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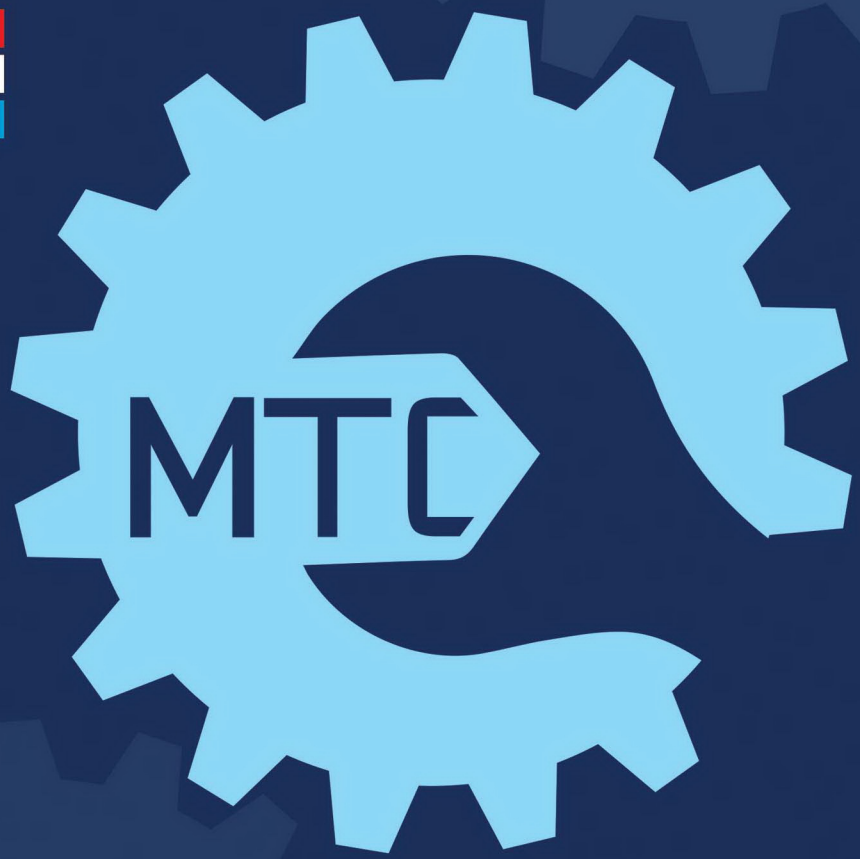

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ORIGINAL SCIENTIFIC PAPERS

TWO LAPLACIAN ENERGIES AND THE RELATIONS BETWEEN THEM

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Abstract:

Introduction/purpose: The Laplacian energy (LE) is the sum of absolute values of the terms μ_i-2m/n, where μ_i, i=1,2,…,n, are the eigenvalues of the Laplacian matrix of the graph G with n vertices and m edges. In 2006, another quantity Z was introduced, based on Laplacian eigenvalues, which was also named „Laplacian energy". Z is the sum of squares of Laplacian eigenvalues. The aim of this work is to establish relations between LE and Z.

Results: Lower and upper bounds for LE are deduced, in terms of Z.

Conclusion: The paper contributes to the Laplacian spectral theory and the theory of graph energies. It is shown that, as a rough approximation, LE is proportional to the tem $(Z-4m^2/n)^{1/2}$.

Keywords: Laplacian spectrum (of graph), Laplacian energy.

Introduction

Let ***M*** be a real symmetric square matrix of order *n*. Let $\zeta_1,\zeta_2,\ldots,\zeta_n$, be the eigenvalues of ***M,*** and let $\zeta_1+\zeta_2+\cdots+\zeta_n=\zeta$. Then the *energy* of ***M*** is defined as (Nikiforov, 2007), (Gutman & Furtula, 2019):

$$E(M)=\sum_{i=1}^{n}\left|\zeta_i-\frac{\zeta}{n}\right| \qquad (1)$$

By using different matrices, one arrives at different „energies". The first among them is the (ordinary) graph energy, based on the

eigenvalues of the (0,1)-adjacency matrix of a graph (Li et al, 2012), (Ramane 2020). It was introduced in 1978. Since then, more than 170 various „energies“ have been considered in the literature; for details see (Gutman & Furtula, 2019). In this paper, we are concerned with the *Laplacian energy.*

Let G be a simple graph possessing n vertices and m edges. Label its vertices by by v1, v2, …, vn . Let deg(vi) be the degree (= number of first neighbors) of the vertex vi. The Laplacian matrix of G, denoted by L(G), is the square matrix of order n, whose (i,j)-element is

$$L(G)_{ij} = \begin{cases} -1 & \text{if } v_i \text{ and } v_j \text{ are adjacent} \\ 0 & \text{if } v_i \text{ and } v_j \text{ are not adjacent} \\ \det(v_i) & \text{if } i = j \end{cases}$$

For details of the theory of Laplacian matrices and their spectra see (Grone et al, 1990),(Mohar, 1992), (Merris, 1994).

Let μ1,μ2,,…, μn be the Laplacian eigenvalues of the graph G, i.e., the eigenvalues of L(G). Then the Laplacian energy of G is

$$LE = \sum_{i=1}^{n} \left| \mu_i - \frac{2m}{n} \right| . \qquad (2)$$

The Laplacian energy was introduced in 2006 by the Chinese mathematician Bo Zhou and the present author (Gutman & Zhou, 2006). Since then, its theory was elaborated in due detail, see (Das & Mojallal, 2014), (Pirzada & Ganie, 2015), (Andriantiana, 2016), (Gutman & Furtula, 2019), (Gutman, 2020), and the references cited therein.

In the same year when the concept of the Laplacian energy was conceived (Gutman & Zhou, 2006), a paper was published in which an unrelated Laplacian-spectral quantity was defined, and also named „Laplacian energy“ (Lazić, 2006). The quantity put forward in (Lazić, 2006) is

$$Z = \sum_{i=1}^{n} \mu_i^2 . \qquad (3)$$

In what follows we refer to Z as to the fake Laplacian energy.

It is evident that Z, Eq. (3), violates the general conditions that an „energy“ needs to satisfy, see Eq. (1). The right-hand side of Eq. (3) is just the second spectral moment of the Laplacian eigenvalues. Naming it „energy“ was a misnomer. This was immediately recognized by all

mathematicians who did research of the true Laplacian energy, Eq. (2), and the paper (Lazić, 2006) was simply ignored.

The inventors of the Laplacian energy (Gutman & Zhou, 2006), as well as the scholars who later studied it, were solely interested in its mathematical properties. However, in recent years, the Laplacian energy has gained popularity for a variety of technical applications, mainly in the area of image analysis and pattern recognition (Luyuan et al, 2010), (Song et al, 2010), (Meng & Xiao, 2011), (Xiao et al, 2011), (Huigang et al, 2013), (Bai et al, 2014), (Deepa et al, 2016), (Pournami & Govindan, 2017), (Zou et al, 2018). In all the quoted papers, the Laplacian energy was computed according to Eq. (2).

Not all scholars who work on applications of the Laplacian energy are experts on its mathematical theory, and some of them seem to have learned about the Laplacian energy by means of Google search. Therefore, it happened that in some papers, instead of the true Laplacian energy, a group of authors used *Z*, Eq. (3) (Qi et al, 2012), (Qi et al, 2013), (Qi et al, 2015). It may be that there are more such erroneous works, spread in the non-mathematical literature.

The existence of papers in which the fake Laplacian energy is used, motivated us to examine the actual (mathematical) relation between *LE* and *Z*.

Relating the two Laplacian energies

In (Gutman 2020), it was pointed out that the relations

$$\sum_{i=1}^{n} \mu_i = 2m$$

and

$$\sum_{i=1}^{n} \mu_i^2 = 2m + \sum_{i=1}^{n} \deg(v_i)^2$$

are well known (Grone et al, 1990). There it was shown that

$$\sum_{i=1}^{n} \mu_i^{*2} = 2m + \sum_{i=1}^{n} \deg(v_i)^2 - \frac{4m^2}{n}$$

where

$$\mu_i^* = \mu_i - \frac{2m}{n}.$$

Recall that

$$\sum_{i=1}^{n} \mu_i^* = 0 \qquad and \qquad \sum_{i=1}^{n} |\mu_i^*| = LE \quad . \tag{4}$$

Bearing in mind Eq. (3), we get

$$Z = 2m + \sum_{i=1}^{n} \deg(v_i)^2 \tag{5}$$

and

$$\sum_{i=1}^{n} \mu_i^{*2} = Z - \frac{4m^2}{n}. \tag{6}$$

Starting with

$$\sum_{i=1}^{n}\sum_{j=1}^{n} (|\mu_i^*| - |\mu_j^*|)^2 \geq 0$$

and using Eqs. (4) and (6), we get

$$n\sum_{i=1}^{n} \mu_i^{*2} + n\sum_{j=1}^{n} \mu_j^{*2} - 2\sum_{i=1}^{n}\sum_{j=1}^{n} |\mu_i^*| \cdot |\mu_i^*| = 2\,\mathrm{n}\left(Z - \frac{4m^2}{n}\right) - 2LE^2 \geq 0$$

fom which,

$$LE \leq \sqrt{n\left(Z - \frac{4m^2}{n}\right)}. \tag{7}$$

Starting with

$$LE^2 = \left(\sum_{i=1}^{n} |\mu_i^*|\right)^2 = \sum_{i=1}^{n} \mu_i^{*2} + 2\sum_{i<j} |\mu_i^*| \cdot |\mu_j^*| \geq \sum_{i=1}^{n} \mu_i^{*2} + 2\left|\sum_{i<j} \mu_i^* \cdot \mu_j^*\right|$$

and taking into account that because of (4),

$$2\left|\sum_{i<j} \mu_i^* \cdot \mu_j^*\right| = \left|\sum_{i=1}^{n}\sum_{j=1}^{n} \mu_i^* \cdot \mu_j^* - \sum_{i=1}^{n} \mu_i^{*2}\right| = \sum_{i=1}^{n} \mu_i^{*2}$$

we get

$$LE^2 \geq 2\sum_{i=1}^{n} \mu_i^{*2}$$

i.e.

$$LE \geq \sqrt{2\left(Z - \frac{4m^2}{n}\right)}. \qquad (8)$$

Combining (7) and (8), we arrive at

$$\sqrt{2\left(Z - \frac{4m^2}{n}\right)} \leq LE \leq \sqrt{n\left(Z - \frac{4m^2}{n}\right)}. \qquad (9)$$

Discussion

From the bounds (9), we see that, as a rough approximation, there should exist a linear relation between the Laplacian energy (*LE*) and the term $\sqrt{Z - 4m^2/n}$, with *Z* standing for the fake Laplacian energy. As the first guess, we may have

$$LE \approx \frac{\sqrt{n}+\sqrt{2}}{2}\sqrt{Z - \frac{4m^2}{n}}. \qquad (10)$$

The approximation (10), as well as any other approximation based on the bounds (7) and (8), is of poor quality. Namely, in contrast to the Laplacian energy, the right-hand side of (10) is structure-insensitive. This, of course, is the consequence of the structure-insensitivity of the fake Laplacian energy, *Z*.

For instance, if the graph *G* is regular of degree *r*, then *Z=nr(r+1).* If the graph *G* has n_a vertices of degree *a*, and n_b vertices of degree *b,* so that $n_a + n_b = n$, then

$$Z = \frac{2m - nb}{a - b}a(a+1) + \frac{2m - na}{b - a}\mathrm{b(b+1)}$$

and *Z* is independent of the parameters n_a and n_b. Thus, for the chemically important class of (molecular) graphs with vertices of degree two and three, *Z=6(2m-n),* independent of any other structural detail. Then the same holds also for the right-hand side of Eq. (10).

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Резюме:

Введение/цель: Энергия Лапласа (LE) представляет собой сумму абсолютных значений μ_i-2m/n, где μ_i, i=1,2,...,n являются собственными значениями G графы матрицы Лапласа с вершинами n и ребром m. В 2006 году была введена величина Z, основанная на характерных значениях Лапласа, которая получила название «Лапласова энергия». Z – это сумма квадратов собственных значений Лапласа. Целью данной работы является установление соотношений между LE и Z.

Результаты: Нижняя и верхняя границы для LE выводятся из функции Z.

Выводы: Статья способствует спектральной теории Лапласа и теории энергии графов. В грубой аппроксимации было показано, что LE пропорциональна $(Z-4m^2/n)^{1/2}$.

Ключевые слова: Лапласов спектр (граф), энергия Лапласа.

ДВЕ ЛАПЛАСОВЕ ЕНЕРГИЈЕ И ОДНОСИ МЕЂУ ЊИМА

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ОБЛАСТ: математика
ВРСТА ЧЛАНКА: оригинални научни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Увод/циљ: Лапласова енергија (LE) јесте сума апсолутних вредности појмова μ_i-2m/n, где су μ_i, i=1,2,...,n, сопствене вредности Лапласове матрице графа G са n врхова и m ивица. Године 2006. уведена је друга величина Z, заснована на Лапласовим својственим вредностима, која је такође названа „Лапласова енергија". Z је сума квадрата Лапласових својствених вредности. Циљ овог рада је налажење односа између LE и Z.

Резултати: Доња и горња граница за LE одређене су као функције од Z.

Закључак: Рад доприноси Лапласовој спектралној теорији и теорији енергије графова. Показано је да је, као груба апроксимација, LE пропорционална са $(Z-4m^2/n)^{1/2}$.

Кључне речи: Лапласов спектар (графа), Лапласова енергија.

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ON COVID-19 DIFFUSION IN ITALY: DATA ANALYSIS AND POSSIBLE OUTCOME

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FIELD: Mathematics
ARTICLE TYPE: Original scientific paper
ARTICLE LANGUAGE: English

Abstract:

Introduction/purpose: At the end of 2019, the Coronavirus disease 2019 (COVID-19) was identified first in the Hubei province of China and then it spread over the world causing the coronavirus pandemic. The virus has given very different outcomes in different countries up to day - at the time of writing, Italy has a record number of deaths caused by coronavirus (Google, 2020).

Methods: A mathematical model is applied to describe the behavior of number of cases with respect to time, the obtained data is compared and some predictions given.

Results: The model chosen to represent the evolution of the spread of the disease allows making some projections for the future.

Conclusions: Sound projections could be created with accurate numbers provided the current situation is not perturbed by other external influences.

Key words: Coronavirus, COVID-19, differential equation, data fit.

Introduction

The aim of the paper is to describe in somewhat rigorous terms the spreading of the disease in time, i.e. the number of positive cases for Covid-19. This is a classical problem of population growth that applies equally well to the rate of reproduction of an animal species or of a virus.

Qualitatively, one should expect for a population number to grow exponentially in the first phase and then, with the increase of competition and diminishing resources, to slow down until reaching a plateau in time, i.e. a static situation.

By means of the model applied and available data, it is possible to determine when the growth of cases should diminish, when it will stop and what the total number of cases will be.

Growth equation

The equation used to describe the growth of the number of cases is the same used in the description of the growth of generic population in time *x(t)*, sometimes called the logistic equation (Verhulst, 1838):

$$\frac{dx(t)}{dt} = \frac{x(t)}{a}\left(1 - \frac{x(t)}{c}\right) \tag{1}$$

where *a* is related to the growth rapidity and *c* is the asymptotic total number of cases, or population.

The solution of the equation should be written as

$$x(t) = \frac{c}{1+\exp((b-t)/a)} \tag{2}$$

where the parameter *b* is related to the initial condition

$$x(0) = \frac{c}{1+\exp(b/a)} \tag{3}$$

and also *b* is the growth invertion point, i.e.

$$\frac{d^{(2)}x(b)}{dt^{(2)}} = 0 \tag{4}$$

for *t=b, dx(t)/dt* reaches the maximum.

In order to determine the three positive parameters *a,b* and *c,* one has to compare it to the existing situation.

There exists a GitHub account with Italian official data for the coronavirus disease (Ministero della Salute, 2020) which is updated on a

daily basis and covers most information available since the 24th of February, 2020.

The paper will focus on the date column A and the total number of cases, K of the csv file and will fit the three parameters *a,b* and *c* of solution (2) to the data.

According to the data presented on the 28th of March 2020, 34 days after the start of the disease data collection, the three parameter fit gives the following results:

Table 1 – Fit for parameters a, b and c
Таблица 1 – Ввод по параметрам a,b и c
Табела 1 – Уклапање за параметре a, b и c

Parameter	Value	Error	Error %
a	5.32546	+/- 0.07999	1.502%
b	28.721	+/- 0.2253	0.7846%
c	125043	+/- 2349	1.878%

It can be clearly seen that the numerical results of this fit are very precise, and the associated error is contained within less than 2% (the plot is subsequently going to show they are very accurate as well).

