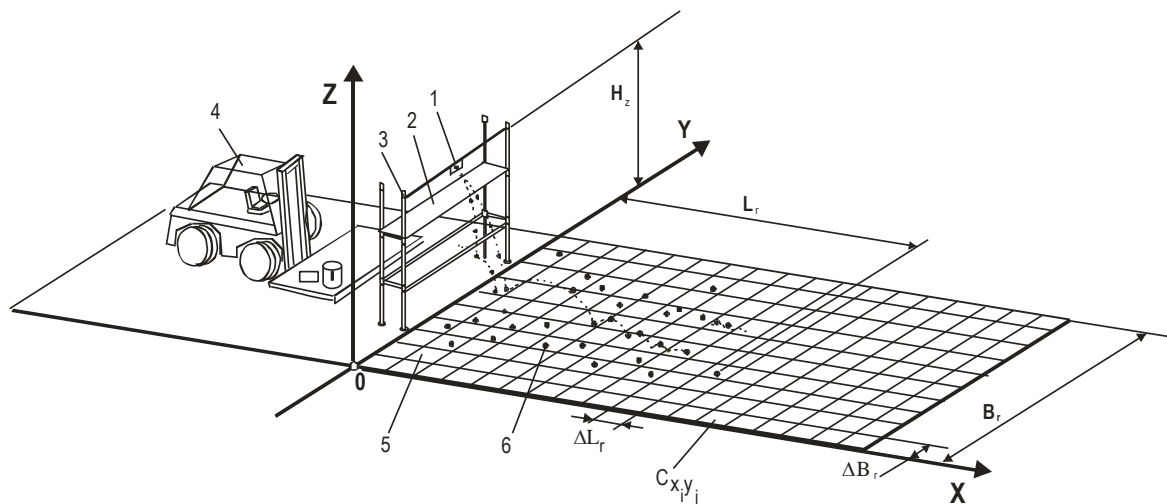


Fig. 2. Experimental system: 1-welded parts; 2- vertical reflecting panel; 3-metal scaffold; 4-work platform;5-non-combustible floor with outlined net of elementary sections $\Delta B_r \times \Delta L_r$; 6-horizontal reflecting panel; 7-waste welding pearl; a, c, e, f-horizontal welds; b, d; g-vertical welds of angular profiles to the metal sheet, Of the metal sheet to the angular profiles and between metal sheets [2,3]

factors was studied.

The experiments for establishing the parameters of ignition of fuels are carried out by the method of "random location of targets". "Targets" are 5 laboratory vessels with height of the side wall 4mm and with diameter 100mm, which were placed at randomly selected points of the quadrants (fig.2) with area $1m^2$. In each vessel was poured 150ml fuel, which was specified through preliminary experiment.

Distribution of cutting pearls in the process of oxyacetylene cutting is a probabilistic process. Therefore the interaction of pearls with the affected objects is accidental. Direct contact occurs only if pearls fall directly into the vessels. Rolling pearls do not enter into contact with the combustible liquids due to the presence of separation wall of the vessels, however they contact with fuel vapors.

Direct contact occurs during experiments with materials soaked with gasoline and diesel fuel.

Results and discussion

The main condition for ignition of materials is occurrence of imission of cutting pearls.

The imission of cutting pearls I_m is determined by their surface distribution. It is assessed by its relative share, in %, of the mass of pearls that have fallen on the elementary section $\Delta B_r \cdot x \Delta L_r$ of the floor.

The following equations of change of I_m from distances Lr and Br were established:

I. Without reflecting surfaces:
 for $0 < Br < 1m$: $I_{zp} = 21,2976e^{-0,52384Lr}$;
 for $1 < Br < 2m$: $I_{zp} = 16,2764 - 6,2142Lr + 0,6437Lr^2$; for $2 < Br < 3m$:
 $I_{zp} = 11,2743 - 6,7283Lr + 0,2677Lr^2$;
 for $0 < Br < -1m$: $I_{zp} = 19,6347 - 3,744Lr + 0,2733Lr^2$; for $-1 < Br < -2m$:
 $I_{zp} = 12,6347e^{-0,7281Lr}$; for $-2 < Br < -3m$: $I_{zp} = 8,4348e^{-0,5477Lr}$;

II. With vertical reflecting surfaces:
 for $0 < Br < 1m$:
 $I_{zp} = 24,2633e^{-0,3255Lr}$; for $1 < Br < 2m$:
 $I_{zp} = 18,3677e^{-0,4437Lr}$; for $2 < Br < 3m$:
 $I_{zp} = 15,6277e^{-0,4738Lr}$; for $0 < Br < -1m$:
 $I_{zp} = 23,4637e^{-0,4463Lr}$; for $-1 < Br < -2m$:
 $I_{zp} = 17,2849e^{-0,5673Lr}$; for $-2 < Br < -3m$: $I_{zp} = 14,5637e^{-0,4258Lr}$;

III. With vertical and horizontal reflecting surfaces:
 for $0 < Br < 1m$:
 $I_{zp} = 9,2453e^{-0,2864Lr}$; for $1 < Br < 2m$:
 $I_{zp} = 8,2764e^{-0,4563Lr}$; for $2 < Br < 3m$:
 $I_{zp} = 5,6237e^{-0,4766Lr}$; for $0 < Br < -1m$:
 $I_{zp} = 6,7364e^{-0,3254Lr}$; for
 $1 < Br < 2m$: $I_{zp} = 3,2677 + 0,6735Lr - 0,1245Lr^2$; for $-2 < Br < -3m$: $I_{zp} = 5,6937e^{-0,2536Lr}$.

Distribution of the mass of pearls depending on their diameter is analogous to the electric-arc welding [1,2]. The range of diameters with minimum mass is wider. It is due to the bigger cavities. Furthermore scattering is much larger. Probably it results from the specificity of the cutting process during which further to melting the metal, it is blown out as a result of the effect of gas pressure.

To analyze the process of ignition were carried out experimental studies, aiming to determine the dependencies of T_z and P_z from the cutting thickness D_p ; the cutting

height H_p ; the size of metal sheet B_p ; the oxygen pressure P_p .

Data obtained from experimental study were processed by the software *Statgraph*, *SPSS*, *REG1* and *REG2*.

Regression models of time T_z and probability P_z of ignition were obtained, which in case of vertical cutting without reflecting surfaces and change of the above-specified technological factors within the established range, are from the type:

I. When cutting metal sheet 10mm:

- Gasoline:

$$T_z(H_z, L_r, B_r) = 23.253783 + 14.374834 * H_z + 3.283774 * L_r + 2.823167 * B_r + 0.256373 * H_z * B_r + 0.126237 * L_r * B_r - 4.934473 * H_z * H_z - 0.327348 * L_r * L_r - 4.436844 * B_r * B_r;$$

$$P_z(H_z, L_r, B_r) = 1.358637 - 0.209154 * H_z - 0.108672 * L_r - 0.189878 * B_r + 0.001875 * H_z * B_r + 0.019688 * L_r * B_r + 0.027083 * H_z * H_z + 0.001886 * B_r * B_r;$$

- Diesel fuel:

$$T_z(H_z, L_r, B_r) = 34.735268 + 14.637251 * H_z + 9.241826 * L_r + 9.226735 * B_r - 0.192734 * H_z * L_r + 0.426327 * H_z * B_r + 0.256337 * L_r * B_r - 4.267344 * H_z * H_z - 0.634733 * L_r * L_r - 1.002636 * B_r * B_r;$$

$$P_z(H_z, L_r, B_r) = 1.338668 - 0.178129 * H_z - 0.131741 * L_r - 0.224628 * B_r - 0.000625 * H_z * L_r + 0.001250 * H_z * B_r + 0.024375 * L_r * B_r + 0.023170 * H_z * H_z + 0.001372 * L_r * L_r + 0.004604 * B_r * B_r;$$