As previously discussed, *b* and *c* are the most relevant parameters, the *b* value of about 29 days shows that the inversion point has already been reached and the growth of new cases is slowing down. The *c* value of around 125 thousand represents the total number of cases, which is still rather far from the current number of total cases (around 100 thousand).

Plot 1 shows the fit of curve (2) with respect to the collected data.

One can clearly see that the agreement with the points is excellent. In fact, only 3 parameters are enough for a fit with a time span exceeding one month. The superposition of the two curves shows that the agreement is also very accurate.

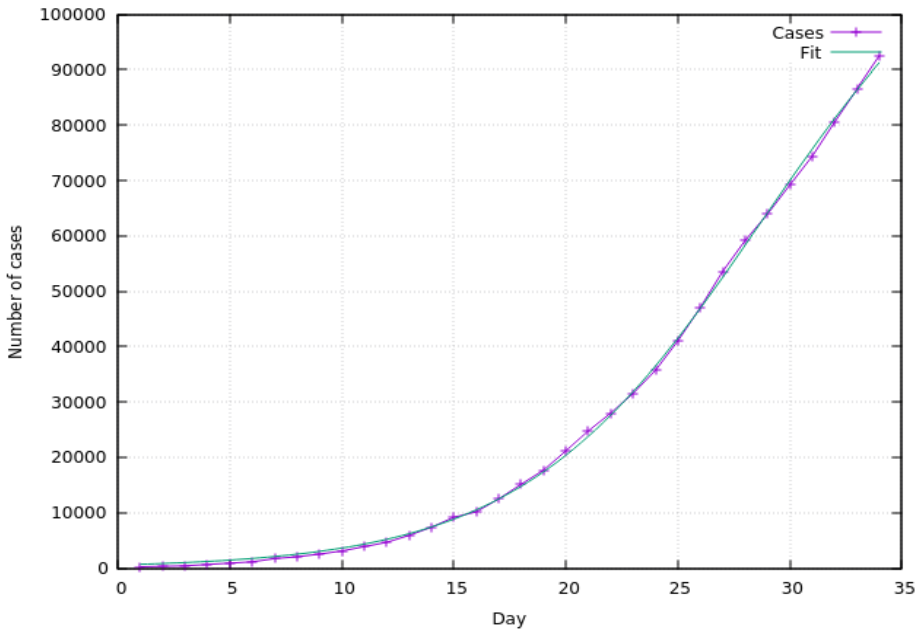

Figure 1 – Data fit: the number of cases with respect to the number of days
Рис. 1 – Совпадение данных: число случаев в соотношении с числом дней
Слика 1 – Уклапање података: број случајева у односу на број дана

Tentative prediction for the future

Using the results obtained in the previous section, we will try to predict the future behavior of the number of cases, using the values obtained by the fit.

We will also compare the data to the derivative of equation (2) (multiplied by a factor of 10 in order to enhance it) in order to better identify the inversion point.

Figure 2 shows the plot of the obtained data so far as a function of time, together with equation (2) for 10 days in the future and its derivative, augmented by a factor of 10 so that it is visible on the plot (the authors are actually concerned only with its maximum value).

A similarity of this derivative to the Gaussian distribution is also worth noticing as well as the number of cases that resembles the error function. The latter shows, however, a fundamental difference from equation (1) that governs the real case, i.e. the tails that would assume that the beginning of the covid disease started in the distant past.

As it can be seen, the graph representing the number of cases slows down its growth and soon approaches a quasi static regime. This

behavior is also confirmed by the derivative function which shows how its peak value has already been surpassed. According to Table 1, the end of the disease should be reached when the number of cases approaches 125 thousand units.

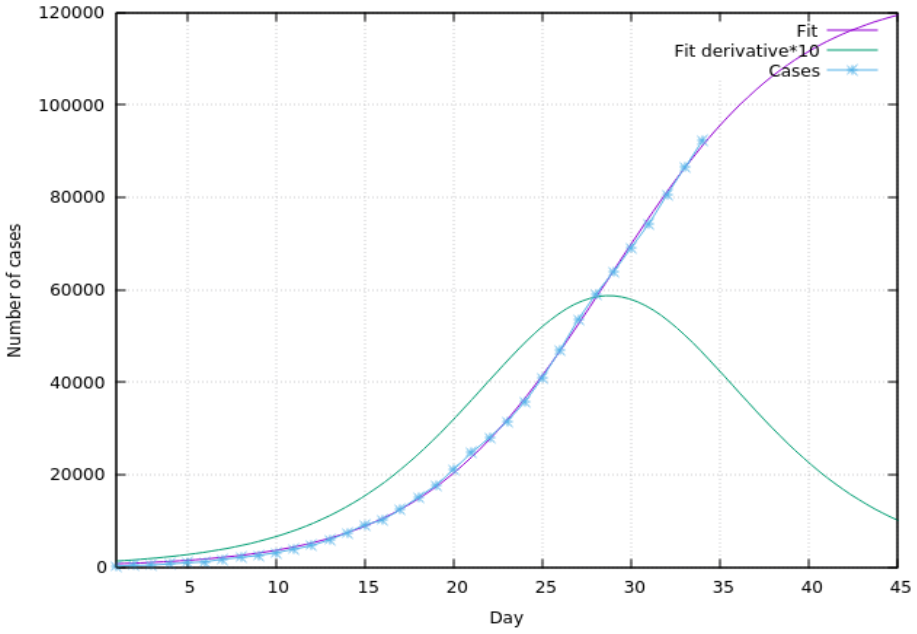

Figure 2 – Extrapolation of the number of cases for the next future
Рис. 2 – Экстраполяция числа случаев на ближайшее будущее
Слика 2 – Екстраполација броја случајева у блиској будућности

Of paramount interest is, of course, a reasonable estimate of the end of the disease. Bearing in mind that the steady state value c of equation (2) is asymptotic, and that the number itself carries an implicit error of its true value depending on the measurement used (various kinds of swabs, CT scans, etc) and by solving the equation in time t for the parameters found in Table 1:

$$x(t) = Fraction\,of\,c \tag{5}$$

one obtains the values shown in Table 2:

Table 2 – Estimated time t for the end of the disease spread based on the value c = 125043 obtained in Table 1
Таблица 2 – Расчетное время t завершения распространения заболевания на основании значения c = 125043, полученного из таблицы 1
Табела 2 – Процењено време t краја ширења заразе, засновано на вредности c = 125 043, добијеној из табеле 1

Fraction of *c*	Time *t*
99.9%	65.5 Days
99.99%	77.8 Days
99.999%	90.0 Days

In other words, it means that, in order to reach a total number of cases equal to 99.9% of *c* as in the first line, one should wait to the end of April 2020 approximately. The other two values will be reached around the middle and the end of May 2020, respectively.

Our prediction model made some implicit assumptions; namely, that the system is closed, so there are neither external interactions over the whole time, nor congregating of people that could drastically increase the local number of patients even in an isolated system, and that we are actually dealing with only one kind of a virus strain, which has already been discussed in (Cereda et al, 2020) and which may explain the extreme agressiveness of the Italian situation compared to those in other countries (see (Google 2020) for data on other countries).

In reality, there is a possibility that interactions among different countries will restart before the situation in the whole world settles down, meaning that some minor disease spreads could reoccur before its disappearing, looking like damp copies of the derivative of equation (2) repeated in a more or less periodic way depending on the reopening of borders for goods deliveries and traveling.

Conclusion

The model of population growth has been used and it has been found out that it agrees with the current data of Covid-19 diffusion surprisingly well, using just a few parameters. The determination of these parameters allows us to notice that the peak growth that happened at about 30 days after the start of the disease has already been surpassed. The total number of Covid-19 cases, about 125 thousand, is still far off and should be reached in approximately 30 days, provided Italy remains isolated from other countries and keeps away from internal traveling as much as possible to avoid other possible causes of infections.

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О РАСПРОСТРАНЕНИИ ЗАБОЛЕВАНИЯ COVID-19 В ИТАЛИИ: АНАЛИЗ ДАННЫХ И ВОЗМОЖНЫЙ ИСХОД

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РУБРИКА ГРНТИ: 27.29.00 Обыкновенные дифференциальные уравнения
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Введение/цель: В конце 2019 года Коронавирусная инфекция (COVID-19) первоначально была обнаружена в китайской провинции Хубэй, а затем распространилась по всему миру, вызвав пандемию коронавируса. Вирус проявлялся в разных странах по-разному, на сегодняшний день, пока мы пишем данную статью, в Италии зарегистрировано рекордное количество умерших от коронавируса (Google, 2020).

Методы: Вышеописанная прикладная математическая модель, фиксирует поведенческие особенности случаев в отношении времени, выполнено сравнение с полученными данными и приведен прогноз на будущее.

Результаты: Данная модель представляет эволюцию расширения заболевания, и дает возможность создать соответствующие условия в будущем.

Выводы: Звуковые проекции могут дать точные числа, но только при условии, если текущая ситуация не будет нарушена другими внешними воздействиями.

Ключевые слова: Коронавирус, COVID-19, дифференциальное уравнение, совпадение данных.

О ДИФУЗИЈИ COVID-19 У ИТАЛИЈИ: АНАЛИЗА ПОДАТАКА И МОГУЋИ ИСХОД

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ОБЛАСТ: математика
ВРСТА ЧЛАНКА: оригинални научни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Увод/циљ: Крајем 2019. године, инфекција коронавирусом (COVID-19) идентификована је најпре у кинеској провинцији Хубеи, а затим се проширила по свету узрокујући пандемију. Различит је број заражених овим вирусом у земљама широм света. У тренутку писања овог текста у Италији је забележен највећи број смртних исхода проузрокованих коронавирусом (Google, 2020).

Методе: Примењен је математички модел који описује карактеристике броја случајева у односу на време. Извршено је поређење са добијеним подацима и прогнозиран даљи ток оболевања од инфекције коронавирусом.

Резултати: Овај модел, који представља еволуцију ширења болести, омогућава да се изврше одређена предвиђања ширења коронавируса у будућности.

Закључци: Поуздано се могу предвидети тачне бројке броја умрлих и инфицираних под условом да се на тренутну ситуацију не одразе други спољни утицаји.

Кључне речи: коронавирус, COVID-19, диференцијална једначина, уклапање података.

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Paper accepted for publishing on / Дата окончательного согласования работы / Датум коначног прихватања чланка за објављивање: 08.04.2020.

INTERATOMIC INTERACTION IN DIATOMIC MOLECULES WITH TAKING INTO ACCOUNT THE REPULSION OF IONS IN A POSITIVELY CHARGED CORE

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FIELD: Physical Chemistry
ARTICLE TYPE: Original scientific paper
ARTICLE LANGUAGE: English

Abstract:

Introduction/purpose: Different types of interactions in diatomic molecules of complex atoms are analysed.

Methods: The empirical formulas of Lennard-Jones, Buckingham, Buckingham-Corner, Morse, Danem, Gulbert-Hirschfelder, Klein and their combinations without their clear physical justification are used to take into account the repulsive and attractive forces in the molecule. To improve the situation of the binary interaction inside condensed matter, Gretchikhin and his associates proposed applying the Heitler-London quantum theory, but only at distances greater than equilibrium. At distances less than equilibrium between atoms in the binary interaction, the Lennard-Jones formula was still used. Using various kinds of fitting coefficients, in each case we obtained a match with the experimental data on the dissociation energy. A more general idea of all possible types of interactions was completely absent. In this connection, the need arose to reveal all possible types of interactions inside diatomic molecules and theoretically obtain dissociation energy, activation energy, and standard atomization enthalpy. The application of quantum mechanics methods in the Heitler-London theory allowed to take into account not only the Coulomb deterrence during exchange interaction, but also the Coulomb repulsion of nuclei.

Results: The electric dipoles for neutral atoms and for positively charged ions of the core of diatomic molecules were calculated. This made it possible to calculate the electron-dipole and dipole-dipole interactions. A theory of the repulsion of positively charged nuclei of complex atoms in diatomic molecules has been developed. The interaction potentials for the molecules of carbon, nitrogen, oxygen, aluminum, silicon, and sodium are

calculated. The developed physical model of the formation of diatomic molecules is compared with the empirical potentials of Lennard-Jones and Morse. At the internuclear distance equal to the sum of the energy radii of atoms in the molecule, a potential jump occurs with a transition from the negative to the positive region of binding energies, which determines the activation energy of the formation of diatomic molecules.

Conclusion: From the obtained interaction potentials of atoms in diatomic molecules, the activation energy, ionization energy, standard atomization enthalpy, and electron affinity are determined.

Key words: interaction potential, covalent bond, ionic bond, electric dipole, induced bond, diatomic molecule.

Introduction

The interaction of atoms is a rather complicated process. This mechanism is understood qualitatively under the assumption that there are attractive and repulsive forces between the interacting atoms. However, these forces are extremely entangled and that is why creating a model of their interaction appeared to be a difficult task. Therefore, a simpler way of applying the regression analysis to describe the interaction potential between atoms was used. As a result, Lennard-Jones, Buckingham, Buckingham-Corner, Morse, Dunham, Hulbert-Hirschfelder, and Klein potentials were obtained as well as their combinations (Hirschfelder et al, 1954). The first, quite widespread formula, representing the interaction potential, was proposed by Lennard and Jones in the following form (Gretchikhin, 2018), (Yelyashevich, 1962):

$$V(r) = -\frac{a}{r^6} + \frac{b}{r^{12}}, \tag{1}$$

where *a* and *b* constants are fitting coefficients.

The formula proposed by Dunham turned out to be more universal:

$$V(r) = V_0\left\{\left[b_0\left(1-\frac{r_0}{r}\right)^2\right]\cdot\left[1+\sum_{n=1}^{N} b_n\left(1-\frac{r_0}{r}\right)^n\right]\right\}, \tag{2}$$

where: V_0 is the depth of a potential well; r_0 is the equilibrium value of the radius corresponding to the minimum interaction potential $V(r_0)$; and b_0, b_n and n are the fitting parameters.

For diatomic molecular systems the potential proposed by Morse is usually used (Gretchikhin, 2018):

$$V(r) = D_e\left[1-\exp(-\beta\Delta r)\right]^2. \tag{3}$$

The initial parameters for constructing the Morse potential are the dissociation energy D_e, the distance difference relative to the location of one of the nuclei Δr, and β, which is determined as follows: $\beta = \sqrt{o/2D_e}$. In turn, the force constant O is found from the vibrational spectrum and was obtained for most diatomic molecules.

To exclude any fitting coefficients, the paper (Gretchikhin, 2018) proposed a slightly different approach presented in the following form for the condensed systems:

$$V_{res.}(r) = \begin{cases} -\dfrac{2V_0 r_e^6}{r^6} + \dfrac{V_0 r_e^{12}}{r^{12}}, & at \quad r \le r_e; \\ \sum\limits_{i=1}^{3} N_i \kappa_i^2 \left[\sum\limits_{k=0}^{3} \sum\limits_{l=0}^{3} Z_{a,k}^* Z_{b,l}^* \int\limits_{(a)} \int\limits_{(b)} \rho_{e,a}(\varepsilon_k) \rho_{e,l}(\varepsilon_l) \left(\dfrac{H_{1,1} + H_{1,2}}{1+S} \right) d\varepsilon_k d\varepsilon_l \right] & \text{at} > r_e \end{cases} \quad (4)$$

Here $V_{\text{res.}}(r)$ is the interaction potential of particles depending on the distance between the particles; $V_0 = D_e$ is the energy of interaction of the particles at the equilibrium distance which is equal to the energy of dissociation; r_e is the equilibrium distance between the interacting particles; $N_{k(l)}$ is the number of particles within the *k(l)*-th energy state; κ_i is the visibility coefficient; $Z_{a,k}^*, Z_{b,l}^*$ are effective charges of the interacting particles; $\rho_{e,a}(\varepsilon_k), \rho_{e,b}(\varepsilon_l)$ is the distribution of the electron density ρ_e of the particles around the power centers *A* and *B* of the interacting particles with the energies $\varepsilon_{\text{k and}}\ \varepsilon_{\text{l}}$ in the *k*-th and *l*-th energy states; $H_{1,1}$, $H_{1,2}$ и *S* are the Coulomb, exchange, and overlap integrals, respectively.

This formation of the interaction potential between atoms in a diatomic molecule involves two problems. The first one is that the equilibrium distance is always greater than the value obtained from the analysis of the vibrational spectrum of the resulting molecule, since the repulsion energy of ions in a positively charged core is not taken into account.

The second problem arose in that the overlap integral at the equilibrium distance turned out to be greater than the unity which does not correspond to the physical nature of this integral. The integral should always be less than one.

In this connection, it is vital to set the following goal: to develop a model of the interaction of atomic structures that would allow, by applying the initial data on the ionization potentials experimentally obtained for all

atoms of the periodic table, to fully obtain the interaction potential between the atoms. To achieve this goal, it is essential to solve the following tasks:

- to find out the conditions of applicability of different types of chemical bonds that arise between the interacting atoms;
- to formulate a model of the interaction between the ions of a positively charged core;
- to develop a model of the interaction between different energy states of a positively charged core;
- to make a comparative analysis of the interaction potentials using a number of examples and taking into account the presence of covalent, ionic, induced, electron-dipole, and dipole-dipole bonds, as well as the repulsion energy of atoms and positive core ions in the initial atomic structures.

Let us consider, one after another, these problems.

A Analysis of different types of chemical bonds between interacting atoms

A fairly detailed analysis of different chemical bonds was performed in the paper (Gretchikhin, 2018). The paper shows how the following interactions are formed: covalent, ionic, induced, electron-dipole and dipole-dipole ones. However, the interactions resulting from the presence of a positive core inside the molecule were not considered.

A covalent bond is formed by the exchange of electrons between interacting particles. Heitler and London, using quantum mechanics, developed the theory of this type of interaction and applied it to the analysis of the hydrogen molecule. Figure 1 shows a schematic diagram of the electron exchange. Based on the general ideology considered in the paper (Gretchikhin et al, 1990), the exchange interaction potential in the notation shown in Figure 1 is represented in the following form:

$$U = \frac{1}{4\pi\varepsilon_0}\left(\frac{e^2}{r_e} + \frac{e^2}{r_{1,2}} - \frac{e^2}{r_{a,b}} - \frac{e^2}{r_{b,a}}\right), \tag{5}$$

where ε_0 is the dielectric constant of the vacuum while $r_{1,2}$ is the distance between the electrons.

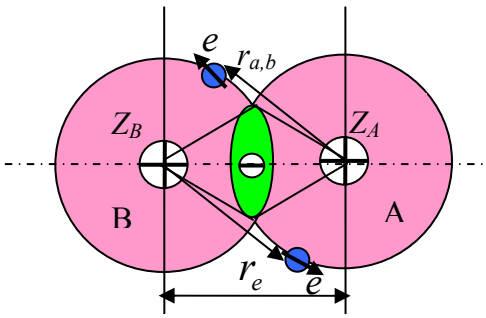

Figure 1 – Schematic diagram of the electron exchange between two identical atoms
Рис. 1 – Схема обмена электронами между двумя одинаковыми атомами
Слика 1 – Шематски приказ размене електрона између два идентична атома

In the case of the interaction of identical atoms, the exchange of electrons occurs in the zone of overlapping wave functions, which is located at a distance of ~$r_e/2$ from both atoms. Taking into account the probability P_a of a valence electron being in the overlap zone, an electron that passes from the atom A to the atom B and is held by the electric field of the atom A has the following energy:

$$U_a^+ = P_a e^2 / 4\pi\varepsilon_0 (r_e/2).$$

A similar electron holding potential arises for the atom B:

$$U_b^+ = P_b e^2 / 4\pi\varepsilon_0 (r_e/2).$$

The resulting potential that holds the exchange of electrons for identical atoms at relatively small distances r_e is equal to $P_a \cong P_b \approx 0.5$ and therefore amounts to: $U^+ = U_a^+ + U_b^+ \cong e^2 / 4\pi\varepsilon_0 r_e$.

Based on the form of the resulting confining potential, it was thought that the potential takes into account the repulsion of the nuclei of interacting atoms. Therefore, it was believed that the Heitler-London theory already took into account the interaction of the nuclei. This mistake costs us dearly. The first term in the interaction potential (5) does not take into account the repulsion of the nuclei, but confines the electrons during the transition from one atom to another. The repulsion of

the nuclei should be taken into account separately and in a completely different way.

Potential (5) was written for a hydrogen molecule in which identical atoms interact. For diatomic molecules composed of different atoms, potential (5) has a different form and, therefore, the Heitler-London theory in this case needs to be further developed.

The direct exchange of valence electrons between the interacting particles creates the bond exchange energy in dynamics. In the process, each electron of the atom A independently interacts with all electrons of the atom B. The resulting energy of the bond was obtained in the paper (Gretchikhin, 2004)

$$E_{ков} = \sum_{k}^{N_A} \sum_{l}^{N_B} \left(\frac{H_{1,1} + H_{1,2}}{1+S} \right)_{k,l} . \quad (6)$$

Here, N_A is the number of energy levels of the particle A and N_B is the number of energy levels of the particle involved in the interaction, while the other values are as follows:

$H_{1,1} = \iint \psi_a^*(r_{a,1}) \psi_b^*(r_{b,2}) \widehat{H}' \psi_a(r_{a,1}) \psi_b(r_{b,2}) d\xi_1 d\xi_2$ is the Coulomb integral,

$H_{1,2} = \int \int \psi_a^*(r_{a,2}) \psi_b^*(r_{b,1}) \widehat{H}' \psi_a(r_{a,2}) \psi_b(r_{b,1}) d\xi_1 d\xi_2$ is the exchange integral,

$S = \iint \psi_a^*(r_{a,1}) \psi_b^*(r_{b,2}) \psi_a(r_{a,2}) \psi_b(r_{b,1}) d\xi_1 d\xi_2$ is the overlap integral.

Accordingly, ψ_a and ψ_b are the wave functions of the atom A and the atom B in the ground state.

The probability of a valence electron being in the contact zone of the first and second interacting particles is determined as follows:

for the atom A $P_{a,k} = 1 - \frac{2\alpha_k}{4\pi}$, (7)

and for the atom B $P_{b,l} = 1 - \frac{2\beta_l}{4\pi}$. (8)

Here the angles are:

$$\alpha_k = \arctan\left(\frac{\sqrt{r_{a,k}^2 - r_{1,k}^2}}{r_{1,k}} \right) \text{ и } \beta_l = \arctan\left(\frac{\sqrt{r_{b,l}^2 - r_{2,l}^2}}{r_{2,l}} \right) \quad (9)$$

In addition, it is necessary to take into account the mutual shading of each internal energy state by external electrons. This process is taken

into account by the share in the exchange interaction of each electronic state, which should be determined as follows:

$$\delta = \frac{Z_k^* = \sum_{i=1}^{i=k-1} Z_i^*}{Z_1^*} \ . \qquad (10)$$

In the process of electron exchange, a situation arises when both electrons are near one of the interacting atoms. In this situation, an ionic bond occurs, i.e., the interaction of a negative ion with a singly ionized atom is realized.

Ionic bond. The theory of ionic bonding which makes it possible to determine quantitatively the magnitude of ionic bonding based on the residence time of valence electrons near interacting particles has been developed in the papers (Gretchikhin, 2004) and (Gretchikhin, 2008) not only for neutral particles, but also for each multiplicity of ionization.

The probability of a valence electron being in the contact zone near the first and second interacting particles is determined as follows:

for the atom A:

$$P_a = \frac{2\arctan\left(\frac{\sqrt{r_a^2 - r_1^2}}{r_1}\right)}{4\pi}, \qquad (11)$$

and for the atom B

$$P_b = \frac{2\arctan\left(\frac{\sqrt{r_b^2 - r_2^2}}{r_2}\right)}{4\pi}. \qquad (12)$$

Given this, the probability that the valence electron of the atom A will go over to the atom B will amount to $P_a S$ while the probability that the valence electron of the second atom is not within the contact zone amounts to (1–P_b). The resulting probability of this event is equal to $P_a S$ (1- P_b). A similar situation occurs when the valence electron of the second atom is within the contact zone and passes to the first atom while the electron of the first atom is not within the contact zone; the probability is equal to $(1-P_b)$. In this case, the probability of the event is equal to (1- P_a)·$P_b S$. Both in the first and second cases, an ionic bond arises. The

total probability of the ionic bond formation is the sum of these probabilities

$$\Theta = P_a(1-P_b)S + P_b(1-P_a)S\,. \tag{13}$$

Therefore, in the binary interaction of two identical atoms, the ionic bond energy, in general, is determined by the following formula:

$$E_{ion} = \Theta\frac{e^2}{4\pi\varepsilon_0 r_e}. \tag{14}$$

Table 1 shows, as an example, the shares of the ionic bond arising from the binary interaction of two atoms with the formation of a diatomic molecule.

Table 1 – Shares of an ionic bond and electric dipole moments for diatomic molecules
Таблица 1 – Доля ионной связи и дипольные электрические моменты для двухатомных молекул
Табела 1 – Удео јонске везе и електричних диполних момената за двоатомске молекуле

Parameter	C_2	N_2	O_2	Si_2	Al_2	Na_2
Θ (%)	16.70	10.61	33.6	13.78	43.15	30.26
$p_{э,1(2)}\cdot10^{30}$ C·m	5.196	3.429	2.228	5.705	4.916	-
$p_{э,3(4)}\cdot10^{30}$ C·m	3.160	2.228	3.158	2.626	-	-
$p_{э,5(6)}\cdot10^{30}$ C·m	-	1.094	2.165	-	-	-
$p_{э,7(8)}\cdot10^{30}$ C·m	-	-	1.184	-	-	-
EA (kJ/mol)	-	16.42	57.6	89.08	405.4	321.1

It turns out that, even for identical atoms, the fraction of the ionic bond energy is noticeable and not equal to zero.

In the process of electron exchange, an uncompensated charge arises in the region of overlapping wave functions. This charge, interacting with the positive core of the molecule, additionally increases the binding energy of the atoms in the diatomic molecule, i.e., the binding energy arises due to the induced electric charge. (Gombás, 1950)

Induced bond. An induced bond is determined by a potential barrier occurring between the interacting particles when exchanging valence electrons.

The electron of the atom A and the electron of the atom B create a negative potential barrier independently of each other. The electron when traveling from one particle to the other is partially reflected and retarded at the boundary interacting particles. The probability of such an event is equal to the product $P_a(1-P_b)(1-S)$. At the same time, the second electron is also reflected from the boundary with the probability of $P_b(1-P_a)(1-S)$. Therefore, the probability of the formation of a negative potential barrier is equal to the sum of these probabilities. Thus, the value of the negative charge in the contact zone will amount to

$$\Delta Q = [P_a(1-P_b) + (1-P_a)P_b](1-S)e. \quad (15)$$

As a result, additional binding energy arises:

$$E_{ind.} = \frac{2\Delta Qe}{4\pi\varepsilon_0 r_e}\left((1-P_a)Z_a^* + (1-P_b)Z_b^* + P_aP_a^+Z_a^{*+} + P_bP_b^+Z_b^{*+} + P_aP_a^{++}Z_a^{*++} + ...\right), \quad (16)$$

where Z_a^*, Z_b^*, Z_a^{*+}, Z_b^{*+} и Z_a^{*++}, Z_b^{*++} are accordingly, the effective charges of atoms and ions of the first and second degrees of ionization of the interacting particles, respectively.

Most atoms and ions of complex atomic structures feature a built-in and induced dipole electric moment. Therefore, the electron–dipole and dipole–dipole interactions should be taken into account.

Electron-dipole interaction. In the process of the interaction of the atomic particles the built-in dipole electric moments are arranged so that they ensure maximum overlap of the wave functions of the interacting particles with their orbits. In the process of the exchange interaction between the interacting particles, a negative charge *ΔQ* arises; the value of the charge is determined above by formula (15). This negative charge interacts with the dipole moments of the first and second interacting particles, weakening the binary bond between the particles. The energy of this bond is as follows:

$$E_{e-d} = \frac{8\Delta Q}{4\pi\varepsilon_0 r_e^2}\left((1-P_a)p_{э,1} + (1-P_b)p_{э,2} + P_aP_a^+p_{э,3} + P_bP_b^+p_{э,4} + P_aP_a^{++}p_{э,5} + ...\right), \quad (17)$$

where $p_{э,1}$, $p_{э,2}$, $p_{э,3}$, $p_{э,4}$, $p_{э,5}$ и $p_{э,6}$ are the built-in dipole electric moments of ions of the first, second and third ionization of interacting particles. Odd values refer to atom A while even values refer to atom B.

The presence of built-in electric moments in the interacting particles leads to the appearance of a dipole-dipole bond.

Dipole-dipole bond. A dipole-dipole bond in the binary interaction of complex particles is determined according to the following formula:

$$E_{dip.-dip.} = 2[(1-P_a)(1-P_b)\frac{p_{э,1}p_{э,2}}{4\pi\varepsilon_0 r_e^3} + P_a^+ P_b^+ \frac{p_{э,3}^+ p_{э,4}^+}{4\pi\varepsilon_0 r_e^3} + P_a^{++} P_b^{++} \frac{p_{э,5}^{++} p_{э,6}^{++}}{4\pi\varepsilon_0 r_e^3} + ...] \quad (18)$$

In the formation of an ionic bond, a cross interaction of dipole electric moments is formed. Then, taking into account (18)

$$E_{dip.-dip.}^+ = 2\Theta\frac{p_{э,1}p_{э,4}}{4\pi\varepsilon_0 r_e^3} + 2\Theta\frac{p_{э,2}p_{э,3}}{4\pi\varepsilon_0 r_e^3}. \quad (19)$$

In the process of the binary interaction, a particle with shared electron shell is formed due to sharing of outer electrons. The bond breaking energy for a newly formed particle is determined by all types of bonds combined. In this case, it is essential to know the effective radiuses of the interacting particles and the equilibrium distances between them. The interaction potential, even considered with taking into account all the above interactions at close distances, does not make it possible to obtain a significant decrease in the binding energies (D_e). In this regard, let us consider the process of the interaction of the ions of a positive core, which quite effectively reduces the binding energy of the interacting atoms in a diatomic molecule.

Coulomb repulsion of the particles of a positively charged ionic core

In complex molecular systems, the valence electrons of individual atoms are shared, and a condensed medium appears in the form of a two-component mixture consisting of a generalized electron cloud and an ionic core of single ions. The electrons of neutral atoms are bound to a positively charged core with their effective charge. These effective charges interact with each other when they open due to the overlap of their wave functions. Based on the divergence theorem, the flux of the electric displacement vector is equal to the charge inside a closed surface. In the presence of a second positive charge, the flux of the electric displacement vector is deformed and a third one - negative charge - arises on the surface that separates two positive charges. The electric displacement vector is directed perpendicular to the surface.

Then the flux of the electric displacement vector through this surface amounts to:

$$N_{a,(b)} = \int_0^{\pi r_0^2} \frac{z^* e \cos(\alpha)}{4\pi r_{a,(b)}^2} dS \,, \tag{20}$$

where z^* is the effective charge of a positive ion, $dS = 2\pi r dr$ and $r_0 = \sqrt{r_{a,(b)}^2 - (r_e / 2)^2}$, $\alpha = \arctan\left(\frac{2r}{r_e}\right)$.

Accordingly, the share of the charge involved in the mutual repulsion is:

$$\xi_{a,(b)} = N_{a,(b)} / Z^* e \,. \tag{21}$$

In addition, the mutual screening of the effective charge should be taken into account since each successive ion charge is screened by the previous energy levels of the atomic system, i.e.:

$$Z^*_{a,k} = Z_{a,k} - Z_{a,k-1} - Z_{a,k-2} - \ldots$$

Then the repulsion energy amounts to:

$$U_a = P_a P_b \frac{\xi_a \xi_b Z_a^* Z_b^*) e^2}{4\pi\varepsilon_0 r_e} + P_a^+ P_b^+ \frac{\xi_a^+ \xi_b^+ Z_a^{*+} Z_b^{*+} e^2}{4\pi\varepsilon_0 r_e} + P_a^{++} P_b^{++} \frac{\xi_a^{++} \xi_b^{++} Z_a^{*++} Z_b^{*++} e^2}{4\pi\varepsilon_0 r_e} + \ldots \tag{22}$$

When negative ions are formed, a repulsion arises between the induced charge and the external electron of the negative ion, i.e.

$$E = \frac{\Delta Q e}{4\pi\varepsilon_0}\left(\frac{1}{r_1} + \frac{1}{r_2}\right). \tag{23}$$

Therefore, positive ions inhibit the exchange of electrons within the ionic core, and this is precisely what is taken into account in the Heitler-London theory. In addition, they mutually repel according to Coulomb's law. Each valence electron can be, with a certain probability, in the region of overlapping wave functions of neutral atoms and positive ions inside the core. In this case, based on the principle of superposition of electric fields, it is necessary to take into account the interaction of each ion with all other ions inside the positive core of the molecule. Specifically, for the binary interaction, this situation is shown in Figure 2.