II. When cutting metal sheet 15mm:

- Gasoline:

$$T_z(H_z, L_r, B_r) = 27.276355 + 4.118201 * H_z - 0.211403 * L_r + 0.172855 * B_r + 0.014251 * H_z * B_r + 0.027310 * L_r * B_r -$$

$$0.026277 * H_z * H_z - 1.178210 * L_r * L_r - 3.823764 * B_r * B_r;$$

$$P_z(H_z, L_r, B_r) = 1.235366 - 0.018236 * H_z - 0.089247 * L_r - 0.056378 * B_r + 0.000356 * H_z * B_r + 0.005346 * L_r * B_r + 0.003536 * H_z * H_z + 0.000342 * B_r * B_r$$

- Diesel fuel:

$$T_z(H_z, L_r, B_r) = 29.276640 - 8.201926 * H_z + 1.152677 * L_r + 2.743601 * B_r - 4.378422 * H_z * L_r + 3.934082 * H_z * B_r + 4.726630 * L_r * B_r - 0.067218 * H_z * H_z - 0.017234 * L_r * L_r - 0.187320 * B_r * B_r;$$

$$P_z(H_z, L_r, B_r) = 1.028371 - 0.078230 * H_z - 0.045410 * L_r - 0.037455 * B_r - 0.000124 * H_z * L_r + 0.0004352 * H_z * B_r + 0.003546 * L_r * B_r + 0.000253 * H_z * H_z + 0.000352 * L_r * L_r + 0.000352 * B_r * B_r;$$

III. When cutting metal sheet 20mm:

- Gasoline:

$$T_z(H_z, L_r, B_r) = 22.348293 + 2.832010 * H_z - 3.278374 * L_r + 1.012351 * B_r + 0.0034271 * H_z * B_r + 0.035562 * L_r * B_r - 0.078364 * H_z * H_z - 2.356277 * L_r * L_r - 2.8637745 * B_r * B_r;$$

$$P_z(H_z, L_r, B_r) = 1.212457 - 0.17230 * H_z - 0.042371 * L_r - 0.092735 * B_r + 0.000637 * H_z * B_r + 0.003820 * L_r * B_r + 0.000172 * H_z * H_z + 0.000201 * B_r * B_r;$$

- Diesel fuel:

$$T_z(H_z, L_r, B_r) = 24.637738 - 4.567344 * H_z + 0.723562 * L_r + 0.046277 * B_r - 3.621700 * H_z * L_r + 2.345266 * H_z * B_r + 3.426610 * L_r * B_r - 0.002452 * H_z * H_z - 0.004253 * L_r * L_r - 0.003455 * B_r * B_r;$$

$$P_z(H_z, L_r, B_r) = 1.120102 - 0.245162 * H_z - 0.118236 * L_r - 0.162753 * B_r - 0.000034 * H_z * L_r + 0.000431 * H_z * B_r + 0.000531 * L_r * B_r$$

$$0.000645*H_z*H_z+0.000271*L_r*L_r+0.000743*Br*Br.$$

To determine the time T_z and the probability P_z of ignition, experiments were carried out individually with soaked with gasoline and fuel oil mixtures of: a) Paper – newspapers, wrapping paper, posters, cardboard, corrugated cardboard; b) Textile – cloths, threads and fabrics for working clothes; c) Wood chips – from smoothing planer, circular saw, grinder, manual work with a jointer.

The following adequate models were obtained

a) gasoline soaked paper:

$$T_z(H_z, L_r, Br, Om) = 1.743774 + 8.614023 * H_z + 5.758464 * L_r - 5.391345 * Br - 0.167463 * Om - 0.474219 * H_z * L_r + 0.003688 * H_z * Om + 0.05546 * L_r * Br + 0.004594 * L_r * Om + 0.023813 * B * Om - 1.037611 * H_z * H_z + 0.038254 * L_r * L_r + 1.47176 * Br * Br + 0.00036 * Om * Om;$$

$$P_z(H_z, L_r, Br, Om) = 0.270265 + 0.00583 * H_z - 0.25752 * L_r - 0.14167 * Br + 0.02250 * Om - 0.01000 * H_z * L_r - 0.006250 * H_z * Br - 0.015000 * H_z * Om + 0.162500 * L_r * Br + 0.036250 * L_r * Om - 0.025000 * Br * Om + 0.038368 * H_z * H_z + 0.057118 * L_r * L_r - 0.017882 * Br * Br - 0.012882 * Om * Om ;$$

b) diesel fuel soaked paper:

$$T_z(H_z, L_r, Br, Om) = 4.723872 + 6.923764 * H_z + 9.298366 * L_r - 2.436273 * Br - 0.004325 * Om - 0.0345216 * H_z * L_r + 0.000625 * H_z * Om + 0.0023415 * L_r * Br + 0.000534 * L_r * Om + 0.001746 * Br * Om - 0.004882 * H_z * H_z + 0.00133 * L_r * L_r + 7.83462 * Br * Br + 0.00097 * Om * Om;$$

$$P_z(H_z, L_r, Br, Om) = 0.198236 + 0.004653 * H_z - 0.162726 * L_r - 0.115268 * Br + 0.017835 * Om - 0.000129 * H_z * L_r -$$

$$0.004237 * H_z * Br - 0.009263 * H_z * Om + 0.153274 * L_r * Br + 0.016773 * L_r * Om - 0.018553 * Br * Om + 0.093771 * H_z * H_z + 0.036886 * L_r * L_r - 0.003102 * Br * Br - 0.011290 * Om * Om;$$

c) gasoline soaked textile:

$$T_z(H_z, L_r, Br, Om) = 3.632601 + 9.267738 * H_z + 7.271182 * L_r - 2.662011 * Br - 0.112384 * Om - 0.213362 * H_z * L_r + 0.00942 * H_z * Om + 0.08735 * L_r * Br + 0.009660 * L_r * Om + 0.04637 * Br * Om - 0.099245 * H_z * H_z + 0.067335 * L_r * L_r + 1.683790 * Br * Br + 0.00012 * Om * Om;$$

$$P_z(H_z, L_r, Br, Om) = 0.342567 + 0.00637 * H_z - 0.027362 * L_r - 0.102466 * Br + 0.012536 * Om - 0.000621 * H_z * L_r - 0.002391 * H_z * Br - 0.009266 * H_z * Om + 0.103801 * L_r * Br + 0.087660 * L_r * Om - 0.012572 * Br * Om + 0.017239 * H_z * H_z + 0.018873 * L_r * L_r - 0.011772 * Br * Br - 0.020371 * Om * Om;$$

d) diesel fuel soaked textile:

$$T_z(H_z, L_r, Br, Om) = 9.912801 + 8.823655 * H_z + 9.356277 * L_r - 1.330170 * Br - 0.006932 * Om - 0.034657 * H_z * L_r + 0.000362 * H_z * Om + 0.00490 * L_r * Br + 0.000783 * L_r * Om + 0.00273 * Br * Om - 0.006772 * H_z * H_z + 0.005639 * L_r * L_r + 2.267366 * Br * Br + 0.00083 * Om * Om;$$

$$P_z(H_z, L_r, Br, Om) = 0.128115 + 0.001367 * H_z - 0.1008256 * L_r - 0.102471 * Br + 0.0129012 * Om - 0.000102 * H_z * L_r - 0.00237 * H_z * Br - 0.004627 * H_z * Om + 0.116249 * L_r * Br + 0.010723 * L_r * Om - 0.012473 * Br * Om + 0.072901 * H_z * H_z + 0.024516 * L_r * L_r - 0.002341 * Br * Br - 0.014839 * Om * Om ;$$

e) gasoline soaked wood chips:

$$T_z(H_z, L_r, Br, Om) = 1.72664 + 12.356233 * H_z + 9.723627 * L_r - 1.732804 * Br - 0.936270 * Om - 0.145277 * H_z * L_r + 0.015604 * H_z * Om + 0.09327 * L_r * Br + 0.012380 * L_r * Om + 0.03566 * Br * Om -$$