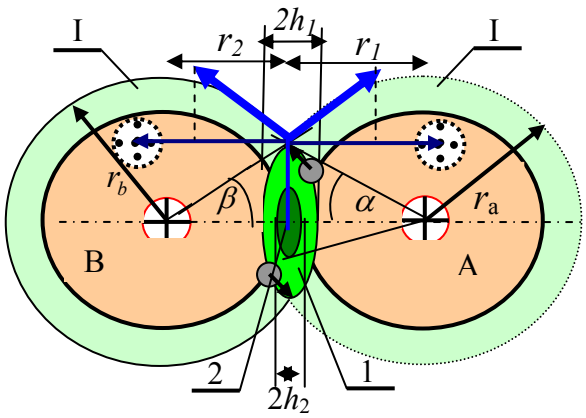

Figure 2 – Coulomb interaction of nuclei in the binary interaction of atoms
Рис. 2 – Кулоновское взаимодействие ядер в бинарном взаимодействии атомов
Слика 2 – Кулонова интеракција нуклеуса у бинарној интеракцији атома

The overlap zone for the valence electron of the neutral atom A is formed by the angle α while the one for the atom B is formed by the angle β; these angles are determined by formulas (11) and (12). The overlap zone of the wave functions of the single ionization is indicated by the number 1, and the overlap zone of the wave functions of the double ionization is indicated by the number 2.

The interaction energy of the positive ions of the core amounts to:

$$U_{res.}^{+} = \sum_i P_i^{+} \frac{Z_i^2 e^2}{4\pi\varepsilon_0 r_e}. \qquad (24)$$

Thus, the total energy of the interaction of atoms in a diatomic molecule is realized as the following sum:

$$E_{res.} = E_{\text{cov.}} + E_{ion} + E_{ind.} + E_{el.-dip.} + E_{dip.-dip.} + U_{res.}^{+}. \qquad (25)$$

Thus, the interaction potential of atoms in a diatomic molecule is determined as such a complex aggregate. Below the interaction potentials for some diatomic molecules were calculated in comparison with the Lennard-Jones and Morse potentials as an example.

Interaction potentials of the diatomic molecules and their analysis

The calculations of the interaction potentials have been performed under the following restrictions:

1. At the internuclear distance of $r_e = r_a + r_b$ and farther, only the exchange interaction occurs, the repulsion of the ions of the positive core is sharply weakened while the interaction of the built-in electric dipoles occurs only for neutral atoms.

2. For distances at which the overlap integral *S* is greater than unity, the ionic, induced, and electron-dipole bonds are equal to zero.

3. At all internuclear distances, the bond exchange energy is always greater than the dipole-dipole bond.

4. The overlap integral is always less than one.

Specific calculations of the interaction potentials have been performed for diatomic molecules of carbon, nitrogen, oxygen, silicon, aluminum and sodium, for which the dissociation energy varies from a maximum value of 9.76 eV to a minimum value of 0.76 eV and they are shown in Figures 3 to 8. This is enough to fully understand the dynamics of the formation of interaction potentials during the formation of diatomic molecules.

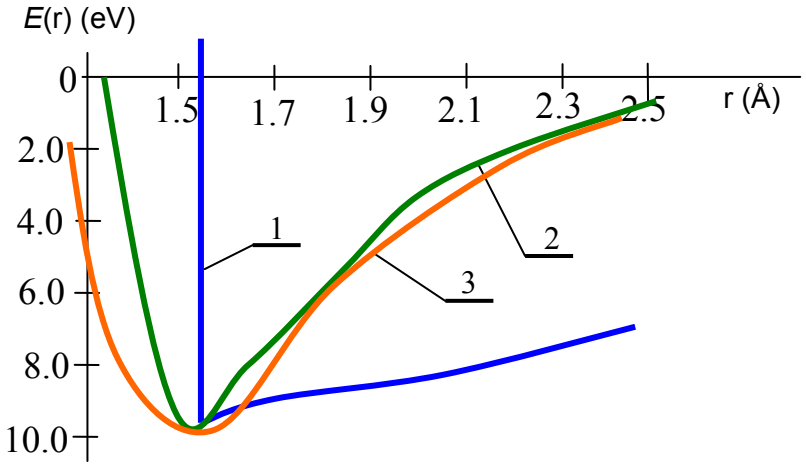

Figure 3 – Interaction potential in the diatomic nitrogen molecule obtained using: 1 - formula (25); 2 - Lennard-Jones formula; 3 - Morse formula
Рис. 3 – Потенциал в двухатомной молекуле азота полученный по формуле: 1 - (25); 2 - Леннарда-Джонса; 3 - Морзе
Слика 3 – Потенцијал интеракције у двоатомском молекулу водоника добијен помоћу: 1 - формуле 25, 2 - Ленард-Џонсове формуле, 3 - Морзеове формуле

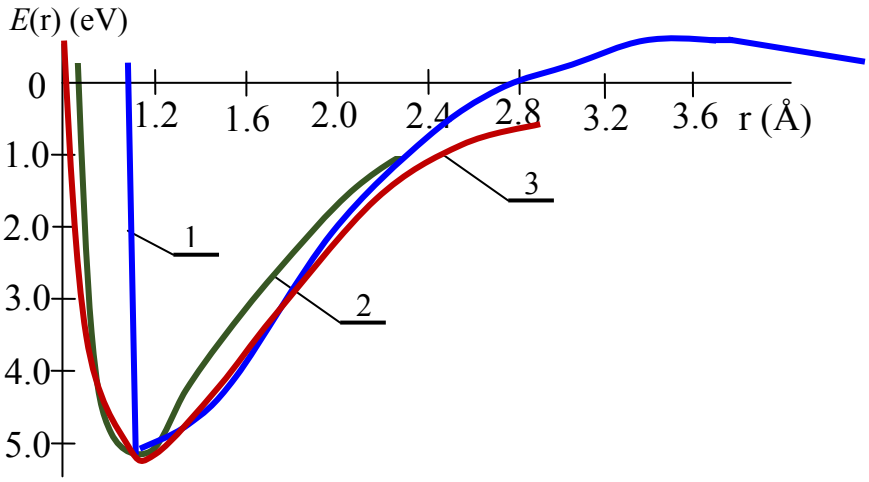

Figure 4 – Interaction potential in the diatomic oxygen molecule calculated using: 1 - formula (25); 2 - Lennard-Jones formula; 3 - Morse formula

Рис. 4 – Потенциал в двухатомной молекуле кислорода полученный по формуле: 1 - (25); 2 - Леннарда-Джонса; 3 - Морзе

Слика 4 – Потенцијал интеракције у двоатомском молекулу кисеоника добијен помоћу: 1 - формуле 25, 2 - Ленард-Џонсове формуле, 3 - Морзеове формуле

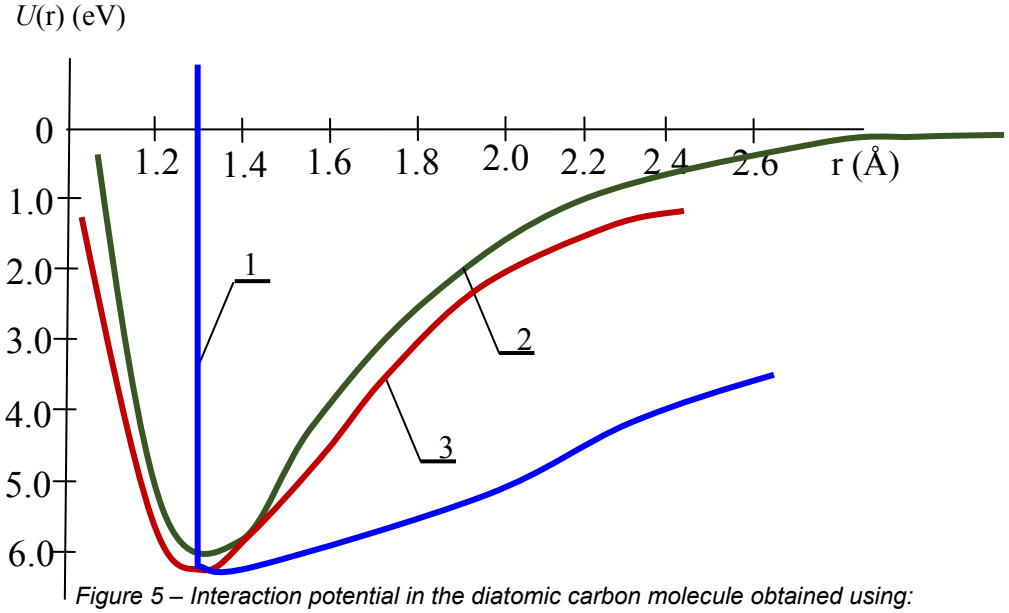

Figure 5 – Interaction potential in the diatomic carbon molecule obtained using: 1 - formula (25); 2 - Lennard-Jones formula; 3 - Morse formula

Рис. 5 – Потенциал взаимодействия в двухатомной углерода полученный по формуле: 1 - (25); 2 - Леннарда-Джонса; 3 - Морзе

Слика 5 – Потенцијал интеракције у двоатомском молекулу угљеника добијен помоћу: 1 - формуле 25, 2 - Ленард-Џонсове формуле, 3 - Морзеове формуле

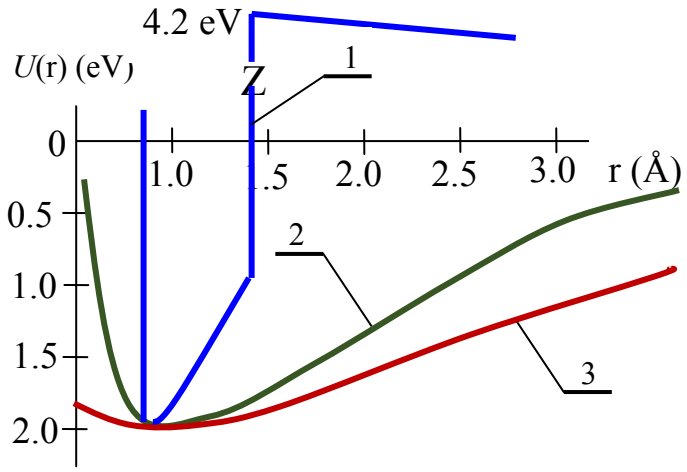

Figure 6 – Interaction potential in the diatomic aluminum molecule obtained using: 1 - formula (25); 2 - Lennard-Jones formula; 3 - Morse formula
Рис. 6 – Потенциал взаимодействия в двухатомной молекуле алюминия полученный по формуле: 1 - (25); 2 - Леннарда-Джонса; 3 - Морза
Слика 6 – Потенцијал интеракције у двоатомском молекулу алуминијума добијен помоћу: 1 - формуле 25, 2- Ленард-Џонсове формуле, 3 - Морзеове формуле

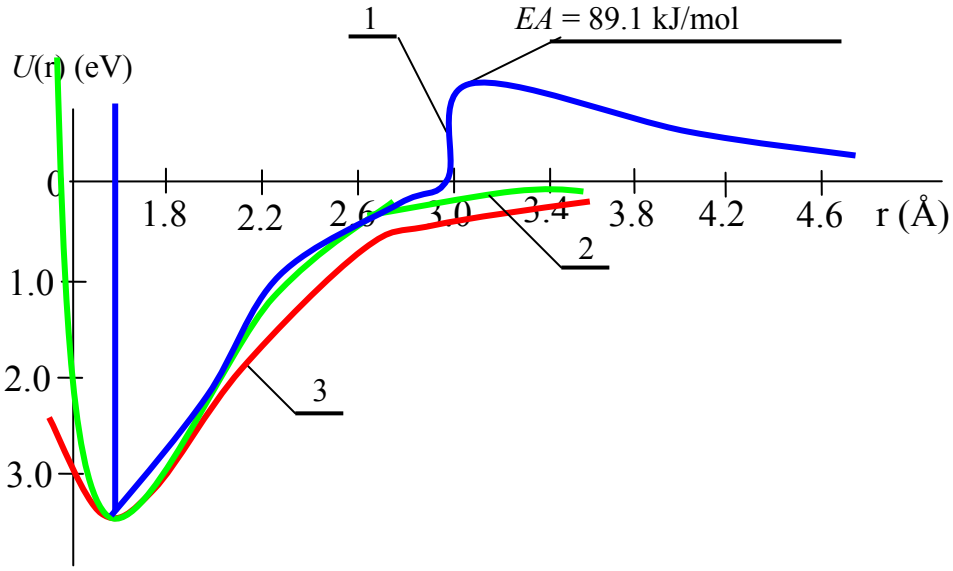

Figure 7 – Iinteraction potential in the diatomic silicon molecule obtained using: 1 - formula (25); 2 - Lennard-Jones formula; 3 - Morse formula
Рис. 7 – Потенциал взаимодействия в двухатомной молекуле кремния полученный по формуле: 1 - (25); 2 - Леннарда-Джонса; 3 - Морза
Слика 7 – Потенцијал интеракције у двоатомском молекулу силицијума добијен помоћу: 1 - формуле 25, 2 - Ленард-Џонсове формуле, 3 - Морзеове формуле

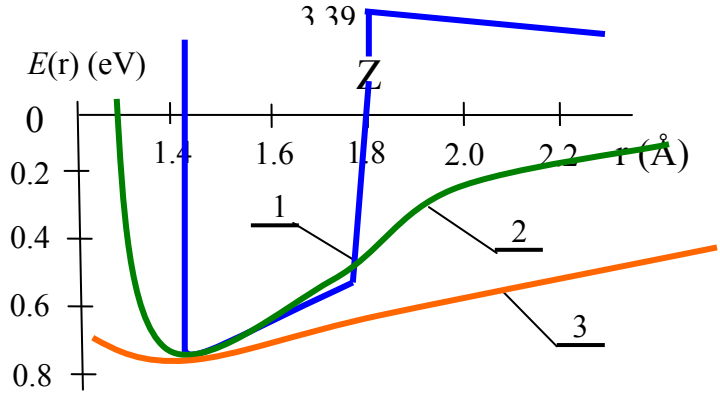

Figure 8 – Interaction potential in the diatomic sodium molecule obtained using: 1 - formula (25); 2 - Lennard-Jones formula; 3 - Morse formula
Рис. 8 – Потенциал взаимодействия в двухатомной молекуле натрия полученный по формуле: 1 - (25); 2 - Леннарда-Джонса; 3 - Морза
Слика 8 – Потенцијал интеракције у двоатомском молекулу натријума добијен помоћу: 1 - формуле 25, 2 - Ленард-Џонсове формуле, 3 - Морзеове формуле

Table 2 – Radii of atoms and the values of different binding energies in the energy of dissociation
Таблица 2 – Радиусы атомов и значения разных энергий связи в энергии диссоциации
Табела 2 – Пречници атома и вредности различитих везивних енергија у енергији дисоцијације

Mo-lec.	The calculated atomic radii and internuclear distances as well as the values of different interaction energies in eV								
	r_a (Å)	r_e (Å)	$E_{cov.}$	E_{ion}	$E_{ind.}$	$E_{el.-dip.}$	$E_{dip-dip.}$	$E_{разл.}$	D_e
N_2	1.109 0.746	1.3974/1.098 1.0696	-7.402 -2.464	-1.533 -1.873	-1.613 -0.778	0.102 0.070	0.111 0.096	0.575 0.119	9.760/9.76 4.829
C_2	1.201	1.2896/1.242	-4.450	-1.010	-3.007	0.360	0.510	1.476	6.200/6.2
O_2	0.8675 0.74 0.672	1.189 /1.207 1.07 0.992	-3.304 -2.404 -1.983	-1.720 -1.804 -1.897	-1.023 -0.791 -0.714	-0.104 -0.086 -0.052	0.545 0.408 0.169	0.487 0.235 0.152	5.120/5.12 4.370 4.053
Si_2	1.502 1.56	1.985/2.246 2.035	-1.561 -1.330	-0.255 -0.190	-2.132 -2.346	0.002 0.003	-0.038 -0.037	0.581 0.654	3.400/3.4 3.247
Al_2	0.718	1.096/2.56	-0.736	-0.863	-815	0.110	0.052	0.253	2.00/2.0
Na_2	0.8867	1.4565/3.077	-.404	-.230	-0.290	0	0	0.174	- 0.750

An important property of the interaction potentials is that for given ionization potentials and dipole electric moments, the experimental value of the dissociation energy is realized with a strict ratio of the effective energy radius of a neutral atom and the distance between nuclei in a diatomic molecule. In this case, the effective energy radius should not coincide with the radius of the atom, since the radius of the atom corresponds to the maximum of the electron density distribution function while the effective energy radius of the interaction is determined by the mutual compensation of the positive and negative binding energies at an equilibrium distance. Predominantly, the energy radius turned out to be greater than the radius of the atom obtained by calculations using the Hartree-Fock wave functions (Brattsev, 1966). Only for silicon, the energy radius turned out to be ~ 10% less while for sodium both radii completely coincided.

For most diatomic molecules, the calculated equilibrium distance between atoms turned out to be greater than the equilibrium distance obtained from the vibrational spectra. Only for silicon and sodium did these values turn out to be less than the equilibrium distance obtained from the vibrational spectra.

The specific calculated values of the energy radii and the equilibrium distances of the interacting atoms as well as the values of different binding energies in diatomic molecules are summarized in Table 2.

The internuclear distance for all molecules does not coincide with the values obtained from the vibrational spectra. These values in Table 2 are shown after slash.

The induced binding energy, which was substantiated in the work (Gretchikhin et al, 2015, pp.29-41), and the repulsion energy introduced in this article, turned out to be determining. Without taking them into account, the interaction potential in diatomic molecules cannot be determined.

Average effective radius of molecules and ionization energy of binary formations

In diatomic molecules, the valence electrons travel each around their atoms. When both electrons enter the overlap zone, an exchange of electrons occurs. The bond of one of the external electrons with the core of the molecule determines the ionization potential while the second electron screens the core of the molecule. Obviously, such screening should be different depending on the size and structure of the electron shells of the interacting atoms. Each of the external valence electrons in

the diatomic molecule interacts with one of the nearest atomic nuclei in two positions shown in Figure 2. Thus, the effective radius of the molecule can be represented as follows:

$$r_m = [(r_a + r_1) + (r_b + r_2) + \sqrt{r_a^2 - r_1^2} + \sqrt{r_b^2 - r_2^2}]/4 \qquad (26)$$

The probability of electrons being in the overlap zone is determined by formulas (11) and (12) while taking into account the fact that they do not exchange their states. Accordingly, for each electron, the resulting probability of staying in the overlap zone is $P_a(1-S)$ и $P_b(1-S)$.

Outside the overlap zone, the ionization energy of the atom A is equal to the single ionization of the atom A. In the overlap zone, if the electron does not transfer from the atom A to the atom B, the ionization energy still corresponds to the atom A. The electron in the atom A is either in the overlap zone or outside this zone. The resulting probability of this event for the atom A, taking into account the fact that the valence electron is located at a distance of r_1 from the nucleus of the atom, is equal to $[(1-P_a) + P_a(1-S)r_a/r_1]$ while the probability for the atom B is equal to $[(1-P_b) + P_b(1-S)r_b/r_2]$. Then, for the electron near the atom A, the ionization energy of the molecule will amount to:

$$IP_a = [(1-P_a) - P_a(1-S)r_a/r_1]\theta_a + P_a(1-)\theta_b - P_a\frac{dqe}{4\pi\varepsilon_0 r_1)}, \qquad (27)$$

while that for the electron near the atom B will amount to:

$$IP_b = [(1-P_b) + P_b(1-S)r_b/r_2]\theta_b + (1-P_b)P_a\theta_a - P_b\frac{dqe}{4\pi\varepsilon_0 r_2)}. \qquad (28)$$

Here θ_a and θ_b are the ionization energies of the atom A and the atom B, respectively.

The results of the calculations of the ionization energies and the radii of neutral molecules and their ions of the first as well as the second multiplicity of ionization of some diatomic molecules are presented in Table. 3 as an example. The reference data for the first multiplicity of ionization of some diatomic molecules is shown in Table 3 after slash.

Agreement with the data for diatomic molecules, given in the handbook (Radzig & Smirnov, 1985), for the energies of single ionization, is quite satisfactory. A number of molecules feature a relatively large dipole electric moment. This property of molecules is still not clear. When the molecules in which the initial atoms have a built-in dipole electric moment are considered, this property of molecules can be understood.

However, even in the case of simple diatomic molecules, such as BH and LiH, in which the initial atoms do not have a built-in dipole electric moment, their own dipole electric moments are quite substantial. This property of molecules needs further justification.

Table 3 – Ionization energy of diatomic molecules of the single and double ionization multiplicity

Таблица 3 – Энергия ионизации двухатомных молекул первой и второй кратности ионизации

Табела 3 – Јонизациона енергија двоатомских молекула једноструке и двоструке мултипликативности јонизације

Parameters	Molecules					
	C_2	N_2	O_2	Al_2	Si_2	Na2
$r_{m,1}$ (Å)	1.410	1.550	1.067	2.129	1.811	1.060
Z_1^*	1.173	1.618	0.909	0.964	0.954	0.361
Θ_1 (eV)	11.87/ 11.9	15.05/ 15.58	12.515/ 12.077	6.527 -	7.596/ 7.4	4.916/ 4.9
$r_{m,2}$ (Å)	0.953	0.965	0.756	1.488	1.277	0.908
Z_2^*	2.173	2.618	1.909	1.964	1.954	1.361
Θ_2 (eV)	32.87	39.11	36.40	19.026	22.057	21.6

In order to exclude the influence of intrinsic built-in dipole electric moments of the initial atoms, let us consider, as an example, the aforementioned simple diatomic molecules BH LiH. For these molecules, the dipole electric moments are respectively 4.33·10-30 C·m and 19.6·10-30 C·m (Radzig & Smirnov, 1985). The first value was obtained with an error exceeding 10% while the second one - with an error not exceeding 1%, i.e., quite accurately.

The calculation of the dissociation energies of these molecules is presented in Table 4.

Table 4 – Values of the binding energies of diatomic molecules from different atoms without built-in dipole electric moments

Таблица 4 – Величина энергий связи двухатомных молекул из разных атомов без встроенных дипольных электрических моментов

Табела 4 – Вредности везивних енергија двоатомских молекула састављених од различитих атома без уграђених електричних диполних момената

Mo-lec.	r_a (Å)	Values of different binding energies (eV)						r_e (Å)	$p_{e,m}$ $\cdot 10^{-30}$
		$E_{cov.}$	E_{ion}	$E_{exch.}$	$E_{res.}(D_0)$	*IP* (eV)	r_m (Å)		
B+H	1.16	-1.854	-1.306	-0.241	3.39	11.06	1.010	1.290	11.64/ 4.43
Li+H	1.68	-0.548	-0.835	-1.047	2.429	8.81/ 7.78	1.238	1.688	18.39 19.6
O+H	0.67	-3.529	-0.702	-0.123	4.40	12.91	0.942	1.510	

The dissociation energy and the internuclear distance for the HV molecule are obtained from the equality of the theoretical value of the dissociation energy obtained experimentally with an error not exceeding 10%, which is quite an acceptable value. Therefore, the obtained value of the dipole electric moment by theoretical calculation presents quite a realistic value. The probability of the presence of both valence electrons near the atom of boron and hydrogen is 0.483 and 0.104, respectively.

For the LiH molecule, the situation is rather complicated since the radius of the lithium atom needs to be clarified. If the radius of the lithium atom calculated using the modified Slater wave functions and given in the handbook (Radzig & Smirnov, 1985) is used, then the minimum potential energy of the interaction between lithium and hydrogen atoms is realized at a distance between atoms of $r_e = 2.5$ Å while the interaction energy amounts only to $D_0 = 1.422$ eV. To obtain, by calculations, an experimental value equal to 2.429 eV, it is necessary to assume that $r_e = 1.688$ Å and the radius of lithium atom $r_a = 1.68$ Å but not $r_a = 2.049$ Å (Radzig & Smirnov, 1985), (Slater, 1937). The probability of the presence of both valence electrons near the atoms of lithium and hydrogen is 0.640 and 0.040. Therefore, both for the HV molecule and for the LiH molecule, the boron and lithium atoms with respect to the hydrogen atom are more negative, which determines such a large value of the dipole electric moment of these molecules. For other molecules the situation is similar.

Thus, the interaction of atoms in a diatomic molecule is a rather complicated process, in which the exchange interaction of electrons of the single ionization of the interacting atoms should be taken into account, as well as the presence of built-in electric moments of the atoms that are directed inside the molecule relative to each other as well as the probability of stay of valence electrons relative to the interacting atoms. It should be specially noted that the positively charged nuclei of the interacting atoms impede the exchange of valence electrons and, in turn, repel each other according to Coulomb's law.

Conclusions

As a result of the studies of different types of chemical bonds between atoms, it was found:

1. The following types of interactions have been clarified: exchange, ionic, induced, electron-dipole, dipole-dipole and nuclear repulsion energies, and the probability of their occurrence has been determined.

2. The covalent bond is not decisive and is due only to the exchange of valence electrons of neutral atoms.

3. It is shown that the probability of valence electrons staying in the overlapping region of wave functions can be determined not only by the residence time of valence electrons near interacting atoms but also by the ratio of the area of the overlapping wave functions to the entire area of the sphere on which the electron travels.

4. A theory of the interaction of atomic nuclei in a diatomic molecule of identical atoms has been developed.

5. The interaction potentials for a number of diatomic molecules have been calculated in comparison with the Lennard-Jones and Morse potentials and the failure of empirical interaction potentials has been shown.

6. At the double energy radius of the molecules, a potential jump occurs with a transition from the negative to the positive region of binding energies and determines the activation energy of the formation of diatomic molecules.

7. The obtained atomic radii and the internuclear distances of diatomic molecules are effective values at which the experimental values of the binding energies are realized.

The development of various theories of chemical bonds, taking into account their probabilities of occurrence, is at the initial stage of their formation.

It seems possible, based on the obtained interaction potentials of atoms in diatomic molecules, to determine the activation energy, ionization energy, standard atomization enthalpy, and electron affinity for diatomic molecules. A lot of scientific work is ahead in this direction.

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МЕЖАТОМНОЕ ВЗАИМОДЕЙСТВИЕ В ДВУХАТОМНЫХ МОЛЕКУЛАХ С УЧЕТОМ РАСТАЛКИВАНИЯ ИОНОВ В ПОЛОЖИТЕЛЬНОМ ОСТОВЕ

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Резюме:

Введение/цель: Проведен анализ разных типов взаимодействий в двухатомных молекулах из сложных атомов.

Методы: Для учета сил отталкивания и притяжения в молекуле используются эмпирические формулы Леннарда-Джонса, Бакингема, Бакингема-Корнера, Морзе, Данема, Гульберта-Гиршфельдера, Клейна и их комбинации без четкого физического обоснования. Улучшить ситуацию бинарного взаимодействия внутри конденсированных сред Гречихин и сотрудники предложили применить квантовую теорию Гайтлера-Лондона, но только на расстояниях больше равновесного. При расстояниях менее равновесного между атомами в бинарном взаимодействии по-прежнему использовалась формула Леннарда – Джонса. Применяя разного рода подгоночные коэффициенты, в каждом конкретном случае получали совпадение с экспериментальными данными по энергии диссоциации. Более общее представление о всех возможных типах взаимодействий полностью отсутствовало. В этой связи возникла необходимость выявить все возможные типы взаимодействий внутри двухатомных молекулах и теоретически получить энергию диссоциации, энергию активации, стандартную энтальпию атомизации. Применение методов квантовой механики позволило в теории Гайтлера-Лондона учесть не только кулоновское сдерживание при обменном взаимодействии, но и кулоновское отталкивание ядер.

Результаты: Проведен расчет электрических диполей у нейтральных атомов и у положительно заряженных ионов остова двухатомных молекул. Это позволило произвести расчет электрон-дипольного и диполь-дипольного взаимодействия. Разработана теория отталкивания положительно заряженных ядер сложных атомов в двухатомных молекулах. Выполнен расчет потенциалов взаимодействия для молекул углерода, азота, кислорода, алюминия, кремния и натрия. Проведено сравнение разработанной физической модели формирования двухатомных молекул с эмпирическими потенциалами Леннарда-Джонса и Морзе. На межъядерном расстоянии, равном сумме энергетических радиусов атомов в молекуле происходит скачок потенциала с переходом из отрицательной в положительную область энергий связи, что определяет энергию активации образования двухатомных молекул.

Выводы: Из полученных потенциалов взаимодействия атомов в двухатомных молекулах определены энергия активации,

энергия ионизации, стандартная энтальпия атомизации и сродство к электрону.

Ключевые слова: потенциал взаимодействия, ковалентная связь, ионная связь, электрический диполь, наведенная связь, двухатомная молекула.

ИНТЕРАКЦИЈА ИЗМЕЂУ АТОМА У ДВОАТОМСКИМ МОЛЕКУЛИМА ПРИ ОДБИЈАЊУ ЈОНА У ПОЗИТИВНО НАБИЈЕНОМ ЈЕЗГРУ

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Сажетак:

Увод/циљ: Анализирају се различити облици интеракција у двоатомским молекулима сложених атома.

Методе: Користе се емпиријске формуле Ленард-Џонса, Бакингема, Бакингем-Корнера, Морзеа, Данема, Гилберт-Хиршфелдера, Клајна, као и њихове комбинације без јасне реалне оправданости, при анализи одбојних и привлачних сила у молекулу. За побољшање ситуације бинарне интеракције унутар згуснуте материје, Гречихин и његови сарадници су предложили примену квантне теорије Хајтлера и Лондона, али само за раздаљине веће од равнотежног стања. Ленард-Џонсова формула била је коришћена и на раздаљинама мањим од равнотежног стања између атома у бинарним интеракцијама. У сваком случају постигли смо поклапање са експерименталним подацима о дисоцијацији енергије користећи различите врсте одговарајућих коефицијената. Уопштенија идеја о свим могућим типовима интеракција потпуно је изостала. С тим у вези, било је потребно открити све могуће типове интеракција унутар двоатомских молекула и теоретски добити енергију дисоцијације, енергију активације и стандардну енталпију атомизације. Примена метода квантне механике у Хајтлер-Лондоновој теорији омогућила је да се узме у обзир не само Кулоново одбијање током интеракције размене већ и Кулоново одбијање нуклеуса.

Резултати: Израчунати су електрични диполи за неутралне атоме и за позитивно наелектрисане јоне језгара двоатомских молекула, што је омогућило израчунавање електрон-дипол интеракција, као и дипол-дипол интеракција. Развијена је теорија

одбијања позитивно наелектрисаних нуклеуса сложених атома у двоатомским молекулима. Израчунати су потенцијали за молекуле угљеника, алуминијума, силицијума и натријума. Развијени физички модел формирања двоатомских молекула упоређен је са емпиријским потенцијалима Ленард-Џонса и Морзеа. На раздаљини између нуклеуса, једнакој збиру енергија пречника атома, у молекулу долази до скока потенцијала с прелазом од негативне до позитивне области енергије везивања, што детерминише активациону енергију формирања двоатомских молекула.

Закључак: Из добијених потенцијала интеракција атома у двоатомским молекулима одређени су енергија активације, енергија јонизације, стандардна енталпија атомизације, као и афинитет према електрону.

Кључне речи: потенцијал интеракције, ковалентна веза, јонска веза, електрични дипол, индукована веза, двоатомски молекул.

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AMMUNITION SUPPLIES, NEW PROPOSAL OF AMMUNITION SUFFICIENCY

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Abstract:

Introduction/purpose:The paper is one of the outcomes of the project in the area of ammunition supply and standard day of supply (SDOS) design for ACR needs. It discusses the current approach of determining the amount and composition of ammunition stocks. Possible solutions to increase efficiency are considered. The aim is to achieve greater objectivity of the planning process where operations management and crisis management are included.

Methods: Basic scientific methods were usedtogether with specific methods such asthe target-oriented method (TOM) and the effort level method (LoE).

Results: The result of the scientific research is to determine the effective ammunition stock of the battalion level in order to achieve higher objectivity of the planning process of conducting operations and coping with crisis situations. The authors deal with a description of the current system of ammunition supply creation in the Czech Armed Forces and NATO, strengths and weaknesses included. A new consolidated system is proposed to improve a stock pile planning process for effective provision and sustainment to achieve operational success and risk mitigation. Objectives from NATO and EU task forces and current operations have been taken into account. The research used the target-oriented method (TOM) and the effort level method (LoE).