$$0.0735267*Hz*Hz+0.02736*Lv*Lv+1927830*Br*Br+0.000463*Om*Om; \\ Pz(Hz,Lv,Br,Om)=0.42351+ \\ 0.00283*Hz-0.013267*Lv- \\ 0.126735*Br+0.020063*Om- \\ 0.000237*Hz*Lv-0.001342*Hz*Br- \\ 0.003647*Hz*Om+0.13256*Lv*Br+ \\ 0.093478*Lv*Om-0.010471*Br*Om+ \\ 0.011843*Hz*Hz+0.012770*Lv*Lv- \\ 0.010023*Br*Br-0.02738*Om*Om ;$$

f) diesel fuel soaked wood chips:
 $Tz(Hz,Lv,Br,Om)=7.273367+9.002816*Hz+8.378266*Lv-1.120345*Br- \\ 0.0035466*Om-0.012655*Hz*Lv+ \\ 0.000772*Hz*Om+0.00782*Lv*Br+ \\ 0.000936*Lv*Om+0.004563*Br*Om- \\ .002138*Hz*Hz+0.002641*Lv*Lv+ \\ 0.26778*Br*Br+0.000573*Om*Om; \\ Pz(Hz,Lv,Br,Om)=0.107280+0.001026*Hz- \\ 0.117346*Lv-0.193562*Br+ \\ 0.0106377*Om-0.000147Hz*Lv- \\ 0.002980Hz*Br-0.001823*Hz*Om+ \\ 0.148349*Lv*Br+0.018237*Lv*Om- \\ 0.010825*Br*Om+0.003315*Hz*Hz \\ +0.006174*Lv*Lv-0.006730*Br*Br- \\ 0.018926 *Om*Om.$

Conclusion

The analysis of the models shows the following trends:

- Higher risk, determined through the probability of ignition, is established for gasoline and gasoline soaked materials, which is explained with its lower ignition temperature;
- Identical effect of liquid fuels on the risk of ignition of the studied materials;
- Difficult identification of the joint influence of the controllable factors through the derived regression models;

- Completely related effect of distances and wetting with gasoline and diesel fuel on the risk of ignition;

- Complete analogy of the model components, which shows that all controllable factors have effect on the carried out experiments.

To determine the differential risk, defined in [1,2] it is necessary that the dependencies of imissions Im of cutting pearls and time Tz of ignition are established toward one argument. Most appropriate is the distance Lr from the place of cutting along axis X . Since the probability Pz of ignition depends on imissions, their dependence shall be established. This probability shall be bound with probabilistic indicator corresponding to a specified ignition time. Then calculation of differential risk may start.

To determine differential risk of ignition it is necessary that the time Tz is converted from natural to probabilistic value. For that purpose it is necessary to make a check of the hypotheses of the laws of distribution. On the basis of the obtained laws shall be specified the probability Ptz of occurrence of Tz furthermore in the interval $\pm\sigma$ - the dispersion near the average value. Upon change of the controllable factors of the above-specified levels, a system of random values is formed. After their processing the models of probability Ptz by types of materials are established.

The adopted model of the research allows wide variation of controllable factors. Thus the effect of technological and spatial factors on

the risk of ignition may be established.

The systems of regression models of imissions of welding pearls, of risk parameters - probability and time of ignition of studied materials. They allow calculating and establishing differential risks by types of materials. These models allow comparing the fire criticality of materials, which may be considered in forecasting and operational risk analyses.

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Original Contribution

RESEARCH ON THE LIKELIHOOD RATIO OF REGISTERED UNIDENTIFIED SIGNALS OF SATELLITE ENVIRONMENTAL MONITORING OF ATMOSPHERE

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Abstract: Optical studies from the board of satellites are among the most informative. From space, in certain narrow spectral windows of the atmosphere environmental monitoring of the atmosphere is possible to be implemented. Objects of study are natural sources of environmental pollution and anthropogenic sources of pollution.

Key words, atmosphere environmental monitoring

The research of signals from satellites at different background brightness is one of the basic problems which concerns a lot of scientists who work in the sphere of atmospheric monitoring, space physics and distant methods [2,3,6,7,10], in the visible and near infrared part of the optic specter [1,4,5,8,9].

If there is no a priori information about the presence of a signal and this is a typical case in the research process, the likelihood ratio is the only thing that can be concluded from the research. Sometimes in such cases we have 50 % probability: absence or presence of a signal, i.e.

$$P(S)=P(O),$$

where $P(S)$ – a posteriori probability for presence of a signal;

$P(O)$ – a posteriori probability for absence of a signal;

It turns out that the likelihood ratio absolutely characterizes the probability for the presence of a signal in the realization. For most of the observational systems, a very small a priori likelihood for the presence of a signal is characteristic, i.e. $P(S) \ll 1$, and the a posteriori likelihood becomes a proportion from the likelihood ratio

To solve practical problems, the likelihood ratio can be presented by distributing the density of the realizations probability. First the realization of absence of signal is looked at $P(Y/O)$, i.e. when the realization $y(t)$ is only noises.

When the realization is known for a certain period of time τ , with intervals H , and at the end of every interval (in points $t_1, t_2, \dots, t_1, \dots, t_H$) are

recorded the reports $y_i = y(t_i)$, which correspond in the given situation the values of the noise at moments of the time t_i . The sum of reports for the time τ make the kind of Y which can be presented as H -dimensional

$$(1) \quad y_1 < n_1 < y_1 + d_{y_1}.$$

If we use what we know from the probabilities theory, the relationship between the probability P and the

vector which make y_i , where $i = 1, 2, \dots, H$, and the value of the noise in every point t_i is within the limits from y_i to $y_i + d_{y_i}$, i.e.:

$$(2) \quad \omega(x) = \lim_{\Delta x \rightarrow 0} \frac{P(x < X < x + \Delta x)}{\Delta x},$$

probability density $\omega(x)$ of a random value X with probable definitions x , so:

and with multiple distribution:

$$(3) \quad \omega(x_1, x_2, \dots, x_n) = \lim_{\Delta x_1, \dots, \Delta x_n \rightarrow 0} \frac{P(x_1 < X_1 < x_1 + \Delta x_1, \dots, x_n < X_n < x_n + \Delta x_n)}{\Delta x_1 \Delta x_2 \dots \Delta x_n}.$$

On the basis of (3) we get:

$$(4) \quad P(Y/O) = \omega_N(y_1, y_2, \dots, y_H) dy_1 dy_2 \dots dy_H.$$

The last formulae can be presented in short

$$(5) \quad P(Y/O) = \omega_N(Y) dY,$$

where: $dY = dy_1 dy_2 \dots dy_H$ - element of the volume from H - dimensional space

$\omega_N(Y)$ H -dimensional distribution of the noise probability.

Analogically we get the likelihood of the element Y to be present in the volume dY in a situation of signal presence:

$$(6) \quad P(Y/S) = \omega(Y/S) dY,$$

where $\omega(Y/S)$ - relative probability density for realization of Y in a mixture of signal and noise.

Having in mind formulas (5) and (6), the relationship of the relative probability for realization is defined as likelihood ratios, we present it as A_p and the result is:

$$(7) \quad A_p = \frac{\omega(Y/S)}{\omega_N(Y)}.$$

Very often the mixing of signal and noise is an algebraic sum, i.e. it is

signal and additive noise. We often have this case in the experiments:

$$(8) \quad y_i = n_i + S_i,$$

where n_i - value of the noise at a moment of time t_i

S_i - value of the signal at the same moment of time.

In this case the probability for realization of the quantity y_i coincide with the probability for the noise realization with the quantities

$$n_i = y_i - S_i.$$

This means that the probability for realization of the ordinate y_i coincides with the probability to have the ordinate

And these parameters are not absolutely known, the signal form is also unknown and only the realization Y is known. We can presume that the parameters of the signal have random character a_k and the probability density is also known ω_A of their quantities at a certain moment of time:

$$(12) \quad \omega_A(a_1, a_2, \dots, a_k).$$

Then the relationship of the likelihood ratio $P(Y/O)$ from the signal does not depend on $\omega_N(Y)dY$, but the probability $P(Y/S)$ at a certain realization at the presence of a random probable signal is defined by

$$y_i - S_i,$$

In a realization which has only noise. Consequently, when we have additivity of signal and noise, the result is:

$$(9) \quad \omega(Y/S) = \omega_N(Y-S),$$

and:

$$(10) \quad A_p = \frac{\omega_N(Y-S)}{\omega_N(Y)}.$$

A case is researched for a likelihood ratio with unknown parameters when the signal depends on certain A_1, A_2, \dots, A_k and the time and it can be presented like:

$$(11) \quad s(t, A_1, A_2, \dots, A_k),$$

every possible value of the parameters..

To define $P(Y/S)$ we use the formula of the probability density for a certain event B which happens with the likelihood $P(B/A_j)$ at the condition of the event occurrence A_j , which happens only with a certain probability $P(A_j)$:

$$(13) \quad P(B) = \sum_j P(A_j)P(B/A_j),$$

$$\text{and } \sum_j P(A_j) = 1.$$

And in the case of the event A_j , all parameters of the signal are in the set system in the interval

$$(14) a_{j_1} \leq A_1 < a_{j_1} + \Delta a_{j_1}, \dots, a_{j_k} \leq A_k < a_{j_k} + \Delta a_{j_k},$$

and the full set of indexes (j_1, j_2, \dots, j_k) is necessary to ensure the full coverage of the k-dimensional area of the possible values of the parameters A_1, A_2, \dots, A_k . Because of this, the

probability $P(A_j)$ is presented by the density of the parameters distribution $\omega_A(a_1, a_2, \dots, a_k)$:

$$(15) P(A_j) = \omega_{A_j}(a_{j_1}, a_{j_2}, \dots, a_{j_k}) \cdot \Delta a_{j_1} \cdot \Delta a_{j_2} \dots \Delta a_{j_k}.$$

The conditional probability $P(B/A_j)$ is by itself a probability to get the realization Y in the element of the volume dY on the condition that the parameters of the signal are within a

certain interval and they have certain values

$$a_1 = a_{j_1}, a_2 = a_{j_2}, \dots, a_k = a_{j_k} :$$

$$(16) P(B/A_j) = P(Y/a_{j_1}, a_{j_2}, \dots, a_{j_k}) = \omega(Y/a_{j_1}, a_{j_2}, \dots, a_{j_k}) dY.$$

When we substitute (15) and (16) into (13), it can be observed that the sum in (13) is of integral type and the

when the intervals $\Delta a_{j_1}, \Delta a_{j_2}, \dots, \Delta a_{j_k}$ have a tendency towards zero, we get a k-multiple integral:

$$(17) P(Y/S) = dY \int \int \int \dots \int \omega(Y/a_1, a_2, \dots, a_k) \omega_A(a_1, a_2, \dots, a_k) da_1 da_2, \dots, da_k,$$

And the likelihood ratio becomes:

$$(18) A_p = \frac{\int \int \int \dots \int \omega(Y/a_1, a_2, \dots, a_k) \omega_A(a_1, a_2, \dots, a_k) da_1 da_2, \dots, da_k}{\omega_N(Y)}.$$

If the relationship is represented:

$$(19) \frac{\omega(Y/a_1, a_2, \dots, a_k)}{\omega_N(Y)} = A_p(a_1, a_2, \dots, a_k),$$

the final formula for the likelihood ratio is:

$$(20) A_p = \int \int \int \dots \int A_p(a_1, a_2, \dots, a_k) \omega_A(a_1, a_2, \dots, a_k) da_1 da_2, \dots, da_k,$$

where $A_p(a_1, a_2, \dots, a_k)$ characterize the probability of presence of a signal with certain parameters (a_1, a_2, \dots, a_k) .

It can be concluded that with random parameters (A_1, A_2, \dots, A_k) , which have probability density $\omega_{A_j}(a_j)$

their integration with all of their values gives the mathematical expectancy or the average value of the likelihood ratio. Formula (20) gives the probability of the signal presence at different possible values of its random parameters.

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Original Contribution

SHAPING THE PROCESS OF PENETRATION IN THIN TARGETS

Plamen Chernokozhev, Anton Antonov, Plamen Dqnikov

***Abstract:** An analytic model is created describing the process of hitting thin targets. Mathematical expressions for determining the work for forming a stopper, for plastic expansion of the opening, work for friction and work done for heating are suggested.*

The basic destruction types of thin targets are showed in picture 1.

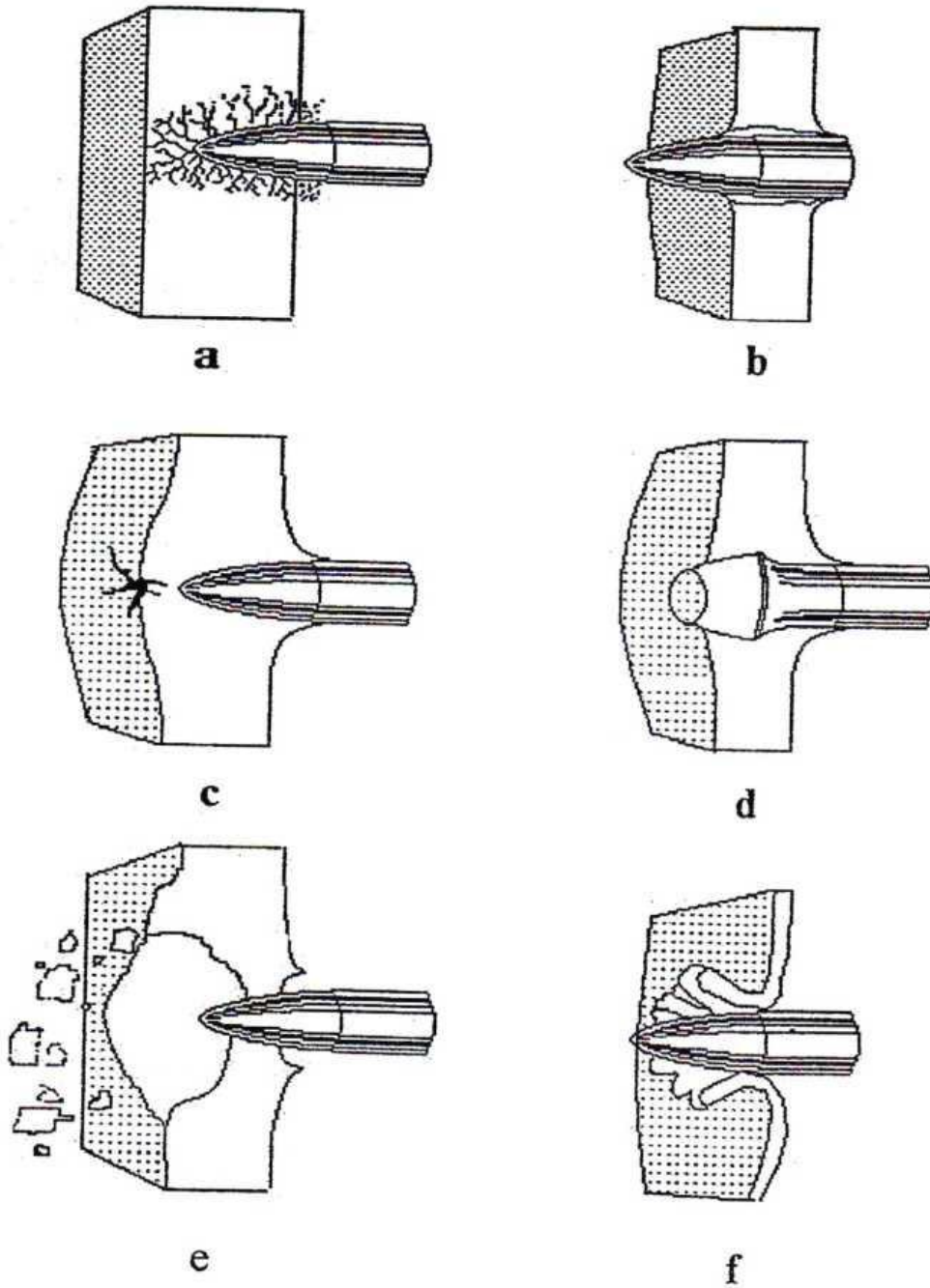
Usually one of the types may be dominating but they are often met in combination. In the present research 5,45 mm bullets are used with prolonged front part the central core of which is made of: steel 10, AÃ 13, 38XH3MÔA, 38XC - Ø, 65Ã, P6A2Ì5. The shooting is made with a ballistic tube from 50 m towards a target made of steel 20; 4; 6; 8 and 10 mm thick. The process of penetrating passes through three common stages and the forming of a stopper and its ejecting from the target is regarded to be a basic mechanism of the penetrating. During the first stage the moving may be ignored and it is considered as a stage of compactness in which the bullet feels the effect of the inertia strength and the strength of compactness.