Conclusion: The result of the scientific research is to achieve higher objectivity of the planning process of conducting operations and coping with crisis situations.

Key words: supplies, standard day of supply (SDOS), combat day of supply (CDOS), risk, war conflict.

Introduction

Successful completion of operation activities and the fulfillment of operational tasks is the main objective of military commanders at all levels of command. A sufficient supply of ammunition is one of the key factors in achieving operational success. Its misinterpretation, whether small or disproportionately high, has negative impacts, not only on planning and implementation of military operations, but also on the area of resource planning, real support and the maintenance of ammunition within its life cycle. Furthermore, properly defining the amount and composition of inventory is crucial and will enable either adequately addressing the threat of a war conflict or leading to effectively concluded combat activities (Zlatník, 2018).

Current state of the discussed issue

Correctly determined levels and the composition of inventory are the cornerstones of military planning and conduct of military operations. If the correct principles are not applied, the amount with negative impacts will be incorrectly determined, both in the case of overvalued and undervalued amounts. In the case of a disproportionate level of inventory, it becomes ineffective to make inessential inventory with additional costs spent on: warehousing, shipping, safety measurements and disposal. Understocking of inventory may result in an inability to effectively cope with the threat of warfare, in extreme cases leading up to a conflict which could potentially have fatal consequences and significant impacts on all spheres of society. It is desirable that inventory levels should be based on mathematical calculations or modeling rather than on an intuitive estimation made in the planning process by experts. The amount and composition of inventories of all kind must be based on good practice and be supported by credible calculations. In order to determine the level of inventory, various methods and principles are applied within armed forces.

The situation is similar in other partner armies and it is necessary to revise ammunition stockpiles (Andrews & Hurley, 2004), (Malbašić & Đurić, 2019).

To obtain basic knowledge and be able to familiarize with the concept of inventory-based issues, it is essential to explain how the concept was developed. The creation of ammunition stocks has evolved over time in terms of its definition, nomenclature and internal division.

Until the year of 2010

In 1997, a military directive Fire averages and distribution of movable ammunition stockpiles was issued (Vševojsk 5-3, 1997) which followed the regulations of the same designation and title issued in 1980, 1985, and 1992. The amendments consisted mainly of minor text modifications and new additions of different types of ammunition. The regulation (Vševojsk 5-3, 1997) was issued in order to determine firing averages and distribution of movable supplies for units, formations and volumes of the Army of the Czech Republic. Until 1997, the firing average was defined as a calculation unit for ammunition supply. Subsequently, the modified text from 1997defined it as a calculation unit to plan the security of combat operations, determining the daily consumption and size of supplies, as well as the amount of ammunition for one weapon.

The amount and composition of the ammunition stockpile was based on the definition of the regulation in 1980 according to the experience of World War II battlefields, taking into account the use of nuclear weapons and other weapons of mass destruction. Moreover, in 1985, this provision was taken out from the regulation, but the actual amount remained the same. The examples are the amount set for tank ammunition and ammunition for rapid-fire cannon infantry fighting vehicles, i.e. the T72M1 tank's daily firing average was 44 and that of the BVP2 was 486 pieces of ammunition.

Years 2010 - 2015

In 2010, the military directive (Vševojsk 5-3, 1997) was superseded by a normative decree (Ministry of Defense of the Czech Republic, 2010). It already reflects the NATO standards. Nonetheless, it still continues to use the term fire average.

The Standard Day of Supply (SDOS) is listed as a calculation standard for the amount of military stock deployed in the Armed Forces of the Czech Republic, based on the average daily consumption of military equipment, where the number of targets and operational parameters of the action is unknown, and expresses the daily requirement for military equipment according to national standards.

The Day-of-Supply (DOS) is a calculation standard for the amount of stock of military equipment to ensure direct combat activity, established by the North Atlantic Treaty Organization (NATO), expressing the exact daily need for military equipment to cover actual consumption, losses and damage as a function of an already-known overview of enemy targets,

expected losses and operational parameters of the task (foreign operations).

The firing averages in this decree are determined by the number of ammunition pieces for each weapon. The sum of all firing diameters of all weapons is the firing diameter of the unit. In comparison with the previous amendment of the regulation (Vševojsk 5-3, 1997), the amount of fire averages for tank ammunition and ammunition for rapid-fire cannon combat vehicles virtually consist of the same amount. Only in BVP2 the level was increased by 14 pieces of ammunition, from 486 to 500 pieces, as in the regulation of 1985. The firing averages were based on World War II with the addition of new types of ammunition during the Cold War. One of the more significant findings is the link between the average fire and the SDOS (DOS) which was solved through the coefficients of operational and mobile stocks, which was based on economic possibilities, not on operational factors.

From 2015 until now

Generally, the issue of inventories is regulated by RMO No. 48/2013 (Ministry of Defense of the Czech Republic, 2013), as amended by RMO No. 54/2017 (Ministry of Defense of the Czech Republic, 2017), MO normative decree No. 16/2017 (Normativní výnos MO č.16/2017). According to the aforementioned RMO, inventories are selected and stored types of movable assets that are prepared to meet the necessary property needs in performing the functions of the department. The creation of ammunition reserves is regulated by the normative decree of the Ministry of Defense 015 (Normativní výnos MO č.39/2015), which was issued in 2015. The regulation fully reflects the NATO's standardized approach meanwhile taking into account the national conditions as well (Normativní výnos MO č.16/2017). The Standard Day of Supply (SDOS) is characterized by the amendment of the Ministry of Defense No. 10/2010 (Normativní výnos MO č.10/2010) as a calculation standard of the amount of ammunition reserves introduced in the Armed Forces of the Czech Republic. When the number of targets and operational parameters of the action is unknown, it is based on the average daily ammunition consumption. It expresses the average daily ammunition requirement according to the national standards.

A newly introduced concept of the Combat Day of Supply (CDOS), which is the total amount of ammunition supplies for one day of combat, introduces intensity factors, the so-called modification coefficients, to the standard daily supply volume. The CDOS expresses the daily need for ammunition to cover actual consumption, losses and damage, depending

on the accurate data concerning enemy's targets, expected losses and operational parameters of the combat task.

Types of supplies are divided into ammunition reserves of common needs, training and technical reserves of ammunition, ammunition reserves for securing combat operations and ammunition reserves for securing foreign operations and task forces.

Unlike the previous modification in (Normativní výnos MO č.10/2010), the firing averages are no longer given. They were replaced by the Table Standard Daily Supply Volume (SDOST), which is modified by the reserve coefficient Kr for the calculation of the SDOS. The reserve coefficient Kr is determined by the class V manager based on the total stock of ammunition and the available resources designated for ammunition.

Principles applied within NATO and the EU

Within NATO, the AJP-01 doctrine (NATO HQ, 2017) has been published, which is essential for planning, implementation and support for Allied operations (NATO HQ, 2017), which is not only used by NATO, but also by the EU and UN operations.

NATO's main logistics doctrine AJP-4 (NATO HQ, 2018) delegates to the sending states the responsibility of equipping troops with the necessary equipment, training and ensuring their sustainability throughout their deployment, either individually or jointly using multinational logistics or NATO agencies such as NSPA primarily. Its own inventory security in the case of initial conflict management within multinational operations is implemented through the NATO Support and Procurement Agency (NSPA) under the Operational and Logistics Support Program (OLSP), but largely the responsibilities of the sending nations remain with regard to the diversity of armaments and equipment.

The arrangement of logistical requirements is based on the conditions for conducting a specific operation based on operational planning. Logistics planning standards in the area of consumption are only focusing on the amount of supplies in kilograms relative to the soldier and the vehicle number. As such, they cannot be used for detailed inventory planning. The standards are used solely to determine logistics capabilities and unit structures at the operational level.

The amount and composition of stocks to deal with crisis situations remaina national responsibility.

Methods used to determine ammunition consumption

To carry out predictions of ammunition consumption within the conduct of combat activities, two basic methods are used, which, based on the simulations and expert predictions, allow the determination of the SDOS ammunition levels.

Target Oriented Methodology

Target Oriented Methodology (TOM) allows the determination of the amount of ammunition needed to destroy an enemy target. It is a probabilistic method assuming the destruction of each given target by an individual ammunition piece. The method is used in the ACROSS system, which is a specially developed NATO software tool, especially for artillery, anti-tank weapons, mortars and tank ammunition. The method is not used for infantry weapons, grenades and short-range anti-tank missiles (RPGs). The goal-oriented method takes into account factors such as enemy targets, own forces and operational parameters. It does not consider the time parameter; the results are given in the number of individual types of ammunition. The ACROSS primarily uses mathematical methods that calculate either the total cost of ammunition or the value of destroyed targets. In the case of total costs, the cost of ammunition required to destroy all targets is calculated. If the indicator is the value of the destroyed targets against the costs incurred, then the relationship between the targets and the value of the ammunition is taken into account so as to achieve the maximum losses of the enemy at the minimum cost. The ACROSS uses an extensive database containing parameters of its own resources and prices of individual types of ammunition, which must be kept up-to-date and accurate. This places considerable demands on the user. The weak point is the use of indirect fire, which targets a space, not clearly defined targets, and whose effectiveness is difficult to define and varies considerably according to the level of protection of the target (Andrews & Hurley, 2004).

Level of Effort Method

The Level of Effort (LoE) method is based on historical ammunition consumption data, or modeling of operations to determine the amount of each type of ammunition. It is not based on specific concepts for conducting specific operations and is more suitable for generating general data. It is not suitable for predicting consumption in specific operations, which differ in many parameters, which can significantly influence the final consumption. The method was mainly used during the

Second World War and the War in Korea, which were characterized by a massive deployment of troops with a significant amount of ammunition consumed. The way of conducting offensive and defensive operations was constant and well predictable. It is no longer relevant. The reason is the lack of data and changes in the way of classical conducting combat operations, without making adjustments to the amount of needs above and the composition of inventory through the modeling of combat activities. The actual modeling of combat activities, however, depends on the ability and experience of individual actors. It does not have to take into account all indirect factors of conducting combat operations, which can significantly affect the resulting calculations. These are primarily the use of indirect fire, continuous training units in shooting, losses in the supply of ammunition due to the enemy's combat activities, fires, weather and transport services. These may also be storage conditions, including strategic parameters such as production and supply capability.

These factors are already included in historical data, but their relevance to time and an operational area is decreasing (Andrews & Hurley, 2004).

Practical application of methods

Individual methods can be practically used in their suitable combinations. This was done as part of a project implemented by the General Staff of the Army of the Czech Republic (ACR). The project was prepared and directed by the Multinational Center for Coordination of Logistics with the support of a wide range of experts from various units of the General Staff of the Army of the Czech Republic in logistics, reconnaissance, planning operations, conducting combat operations, special forces, including the involvement of selected commanders, to brigade and regiment.

Scenario creation

The calculations were preceded by a preparatory phase, in which the following was defined: geopolitical situation, the parameters of combat operations, the structure of own forces and the adversary, the period, including the development of a scenario of conducting combat operations within 30 days. This scenario was identified by the Army of the Czech Republic General Staff as probable in the event of a large-scale conflict under Article 5 of the Washington Treaty (NATO HQ, 1949).

In terms of geopolitical situation, the complex security situation resulting from the long-term economic crisis caused by global changes

and the collapse of the world economy leading to the instability of the north-eastern region of the European Union states, including national animosity, was incorporated into the scenario.

In terms of operational factors, the flat terrain, agriculturally managed landscapes with partial afforestation and numerous water bodies were defined. The operation was situated in the spring with average rainfall.

The structure of own forces was defined at the level of the Brigade Task Force (Ministry of Defense of the Czech Republic, 2019). The structure of the enemy was determined on the basis of a balance of available forces and corresponding to the established structure of units of the strength of the Panzer Division supported by 2 Infantry Divisions and Tactical Air Force (General Staff of Army of the Czech Republic, 2019),

At the same time, the ability of the host nation to provide Host Nation Support under AJP 4-5 has been defined (NATO HQ, 2013).

The scenario is to be understood as a fiction, not a prediction of the future development of the security environment in Europe and its resulting in any military operations.

After the determination of the above decisive factors in the scenario, the probable development of the operational situation over a period of 30 days was started. The time space was based on the NATO strategy currently in place to ensure the sustainability of troops in operations (NATO HQ, 2010), taking into account the maximum predicted duration of deployment of troops in a high-intensity military operation involving all types of combat operations.

Execution of the war game

Two workshops were held to identify new approaches for ammunition consumption. Based on their experience, selected experts defined a possible course of conducting combat operations broken down by type of operation to lead 8 days of defensive operations, 13 days of delayed combat and 9 days of offensive operations at different intensities. An overview and analysis of the conduct of combat operations maneuver units is shown in Table 1.

Table 1 – Course of conducting combat operations
Таблица 1 – Ход ведения боевых действий
Табела 1 –Ток вођења борбених операција

Combat units			
Day	Mission profile	Intensity	Activity
1	Defense	Low	Movement
2	Defense	Low	Emplacement
3	Defense	Low	Defense Built up
4	Defense	Low	Defense Built up
5	Defense	Medium	Defense
6	Defense	High	Position Defense
7	Defense	Very high	Position Defense
8	Defense	Very high	Maneuver Defense
9	Defense	High	Delaying Operation
10	Defense	High	Counter Attack
11	Defense	Medium	Delaying Operation
12	Retreat	Medium	Withdrawal from action
13	Retreat	Medium	Movement
14	Retreat	Low	Movement
15	Retreat	Low	Movement
16	Retreat	Low	Movement

Combat units			
Day	Mission profile	Intensity	Activity
17	Retreat	Low	Movement
18	Retreat	Low	Movement
19	Retreat	Low	Movement
20	Retreat	Medium	Counter Attack to Assault
21	Attack	Low	Movement
22	Attack	Low	Emplacement
23	Attack	Low	Deployment
24	Attack	Medium	Deployment
25	Attack	High	Deployment
26	Attack	Very high	Counter Attack
27	Attack	High	Attack
28	Attack	Medium	Attack
29	Retreat	Medium	Relief of troops
30	Retrograde	Low	Restoration

Creation of the conducting combat operation in relation to its intensity

Depending on the conduct of the operation while taking into account its individual phases, different intensities of conducting combat activities by individual types of troops were created and recorded into the charts. The troop activities were consolidated on the basis of the prediction of

the operation of maneuvering units. Individual phases of conducting combat activities divided by individual types of troops are shown in Figures 1-4.