The strength of compactness

acting upon the bullet is determined by the strength of compactness of the target which is in contact with the bullet. Besides that it is supposed that on this stage of penetrating the mass of the

The second stage of penetrating comes with the moving of the forming stopper along the surface. The stopper will be ejected from the material. On this stage the power for moving the stopper emerging on account of the movement of a part of the material of the target fastened by the bullet is added to the acting strength of the bullet.

During the third stage the bullet and the stopper move together as a solid object overcoming the strength of the tangential tension which acts on the side surface of the stopper and along its whole length



Picture 1: Basic destruction types

- a/ brittle destruction
- b/ destruction with forming of radial leaks
- c/ breaking to pieces
- d/ plastic expansion of the opening
- e/ ejecting a stopper
- f/ forming an opening with a ring

It is necessary to import corrections in the model marking the plastic deformation in the smooth central cores and the brittle destruction of a part from the highstrong central cores. Besides that together with the ejecting of the stopper a plastic expansion of the opening combined with destruction by sagging is received. Similar model is developed in Tailor's and Vetne's works.

Connection between the penetrating and the expansion may be obtained only numerically. That is

$$W = \frac{1}{2} \pi \cdot a^2 \cdot \sigma_s \cdot h_0$$

σ_s - level of drawling of the material of the barrier

h_0 - first thickness of the barrier

a - expansion of the opening from 0 to radius "r"

From the analysis of the existing theories it is obvious that still there isn't a full description of the process of penetrating. This is the reason for involving some other factors influencing this process.

If we mark the full work with A which is done during hitting of the steel barrier

why it is interesting to know how good with Tailor's results the characteristics of the material of the barrier may be predicted, and these characteristics determine the armour piercing and the firmness against hitting.

From the models describing the destruction by sagging which is a basic kind of destruction in slim targets the further developed by Thomson Tailor's model is preferred. The work necessary for penetrating in conformity with this model is:

with A1 - work done for forming the stopper

A2 - work for expansion of the opening

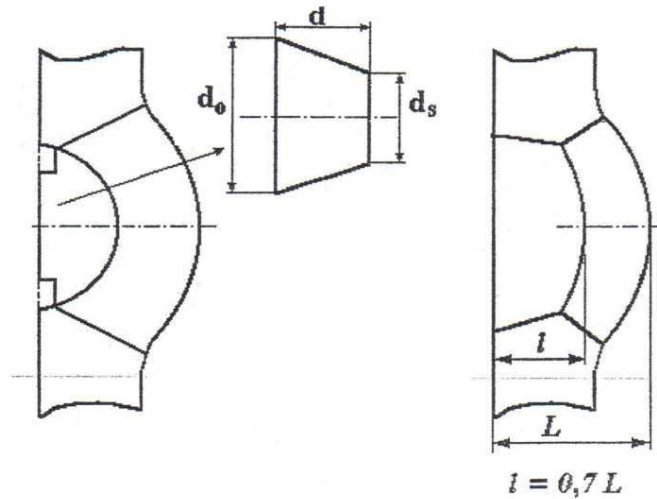
A3 - warmth used for heating the lead mantle

A4 - work for overcoming the friction strength appearing in the process of penetrating

A5 - warmth used for heating the central core

then: $\dot{A} = \dot{A}_1 + \dot{A}_2 + \dot{A}_3 + \dot{A}_4 + \dot{A}_5$

where: $\dot{A}_1 = n \cdot rp^2 \cdot \sigma_s \cdot lp$



Picture 3

Picture 4

rp - radius of the astopper
 σ_s - level of drawing of the respective metal from which the target is made
lp - length of the stopper

$$\dot{A}_2 = \sigma_0 \cdot (V_0' - V_s') = \sigma_0 \cdot \pi \cdot (r_0^2 - r_s^2) \cdot l$$

$\sigma_0 - \sigma_s$ - the tension in which appear plastic deformations

V_0' - volume of the opening

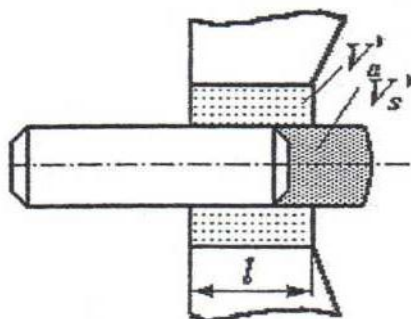
V_s' - volume the opening with diameter corresponding to the

diameter of the central core

r_0 - radius of the opening received plastic expansion

r_s - radius of the central core
 $l \approx 0,7 \cdot L$

L L - full thickness of the stable including the swelling that is obtained by forming a ring entrance+exit



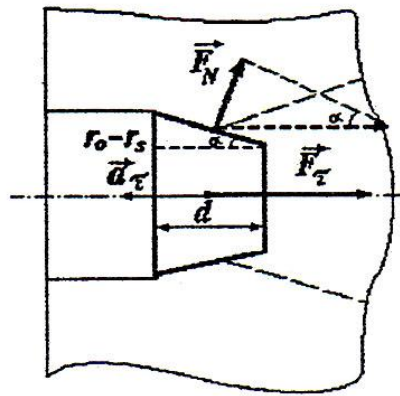
Picture 5

$$\dot{A}_3 = \check{N}_{\check{O}\check{a}} \cdot m_r \cdot \Delta\check{O}$$

$\check{N}_{\check{O}\check{a}}$ - specific heat - capacity

m_r - mass of the lead mantle

$\Delta\check{O}$ - changing the temperature in the process of penetrating in the lead mantle $\Delta\check{O} = 300^\circ\text{C}$



F_τ - friction strength
 F_N - normal strength
 k - friction coefficient $\hat{e} = 0,8 \dots 1$
 a_τ - acceleration

Picture 6

$$|\vec{F}_\tau| = k \cdot |\vec{F}_N|$$

The acceleration a_τ of the stopper is determined from the formulas:

$$l_{st} = V_i \cdot t - a \cdot t^2 / 2$$

$$V_k = V_i - a \cdot t$$

$$t = (V_i - V_k) / 2 \cdot a$$

$$l_{st} = (V_i^2 - V_k^2) / 2 \cdot a$$

$$a = (V_i^2 - V_k^2) / 2 \cdot l_{st}$$

$$m = m_s + m_p$$

m_s - mass of the central core

m_p - mass of the stopper

V_i - speed before the hitting $V_i = 850$ m/s

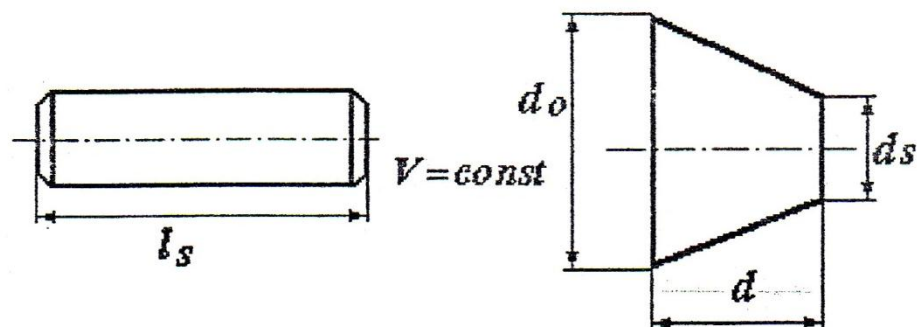
V_k - speed after the hitting

$$F_\tau = m \cdot a; \quad F_\tau = (m_s + m_p) \cdot (V_i^2 - V_k^2) / 2 \cdot l_{st} \hat{e}$$

$$F_N = F_\tau \cdot \sin \alpha$$

before the hitting

after the hitting



Picture 7

$$\pi \cdot r_s^2 \cdot l_s \approx \pi \cdot d \cdot (r_0 + r_s)^2 / 4$$

$$d \approx 4 \cdot r_s^2 \cdot l_s / (r_0 + r_s)^2$$

$$\operatorname{tg} \alpha = (r_0 - r_s) / d \approx (r_0 - r_s) \cdot (r_0 + r_s)^2 / (4 \cdot r_s^2 \cdot l_s)$$

$$\dot{A}_4 = F_N \cdot l_{st} = F_\tau \cdot \sin \alpha \cdot l_{st} = (m_s + m_p) \cdot (V_i^2 - V_k^2) \cdot \sin \alpha \cdot l_{st} / 2 \cdot l_{st}$$

$$\dot{A}_4 = (m_s + m_p) \cdot (V_i^2 - V_k^2) / 2 \cdot \sin [\arctan((r_0 - r_s) \cdot (r_0 + r_s)^2 / (4 \cdot r_s^2 \cdot l_s))]$$

l_s - length of the central core

l_{st} - thickness of the stable

d - length of the central core after the hitting

$A_5 = C_{Fe} \cdot m_s \cdot T$

C_{Fe} - specific heat - capacity of the iron $C_{Fe} = 500 [J/^\circ K]$

The kinetic energy when the bullet meet the barrier is:

$$\dot{A}_1 = m \cdot V_i^2 / 2$$

m - total mass of the bullet and after the hitting it is:

$$\dot{A}_2 = [(m_s + m_p) \cdot V_k^2] / 2$$

Knowing \dot{A}_1 and \dot{A}_2 we can determine what part of the bullet's energy is used for hitting the target

$$\Delta \dot{O} = \dot{A}_1 - \dot{A}_2 = m \cdot V_i^2 / 2 - (m_s + m_p) \cdot V_k^2 / 2$$

Comparing the used work A and the loss of energy

formula $(\Delta T - A) / \Delta T$. 100% we can determine the relative result of the suggested model

In creating the analytic model of hitting the next limitations are made

- the diversion of the speed before the hitting in all experiments is $\pm 5\%$

- the lead mantle and the cover remain in the barrier

- after the penetration of the central core on $0,7 L_{\text{core}}$ depth the stopper is exit.

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Original Contribution

WHY BALLISTIC TESTING METHODS OF BODY ARMOR DO NOT GIVE US ACCURATE INFORMATION

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ABSTRACT: In the security sector always is attention paid to ensure the best possible protection for their employees.

Manufacturers and especially the users of ballistic protection systems need an adequate answer to the question whether the chosen protection is effective against specific threats. Such evaluation is difficult enough, mainly because ballistic systems of body armors are high technology products and they embody last achievements in different branches of technology and science.

The needed ballistic protection from different threats (bullets, fragments, explosions, stab protection, etc.), makes the only verified and reliable method for effectiveness assessment ballistic test. But are the ballistic tests reliable enough? How they express real situation? What is acceptable risk to assume?

The more often used method for assessment of ballistic protection level is determined by series 0101 NIJ Standards: the body armor, mounted on plasticine block is hit by different caliber ammo and at one side there hasn't to be penetration, and at other hand the blunt trauma hasn't to exceed 44 mm. These should guarantee body armor ballistic protection rate.

Other "plasticine" based ballistic testing standards have same imperfections, because their origin from 0101 series of NIJ Standards.

This scenario for bullet resistance testing is needed for general reconstruction: the plasticine has a quite different properties in comparison with different areas of human body; the measured value of penetration has only static component – lack of correspondence with real situations, dynamic component (impact wave propagation, character of wave, etc.) isn't included; and last but not least this criteria for high-speed (rifle) bullets never has been compared with human/animal corpses results.

The goal of this paper is to summarize main problems related with this scenario of testing, to characterize in theory the possible consequences after non penetrating impact – mechanical damages, impact wave propagation and other impact phenomena, due to bullet impacts in relation with impact phenomena, and to provide some directions for development of new methods for ballistic testing.

KEY WORDS: ballistic protection, bullet resistance, body armor, ballistic testing standards

1

. INTRODUCTION

Modern military forces and civil protection agencies place high priority on providing the best protection possible to their personnel – their most valuable resource.

A ballistic vests are the part of personal armor protection that helps absorb the impact from projectiles and fragments from explosions. Soft

vests are made from many layers of woven or laminated fibers and can be capable of protecting the wearer from small-caliber handgun and shotgun projectiles, and small fragments.

For higher level of protection (from rifle rounds and bigger fragments) additional plates can be used with a soft vest. Soft vests are commonly worn by police forces,

civilians, security guards, and bodyguards, whereas hard-plate reinforced vests are mainly worn by combat soldiers and police tactical units.

Because the body armors are of vital importance, both users and manufacturers are need for adequate and correct answer to question how far the given ballistic system is effectively to particular threat. However, evaluating the effectiveness of materials and designs for new armour is extremely difficult: although it is easy to see if a given sample has or hasn't actually been perforated by a given ballistic threat under given circumstances, it is generally not evident what injuries the impact of the projectile might have inflicted on a human wearing the armour under test. The design and configuration of ballistic systems are often determined more by user comfort and perception than by their contribution to protection, yet the body armor blunt trauma can be a critical factor in determining injury resulting from an impinging projectile. The capability of the ballistic system to absorb and dissipate energy is an equally important factor in determining how the energy of the impacting threat is transferred to the human body. Conventional body armor evaluation systems using plasticine-based models of the human thorax provide, at best, only an indication of the maximum tolerable body armor back-face deformation. In world practice and particular in Bulgaria is used great number of standardized methods

by using of plasticine as backing material all of them based on NIJ standard. This standard (NIJ Standard 0101) has endured five main changes and about ten partial corrections to NIJ Standard 0101.06 [17]. Regardless of these corrections, one could say that, this norm has about thirty years prescription, because the changes of testing procedures are only cosmetics. Unfortunately, performed ballistic test may only access the possibility whether the body armor can stop given ballistic threat and to inconsiderable degree to ensure adequate answer whether body armor blunt trauma is or isn't lethal for human [4]. My practice say, the assessment at these tests is highly inaccurate, because there are great possibility different samples to obtain different results. The tests may call valid if they can give us adequate answer whether the body armor is effective in conditions close to the real battle conditions. Unfortunately the existing standardized methods can't answer this question and even they answer them, the answer is not as precise as needed.

2. PROBLEM STATE

2.1. Basis of plasticine standardized ballistics test

The basic principle of plasticine ballistics test is as follows: the vest is mounted on the plasticine backface fixture and determined number of shots is produced. And the armor system should resist every fair hit and BFS should to be lower than limit (44 mm in NIJ Standard series 0101, 30

mm in Bulgarian testing methodology).

The standards based on this physical principle specifies how to conduct ballistic tests on body armor models under controlled conditions in order to establish the ballistic properties of the samples, which retrospectively are carried on the entire lot.