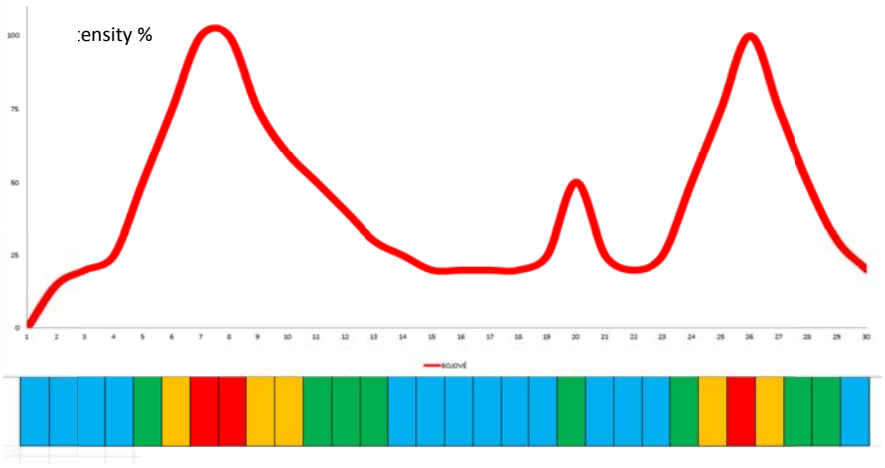

Figure 1 – Course of the intensity of combat operations by ground combat units
Рис. 1 – Ход интенсивности боевых действий сухопутных войск
Слика 1 – Ток интензитета борбених операција копнених борбених јединица

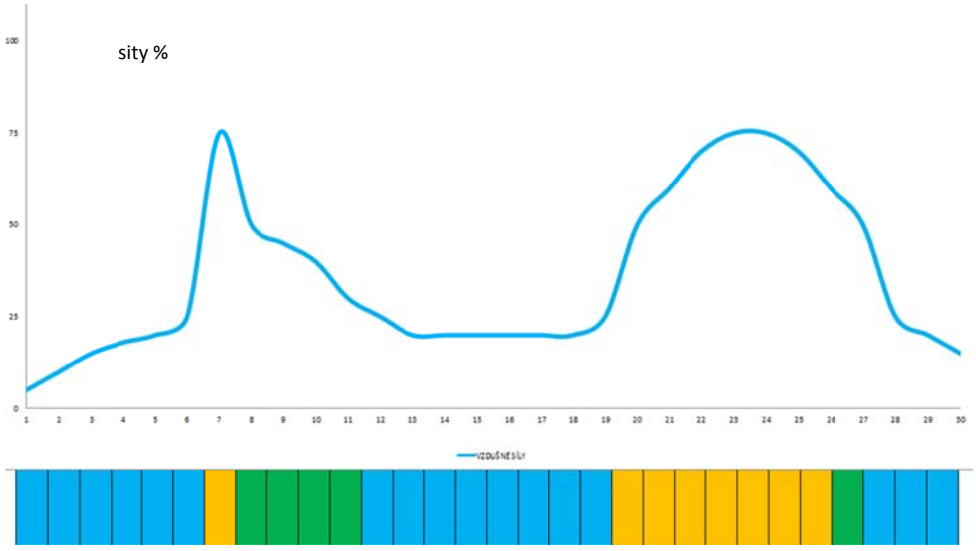

Figure 2 – Course of the intensity of conducting combat operations by air forces
Рис. 2 – Ход интенсивности боевых действий ВВС
Слика 2 – Ток интензитета вођења борбених операција ваздухопловних снага

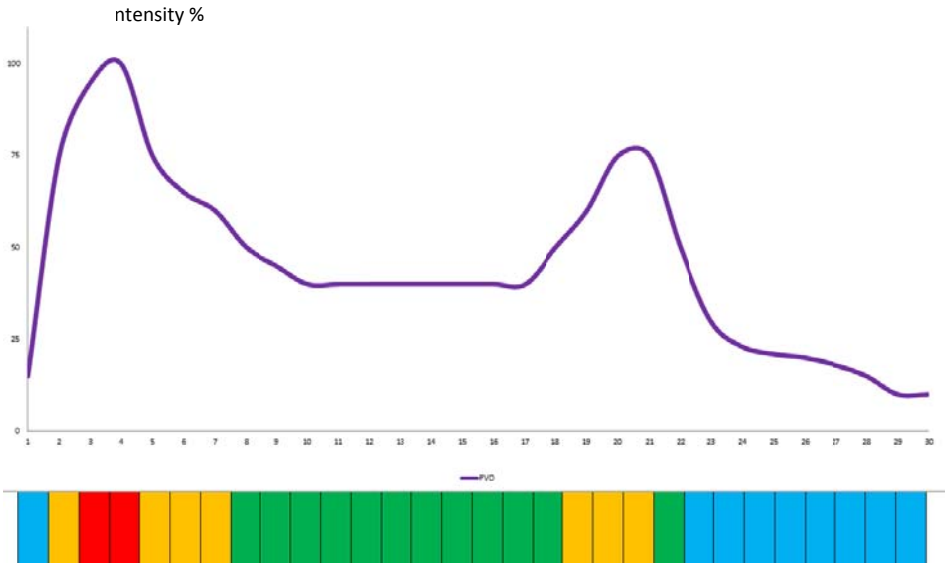

Figure 3 – Course of the intensity of combat operations of air defense
Рис. 3 – Ход интенсивности боевых действий ПВО
Слика 3 – Ток интензитета борбених операција ПВО

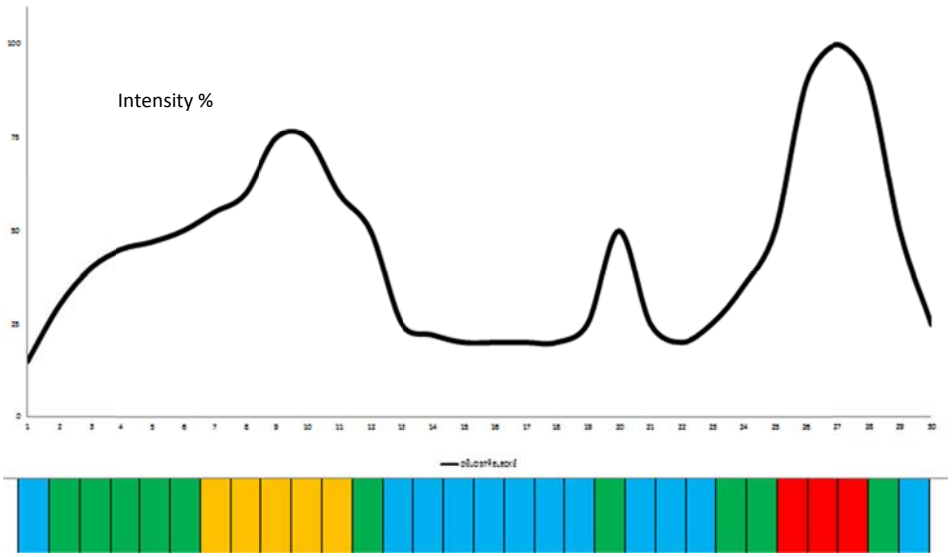

Figure 4 – Course of intensity of combat operations of artillery
Рис. 4 – Ход интенсивности боевых действий артиллерии
Слика 4 – Ток интензитета борбених операција артиљерије

Consumption prediction, SDOS calculation

Based on the intensity of conducting combat activities and the composition of the enemy forces, i.e. targets, expert estimates of ammunition consumption were made based on individual days, weapons and weapon systems.

The actual predictions were identified as non-public confidential information within the project; therefore, they are not included in the article. As an example, a calculation using data that has been modified with respect to the above is shown in Figure 5.

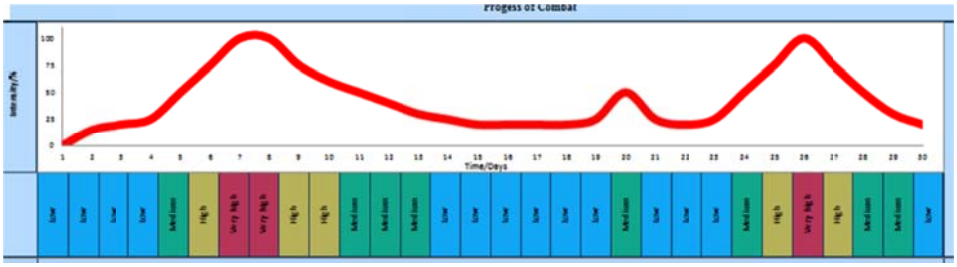

Figure 5 – Calculation of the SDOS of selected weapons of ground forces combat units
Рис. 5 – Расчет стандартной суточной нормы снабжения выбранныхбоеприпасов сухопутных войск
Слика 5 – Израчунавање снабдевачког дана (стандардног дана) за изабрано наоружање борбених јединица копнених снага

A mathematical formula was then used to calculate one SDOS of each type of ammunition

SDOS = (SDOS1 + SDOS2 +… + SDOS30) / 30

where each variable means:

SDOS - Standard daily delivery volume

SDOS1… .30 - average daily ammunition consumption for each day of operation.

Based on the calculations, one SDOS was obtained for each type of ammunition, the details of which are shown in Figure 5. For example, for one 5.56 mm caliber assault rifle, one SDOS is 64 pieces of ammunition, for a 7.62 mm light machine gun, it is 111 pieces of ammunition, for a

wheeled combat vehicle Pandur armed with 30 mm quick-firing cannon one SDOS is 60 missiles, and for a medium tank armed with a 125 mm cannon one SDOS is 7 missiles.

The application of these methods reduced the amount of SDOS ammunition compared to the original approach by approximately 60%. This has a major impact on resources, in particular in terms of the direct cost of purchasing ammunition, but also on the indirect costs associated with the storage and maintenance of the ammunition as part of its life cycle, the means necessary to transport it and the cost of its eventual disposal. At the same time, efficient inventory levels will reduce logistics chain requirements for operations management, i.e. strategic transportation between Level 4 and Level 3 logistics, including storage and transportation within the operations area. This will reduce the logistical presence in the operation and at the same time increase the maneuverability of the entire task force, i.e. increase operational capabilities.

Conclusions

The research revealed that the current principle of ammunition stockpiling is based on historical data without qualified adjustment based on the use of contemporary methods. Economic resource options are considered as modifying parameters for determining the amount of SDOS stocks, which are a limiting factor in terms of meeting complex operational needs to achieve operational success, but they cannot primarily influence the amount of the basic calculation unit.

The application of new methods revealed that the revision of SDOS ammunition is real and leads to more efficient system of ammunition stockpiling. By an appropriate combination of effort and target-oriented methods, it is possible to make more accurate estimates of consumption within each combat day, thereby defining a calculation unit that reflects the prediction of combat operations and which will be the basic calculation unit for determining its own mobile, operational and strategic stocks.

Before the actual implementation of the data obtained by this method into practice, it seems appropriate to use simulation technology and verify individual professional predictions, or to deal with the prediction of combat losses of equipment and its own ammunition stockpiles.

Determining the effective level of stocks is one of the crucial prerequisites for crisis management and for achieving operational

success. The approach to ammunition stockpiling needs to be constantly improvedto respond to the ever-changing security environments and related threats.

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СНАБЖЕНИЕ БОЕПРИПАСАМИ: НОВОЕ ПРЕДЛОЖЕНИЕ ПО ДОСТАТОЧНОСТИ ОБЕСПЕЧЕНИЯ БОЕПРИПАСАМИ

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РУБРИКА ГРНТИ: 78.00.00 ВОЕННОЕ ДЕЛО;
78.75.73 Статистика, учет и отчетность. Технико-экономический анализ в военном деле
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Введение/цель: Данная статья является результатом проекта в области снабжения боеприпасами и формирования стандартной суточной нормы снабжения (SDOS) для нужд армии Чешской Республики. В статье обсуждается действующий подход к определению количества и состава запасов боеприпасов. Обсуждаются возможные решения, способствующие повышению эффективности, с целью достижения большей объективности при планировании процессов управления операциями и кризисными ситуациями.

Методы: В исследовании применялись основные научные методы, а также специальные методы, такие как: целевой метод (метод выбора мощности боеприпаса на основании разведывательных данных (TOM)) и метод уровня усилий (LoE).

Результаты: Результатом данного научного исследования является определение эффективного запаса боеприпасов на уровне батальона для достижения большей объективности в процессе планирования при проведении операций и управлении кризисными ситуациями. Авторы описывают существующую систему снабжения и запасовбоеприпасов в вооруженных силах Республики Чехия и НАТО, включая как ее достоинства, так и недостатки. Предлагается новая система консолидации, с целью улучшения процесса планирования создания запасов с целью обеспечения эффективного снабжения и логистической устойчивости, что приведет к успешному функционированию и снижению рисков. В ходе исследования были приняты во внимание цели тактических целевых групп и текущие операции

НАТО и ЕС. В данной статье были применены методы ТОМ и LoE.

Выводы: Результатом данного научного исследования является достижение большей объективности в процессе планирования при проведении операций и управлении кризисными ситуациями.

Ключевые слова: боеприпасы, стандартная суточная норма снабжения (SDOS), военная суточная норма снабжения (CDOS), риск, военный конфликт.

СНАБДЕВАЊЕ МУНИЦИЈОМ: НОВИ ПРЕДЛОГ ОВЕЗБЕЂЕЊА ЗАЛИХА

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ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Увод/циљ: Овај рад представља један од резултата пројекта у области снабдевања муницијом и креирања стандардног снабдевачког дана (standard day of supply – SDOS) за потребе војске Републике Чешке. Бави се важећим приступом одређивању количине и састава залиха муниције, а разматра и могућа решења која воде повећању ефикасности. Циљ је да се постигне већа објективност при планирању процеса управљања операцијама и кризама.

Методе: Коришћене су основне научне методе, као и посебне методе, попут методе усмерене на циљ (target-oriented method – TOM) и методе нивоа напора (effort level method – LoE).

Резултати: Резултат научног истраживања јесте да се одреде ефективне залихе муниције на нивоу батаљона како би се постигла већа објективност процеса планирања при вођењу операција и управљању кризним ситуацијама. Аутори описују постојећи систем стварања залиха муниције у оружаним снагама Републике Чешке и НАТО-у, укључујући и његове предности и недостатке. Предлаже се нов систем консолидације како би се побољшао процес планирања стварања залиха ради ефикасног снабдевања и логистичке одрживости који воде оперативном успеху и ублажавању ризика. Узети су у обзир циљеви оперативних тактичких група и тренутних операција НАТО и ЕУ. У истраживању су примењени методи ТОМ и LoE.

Закључак: Резултат овог научног истраживања јесте постизање веће објективности процеса планирања вођења операција и деловања у кризним ситуацијама.

Кључне речи: залихе, стандардни снабдевачки дан (SDOS), борбени снабдевачки дан (CDOS), ризик, ратни сукоб.

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AIRCRAFT COLLISION PREDICTION BASED ON BINOMIAL DISTRIBUTION

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Abstract:

Introduction/purpose: Based on the binomial distribution of the probability density function, a new probabilistic model for aircraft position predicting is presented in this paper.

Methods: The proposed algorithm is composed of three different blocks: Data Association, Tracking/Hybrid State Estimation and Calculation of Probability of Conflict. The information about aircraft current positions and flight plans is used to derive an algorithm for detecting possible conflicts between aircraft. The situations where aircraft may come closer than a certain distance to one another are predicted with high probability. The position estimate and indeterminacy refer to target association when two tracks fall in a validation region by using the Probabilistic Data Association Filter.

Results: An efficient collision detection algorithm is designed and tested for a lot of multiple target tracking.

Conclusion: The simulation results of aircraft conflict prevention in two trajectory scenarios verify the efficiency of the proposed algorithm.

Key words: automatic control, probability, target tracking, data association.

Introduction

Air collision is an aviation accident category defined as a collision between aircraft in flight. The main aim of the air colision software tool under development is to analyse radar data in order to identify all proximate events (conflicts, potential conflicts, and potential collisions) within a volume of airspace and time span, to classify them according to various criteria into classes, to estimate the frequency of occurrence, and to calculate the different parameters needed to estimate the probability of aircraft being on a collision course and the probability of Air Traffic Control (ATC) loop resolution failure. The identification and analysis of potential conflicts is based on aircraft track association. Measurements in track association identify when an aircraft is turning, changing its vertical position or modifying its speed, so as to replace the full detailed track of each aircraft with a number of potential positions, from one scan to another.

Continued growth of air travel and recent advances in new technologies for navigation, surveillance, and communication has led to provide reliable and efficient tools to aid Air Traffic Control (ATC). The ATC system is responsible for safe air traffic operations of both commercial and military types. Standard multiple target tracking of wide band maneuvering aircraft is based on Track While Scan (TWS) radar data and Kalman filter processing (Blackman, 1986), (Challa et al, 2011).

To prevent aeroplane conflicts, many of Air Traffic Control (ATC) systems resort to a two part process. In the first part, conflict detection is performed by the following: the estimate positions of all aircraft which fall into a validation region in the future, based on their current positions and flight plan, are predicted, and they are compared so as to detect situations of conflict. Once a conflict has been detected, the trajectories of the aeroplanes involved in the conflict are re-planned in the conflict resolution part. Conflict detection and resolution is actually given consideration at three different levels of the ATC process, which differ in the Euclidian distance over which conflict detection and resolution is performed. They are Long Range (LR), Mid Range (MR), and Short Range (SR).

Many methods are used to ensure safe distance. Bayesian inference and Hierarchical structures are often used to develop statistical estimation and prediction models (Valdés et al, 2018). Some authors suggest a Brownian motion, in which the probability of conflict becomes the probability that a Brownian motion escapes from a time-varying safe region (Hu et al, 1999). An extensive study is performed with a model

introduced to predict the aircraft positions along some look-ahead time horizon, during which each aircraft is trying to follow a prescribed flight plan despite the presence of additive wind perturbations to its velocity. Based on the Markov chain aproximation, a method is introduced to evaluate the criticality of the encounter situation by estimating the probability of conflict, namely, the probability that the two aircraft come closer than a minimum allowed distance at some time instant during the look-ahead time horizon (Hu et al, 2005).