These types of tests not demand for high-technology laboratory equipment and allow easy collection and data processing – the easiest way for users and manufacturers.

However, to date, they apply a hundred percent for ballistic testing of body armor, because of abovementioned fact, and mostly because of the reluctance of manufacturers of materials and ballistic vests to put things on a scientific basis. Placing the issue on a strict scientific basis would lead to increased costs for research, development and testing at manufacturers. Below the main problems of using of plasticine based standards.

2.1. Differences between real fire situations and ballistic standards

There is a large gap between testing standards and real situation.

Firstly, achieved number of test shots in the norm (and in the other norms), only guaranteed assurance that possibility of tested body armor stop given bullet.

Additionally, most plasticine based standards do not provide multi-hit resistance testing. This makes the gap greater.

A good example in this regard can be taken from CAN/CGSB-179.1-2001 Personal Body Armour National Standard, where it introduced the opportunity to test multi-hit resistance, which makes the setting as close to reality. Moreover, increasing the number of shots increases reliability of the system. But the consecutive shots required by the standard by no means guarantee multi-hit ballistic resistance, because the loading from 3-4 shots at intervals of the order of several hundred ms in burst rate and about 2 s in single shot fire rate, applied on particular area is extremely high in comparison with this that achieved by the same number of shots at intervals of a minute and more. This is because of the ballistic system in the second case has time to restore their ballistic resistance.

Another big problem is the required distance between two bullet shot centers or distance between bullet and the ballistic panel edge is highly whopping and this promotes body armour producers.

The performed tests for 5,56x45 mm and 7,62x51 mm bullets, and results from [2] demonstrate that the distances between bullet shot center are between 2 and 4 cm at distances smaller than 100 m.

The results for 7,62x39 mm AK-47, 5,56x45 mm AR-M1, 7,62x54R PKT and 7,62x51 Arsenal LMG showed confirmation with results in [2] and the distances are between 2,5 and 3,5 cm at 50 m distances for 5,56x45 mm AR-M1, 7,62x54R PKT and 7,62x51 Arsenal LMG and

between 3,5 and 4,5 cm at same distance for AK-47.

Another test shows that IIIA type body armor according to NIJ Standard 0101.04 body armor hadn't stopped

the next bullet hit in $3,9 \pm 0,5$ cm distance from previous shot. This distance is about 20% less than required distance from NIJ Standard 0101.04 (fig. 1).



Fig.1. Perforation of IIIA type body armor by next test bullet in distance about 20% closer than required by standard

It's clear that this examined case is particulate and no one could say that all of certified by testing agencies according to NIJ Standard 0101.04 body armors don't stop bullets with distances between their centers less than specified in abovementioned standard. But another thesis is valid too – there is no guarantee that if distance between bullets shot centers is in the gap of 2,5 -4,5 mm (distance in real fire situations), the given body armor resist.

Adding to these problems and the unresolved problem of the influence of aging on the ballistic material quality, the problem is significantly complicated [2].

With regard to "bridge the gap" between the ballistic tests and real fire situations, it is necessary to change the pattern of testing.

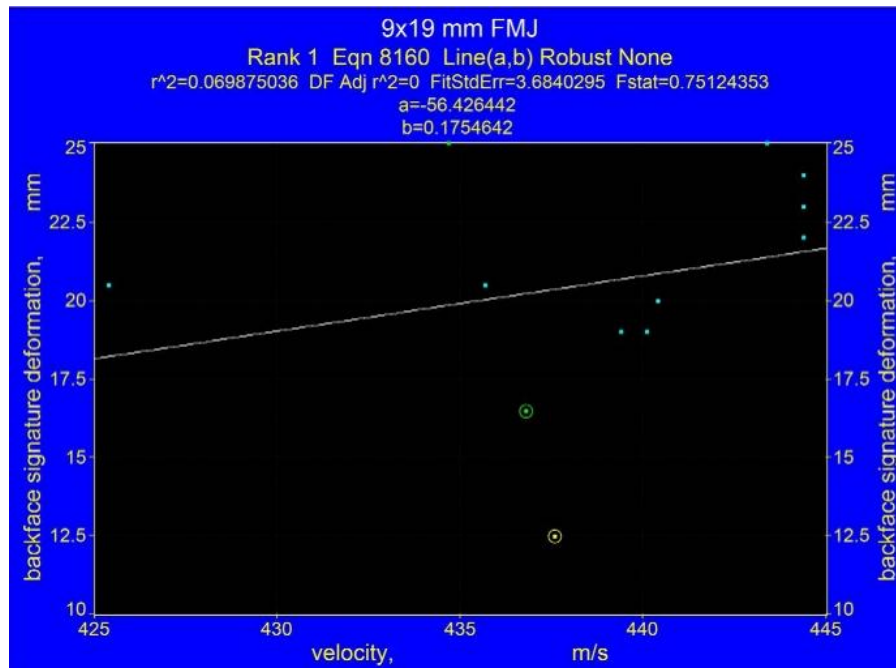
2.2. Shortcoming of plasticine backing material fixture

The other disadvantage for standardized ballistic tests for assessment of bulletproof resistance is backing material fixture:

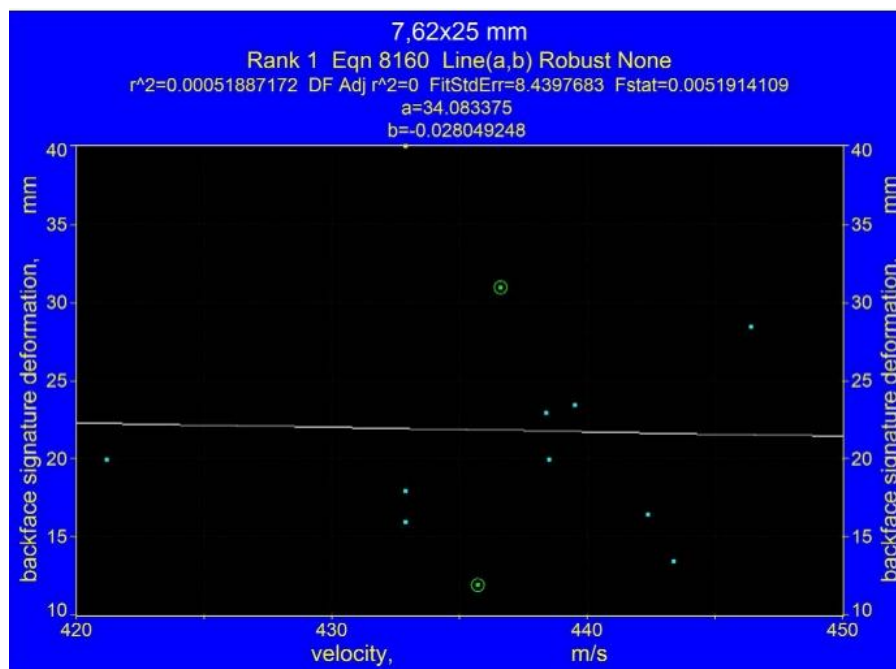
- Plasticine is quite different from human torso;
- Measured value of backface signature penetration (depth of the depression made in the backing material, created by a non-penetrating projectile impact) provides only part of the "static" load, while the "dynamic" components (the waves, history of the deformation process, etc..) can not be registered;
- This criterion of NIJ has never compares favorably correlated with live models (animals) for high-speed bullets.

There are no strong correlation between deformation (backing fixture signature) and achieved bullet velocities (respectively bullet kinetic

energy) (Fig.2) and these values haven't any relation with injuries, especially from rifle bullets.

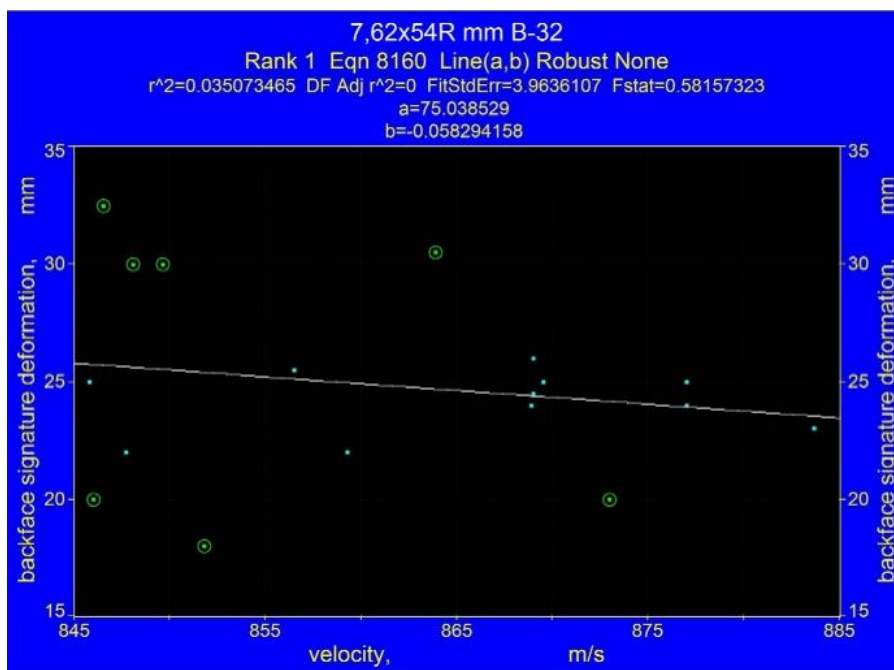


a)



b)

Fig.2 Correlation between deformation (backing fixture signature) and bullet velocities (respectively bullet kinetic energy) for testing ammunition of Bulgarian Army body armor: a) for 9x19 FMJ; b) 7,62x25 mm FMJ (bimetal) and c) 7,62x54R B-32.



c)

Fig.2 (cont.) Correlation between deformation (backing fixture signature) and bullet velocities (respectively bullet kinetic energy) for testing ammunition of Bulgarian Army body armor: a) for 9x19 FMJ; b) 7,62x25 mm FMJ (bimetal) and c) 7,62x54R B-32.

As it's shown there're relatively good correlation for 9x19 mm FMJ (this ammunition is testing for NIJ Standard 0101.04), but the one can say that there are no correlation for other two testing ammunitions (they aren't testing ammunitions for NIJ Standard 0101.04).

Because of the backing material has too different qualitative indices in comparison with human body and the measured value from backface signature test show only the static part of the loading and dynamic part (impact wave propagation, deformation history, etc.) is unknown.

3. SOLUTION PHILOSOPHY

A complex solution for improvement of reliability of ballistic testing is needed.

Firstly, the settings of the experiment should to be modified to near maximum to real fire situations – ballistic test should provide real multi-hit resistance with real distance between centers of test bullets and edges of the garment.

For each caliber have to be tested different weapon systems to real bullets dispersion estimate. Additionally, have to be performed different tests for determination how many hits (3, 4 or more) should to resist ballistic system to be multi-hit capable.

On the other hand should to be provided other backface fixture to:

- “copy” structure of human torso;
- capture the “dynamic” components (the waves, history

of the deformation process, etc.) can not be registered.

Reliability of the tests may be increased if instead of such a material is subjected to use more reliable biomechanical models of human torso [1]. Furthermore, this will avoid segregation and ballistic material, which leads to a greater reliability of the data obtained and repeatability for different specimens.

In the context of automobile accidents, powerful numerical tools

are available to simulate the impact response of thorax. But in the context of body armor blunt trauma, no equivalent numerical model exists: prediction of thoracic trauma, in particular lung injuries, cardiac hemorrhage, ribs fracture etc. is still very approximate. In comparison with typical automobile impacts, the load is applied very rapidly to the thorax in body armor blunt trauma (BAPT) impacts (fig.3).

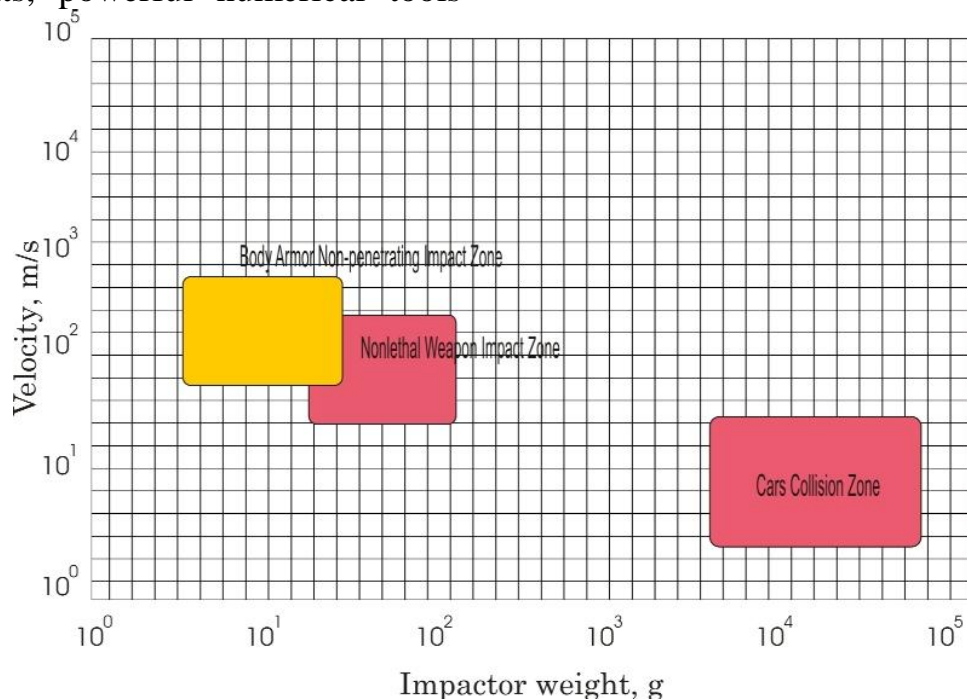


Fig.3. Velocity Mass Diagram for Body Armor Blunt Trauma

At present, the finite element (FE) models of thorax based on a realistic description of the geometry are unable to describe the propagation of the impact energy carried by high frequencies; indeed, the associated waves generated upon impact do not propagate in the FE models because meshes used are too coarse. The required number of elements to describe properly wave propagation is too large. The modeling strategy

followed for low-frequency BAPT phenomena is close to that developed in the context of automobile accidents. And FE of thorax developed for typical automobile impacts may used for stresses and displacement determination.

But there is a need for other model for high-frequency BAPT phenomena. The model shall consider only the main characteristics of the thorax structure implicated in the

transmission of the impact energy in the lung through the thoracic wall. Because the loading duration under consideration is very short, the future studies will be limited to the thorax zone under the impact point, and the response is calculated in a very short time window after impact. The assumption is that within a time window of a few hundreds of microseconds, the response of the thoracic wall and the lung is only weakly perturbed by the other parts of the thorax (heart, spine, etc.) and their influence on impact wave propagation will not be examined.

Combination of injury criteria development from simulations and more “real” fixture for ballistics testing will enhance reliability of results.

4. SUMMARY

Body armors as a part of personal armor protection are systems

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that incorporate last achievements of science and technology.

Because of their importance for the preservation of life of users, ballistic tests are the only reliable way to prove their quality.

But most of the ballistics test used methodology origin in NIJ Standard 0101 series.

Regardless, these standards are changed periodically; the physical basis remains the same and the problems with reliability of the ballistic tests remains. The shortcomings of these standards are divided into two groups – differences between the real fire situations and ballistics tests in standards and unsuitability of plasticine based backface fixture.

A complex approach is proposed by author, because of lack of authentic methods and models – to derive injury criteria and to replace backface signature.

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Original Contribution

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