An algorithm, based on the Probabilistic Data Association Filter (PDAF) algorithm for LR and MR conflict detection is then proposed and its performances are compared by Monte Carlo simulations. The proposed algorithm is composed of three different blocks: Data Association, Tracking/Hybrid State Estimation and Calculation of Probability of Conflict. The improved results of conflict detection probability computation, using the PDAF method, are presented. The proposed algorithm computes the maximum likelihood for all measurements within the validation region, apropos the minimum statistic distance calculated from measurements (target-originated, clatter, false target-originated, etc.) within the gate and target estimate from the previous data sequence.

The paper is organized as follows: after the introductory remarks, the problem of formulation is given in Section 2. Section 3 presents the probabilistic data association filter which is the first step of the proposed algorithm. The description of the proposed conflict detection algorithm is presented in Section 4. Finally, the simulation results of two aircraft motion scenarios are presented in Section 5, which precedes the Conclusion Section.

Problem formulation

Let us assume that two aircraft are flying at the same altitude along the paths the intersection angle of which is time constant during flight and that the probability density of aircraft collision has the Gaussian distribution. The conflict detection algorithm in flight closeness of two aircraft, based on the PDA algorithm, is presented. The probability of conflict is calculated by the use of estimated states and weighting error covariance updates. Aircraft conflict prediction is determined for the duration of one radar scan, before aircraft collision. In our simulation, the safety time is $5s$.

Regarding the validation gate, a safety region is formed beside the aircraft. This condition should be valid for the maximum speed of the

conflict aircraft and the direction of vector speed of the observed aircraft. When the conflict aircraft enters the validation region of the observed aircraft, there is a probability of conflict of two neighboring aircraft at the sample time k. Contemplate the situation for two aircraft flying at the same altitude.

The problem considered is that of tracking a single target in clutter, when the retrieval of two measurements fall in the validation gate. The linear dynamical target state model is given by the following:

$$x(k) = F \cdot x(k-1) + G \cdot w(k-1) \tag{1}$$

$$y(k) = H \cdot x(k) + \nu(k) \tag{2}$$

where F, G, H are the known matrices, $w(k)$ and $\nu(k)$ are independent, zero-mean, white Gaussian noise processes with the covariance $Q(k)$ and $R(k)$, respectively. At the time k, a set of $m(k)$ measurements $\mathbf{Y}(k) = \{y_i(k)\}_{i=1}^{m(k)}$ is detected, where each measurement either originates from one of n known linear measurement models or is a false detection, where $\nu(k)$ is a white, zero-mean Gaussian sequence with the known covariance $R(k)$. The sequences $\nu(k)$ are mutually independent and uncorrelated with the process noise $w(k)$.

Probabilistic data association filter

The PDAF is a suboptimal Bayesian algorithm that associates probabilistically all the validated measurements to the target of interest (Blackman, 1986), (Challa et al, 2011).

The PDAF method associates each validated measurement probabilistic to the estimated track (Reid, 1979).

The case with two measurements in each radar scan is presented (Fig. 1). Prediction computation is necessary for each target-originated measurement, but only one measurement is the target.

The PDAF method assumes that there is only one target of interest whose track has already been initialized.

The basic assumption is the normally distributed filter state according to the latest estimates and the covariance matrix, and the overall state of estimates and covariance is given by the weighted average of all the measurements falling within the validation gate of the target.

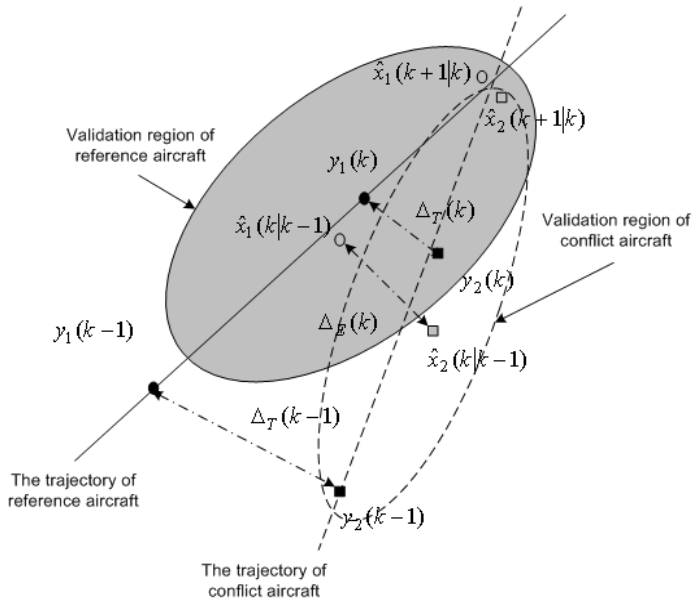


Figure 1 – Illustration of the PDAF with two measurements within the validation gate
Рис. 1 – Иллюстрация фильтра для идентификации данных по вероятности (PDAF) с двумя измерениями внутри подтвержденного окна
Слика 1 – Илустрација филтра за придруживање података по вероватноћи (PDAF) са два мерења унутар потврђеног прозора

Assume that we have measurements at the sample time k. We denote this set of measurements and the set of all cumulative sets up to the time k, by the following assemblies, respectively (Bar-Shalom & Tse, 1975):

$$Y(k) = \left\{ y_1(k),\, y_2(k), \ldots, y_{m(k)} \right\} \tag{3}$$

$$\mathbf{Y}(k) = \left\{ Y(k), Y(k-1), \cdots, Y(0) \right\} \tag{4}$$

Whence, the estimation of the Probabilistic Data Association method is based on the latest set of measurements. The assembly of all possible events, at the sample time k, can be considered as two, mutually exclusive and exhaustive events:

$H_0(k) -$ *none of measuremenst originated from the target*

and

$H_1(k) - i^{th} -$ *mesurement is the target originated*

$$H_i(k) = \{H_0(k), H_1(k)\} = \begin{cases} H_0(k), & i = 0 \\ H_1(k), & i = 1,2,..., m(k) \end{cases} \quad (5)$$

with the probabilities:

$$p_i(k) = P_r\{H_i(k)|\mathbf{Y}(k)\} = \begin{cases} p_0(k) = P_r\{H_0(k)|\mathbf{Y}(k)\}, & i = 0 \\ p_1(k) = P_r\{H_1(k)|\mathbf{Y}(k)\}, & i = 1,2,..., m(k) \end{cases} \quad (6)$$

Explicitly, $p_0(k) + p_1(k) = 1$. The estimate is calculated using the total probability theorem:

$$\hat{x}(k|k) = E\{x(k)|\mathbf{Y}(k)\} = \sum_{i=0}^{m(k)} E\{x(k), H_i(k), \mathbf{Y}(k)\} p_i(k) = \sum_{i=0}^{m(k)} x_i(k) p_i(k) \quad (7)$$

where $x_i(k)$ is the update state conditioned on the event $H_i(k)$ that $y_i(k)$ is the corect mesurement. From the Kalman filter, we have (Bar-Shalom & Fortmann, 1988):

$$x_i(k|k) = \hat{x}(k|k-1) + K(k) r_i(k) \quad (8)$$

$$r_i(k) = y_i(k) - h \cdot x_i(k|k-1) \quad (9)$$

where is the Kalman gain $K(k)$, and the residual of innovation $r_i(k)$ at the time k. After combining prior equations, get the update state:

$$\hat{x}(k|k) = \hat{x}(k|k-1) + K(k) r(k) \quad (10)$$

And the weighted sum of residuals:

$$r(k) = \sum_{i=0}^{m(k)} p_i(k) r_i(k) \quad (11)$$

The error covariance matrix is updated as:

$$P(k|k) = p_0(k)P(k-1) + (1-p_0(k))P^c(k|k) + \widetilde{P}(k|k-1) \tag{12}$$

where $P^c(k|k)$ is given by:

$$P^c(k|k) = [I - K(k)H(k)]P(k-1) \tag{13}$$

and where $\widetilde{P}(k \mid k)$ is given by:

$$\widetilde{P}(k|k) = K(k)[\sum_{i=1}^{m(k)} p_i(k)r_i(k)(r_i(k))' - r(k)r(k)']K'(k) \tag{14}$$

The final step is combining the model-conditioned state estimate and the covariance, according to the following equations:

$$\hat{x}(k|k) = \sum_{i=0}^{m_k} \alpha_i(k)\hat{x}_i(k|k) \tag{15}$$

where $\alpha_i(k)$ is the association probability of the measurement $y_i(k)$, and $x_i(k|k)$ is the estimate associated with the i^{th} measurement and $\hat{x}(k|k)$ is the overall estimate. The association probability in the proposed algorithm is calculated by (Radosavljević & Mušicki, 2011):

$$\alpha_i(k) = \begin{cases} \dfrac{c(k)}{c(k) + \sum_{i=1}^{m(k)} b_i(k)}, & i = 0. \\ \dfrac{b_i(k)}{c(k) + \sum_{i=1}^{m(k)} b_i(k)}, & i = 1,2,...,m(k) \end{cases} \tag{16}$$

where $c(k) = \dfrac{m(k)(1 - P_D P_G)}{P_D P_G V(k)}$ and $b_i(k) = \dfrac{1}{P_G} N[r_i; 0, S(k)]$,

P_D is the probability of detection, P_G is the probability that a measurement falls within the gate, $V(k)$ is the validation region, $N(x; \mu; S)$ is the Gaussian noise process with means μ and varinces S,

$r_i(k)$ is the innovation, and S is the innovation covariance (Bar-Shalom & Dale Blair, 2000).

Measurement validation and gating

A technique, which is sometimes called gating or measurement within a validation region, is able to select which measurement should be associated to the existing track. This track is our airplane. If we assume that we already have one track and we receive new measurements, we can assume that, in order to be able to associate measurements to the track, they must be in the vicinity of the predicted track.

Thus, the validation procedure is able to use the residual from the i^{th} measurement, the track $r_i(k)$, and the innovation covariance S. The distance from the i^{th} measurement to the predicted position of the track is calculated by (Hwang et al, 2003b):

$$d_i^{\,2}(k) = r_i^{\,T}(k) S^{-1} r_i(k) \tag{17}$$

We assume that before tracking is started, the gate probability P_G has been determined. We are able to obtain a quantity $V_i(k)$, using the P_G and χ^2-tables. The probability density function of target measurement is then given by the following expression

$$V_i(k) = \frac{e^{-\frac{d_i^2(k)}{2}}}{2\pi\sqrt{|S|}} \tag{18}$$

where $V_i(k)$ is a threshold such that $d_i < V_i$.

Aircraft conflict detection algorithm

Binomial distribution of aircraft conflict probability

The binomial probability distribution first considers Bernoulli. A Bernoulli trial has only two outcomes - success or failure. To begin, assume C and $\overline{C}$ are two mutually independent, exclusive and exhaustive trials which happen at the either sample time, respectively, by the following (Gad et al, 2004):

$$\begin{cases} P_r\{C|\mathbf{Y}(k)\} = \pi(k) & -conflict \quad will \quad occur \\ P_r\{\overline{C}|\mathbf{Y}(k)\} = 1-\pi(k) & -conflict \quad will \quad not \quad occur \end{cases}, \tag{19}$$

If the total number of successes of both trials before the sample time k is $n^{(k)}$, then the probability that the trial $\pi(k)$ is repeated $l^{(k)}$ times is given by the following equation

$$P_r\left\{C = l^{(k)}\middle|\mathbf{Y}(k)\right\} = \pi(k)^{l^{(k)}} \cdot [1-\pi(k)]^{n^{(k)}-l^{(k)}} \tag{20}$$

The appropriate distribution of probability is denominated binomial distribution given by:

$$P_r\{C,\overline{C}|\mathbf{Y}(k)\} = \sum_{l^{(k)}=0}^{n^{(k)}} \binom{n^{(k)}}{l^{(k)}} \cdot \pi(k)^{l^{(k)}} \cdot (1-\pi(k))^{n^{(k)}-l^{(k)}} \cdot \delta(k-l) \tag{21}$$

Therefore, the probability density function (pdf) of binomial distribution is given by the following:

$$pdf\left(l^{(k)}; n^{(k)}\right) = \frac{n^{(k)}!}{n(k)![n^{(k)}-l^{(k)}]!} \cdot \pi(k)^{l^{(k)}} \cdot [1-\pi(k)]^{n^{(k)}-l^{(k)}} \tag{22}$$

is satisfying the total probability theorem, given in the formula. In general, the mean and the variance of a binomial distribution with the parameters $n^{(k)}$ and the probability of success $\pi(k)$ are given by the following equations (Karlsson, 2002):

$$\mu_N(k) = n^{(k)} \cdot \pi(k) \tag{23}$$

$$\sigma(k)^2 = n^{(k)} \cdot \pi(k) \cdot [1-\pi(k)] \tag{24}$$

respectively.

Conflict detection approach

Suppose $y_0(k), y_1(k)$ are the measurements originating from the conflict and the observed aircraft arriving during the sample time, respectively. The true distance between the observed aircraft and the conflict one can be defined as absolute difference $|y_0(k)-y_1(k)|$. Based on the true distance of the two aircraft, we can define the true probability of conflict as the relative ratio of safety distance and true position distance, which is given in the following (Bar-Shalom & Li, 1999):

$$\sigma(k)^2 = n^{(k)} \cdot \pi(k) \cdot [1 - \pi(k)] \tag{25}$$

Similarly, if $\hat{x}_0(k|k-1), \hat{x}_1(k|k-1)$ are the estimate positions of the conflict and observed aircraft, we can define the estimate position distance as the absolute difference $\left|\hat{x}_0(k|k-1) - \hat{x}_1(k|k-1)\right|$. On the other hand, in the theory of aircraft conflict, it is necessary to satisfy the condition of safe statistical distance: $0 \le d_i^{\,2}(k) \le \varepsilon$. Then the estimate probability of conflict $p_E(k)$ is defined by the relative ratio of the known parameter ε_s-safety distance and estimate position distance:

$$p_E(k|k-1) = \frac{\varepsilon_S}{\left|\hat{x}_0(k|k-1) - \hat{x}_1(k|k-1)\right|} \tag{26}$$

where $y_1(k), y_2(k)$ are the measurements (from the set of all new measurements in the time step k) fall in the validation region and $\hat{x}_0(k|k-1)$, $\hat{x}_1(k|k-1)$ are the analogous estimate positions of measurements, at the sample time k. So, let us define the bound of safety as a dimension of the validation region after which the probability of conflict will have a value of one. The quantity $d_{ij}^2(k)$ is the sum of the squares of two independent Gaussian random variables with zero means and unit standard deviations. For that reason, $d_{ij}^2(k)$ will have the χ_2^2 distribution for correct observation-to-track pairings with the M degrees of freedom and allowable probability $P = 1 - P_d$ of a valid observation falling outside the gate, where P_d is the probability for correct detection. The threshold constant V_{ij} can be defined from the table of the χ_2^2 distribution with two degrees of freedom and allowable probability of a valid observation falling outside the gate (Bar-Shalom & Fortmann, 1988).

From equations (16), (19), and the assumed $m(k)$ measurements, the overall probability density of conflict, for the overall case, if the validation region is within the interval $0 \le d_i^{\,2}(k) \le +\infty$, at the sample time k, is given by the following equation:

$$p_C(k|k-1) = P_r\{H_i(k)|\mathbf{Y}(k-1)\} \cdot P_r\{C, \overline{C}|\mathbf{Y}(k-1)\}, \quad i = 0,1,...,m(k) \tag{27}$$

It is clearly seen that:

$$p_C(k|k-1)=\begin{cases}0, & i=0\\ 1, & i=1,2...,m(k)\end{cases} \tag{28}$$

Finally, after the evolution of the previous equation per all possible hypotheses and assumed "success trials" when position estimates fall in the safety region, we obtain the following (Hwang et al, 2003):

$$p_C(k|k-1)=\begin{cases}0 & ,0\le d_i^{\,2}(k)\le \varepsilon_s, \quad i=0,\\ p_1(k)\cdot\pi(k)^{l^{(k)}}\cdot[1-\pi(k)]^{n^{(k)}-l^{(k)}} & ,\varepsilon_s< d_i^{\,2}(k)\le +\infty, \quad i=1,2,...,m(k)\\ 1 & ,0\le d_i^{\,2}(k)\le \varepsilon, \quad i=1,2,...,m(k)\end{cases} \tag{29}$$

where $d_i^2(k)$ is the distance for the i^{th} measurement to the predicted position of the track, $p_1(k)$ is the probability given by (6) and:

$$\pi(k)=P_r\left\{C\middle|\mathbf{Y}(k)\right\}=p_E(k|k-1) \tag{30}$$

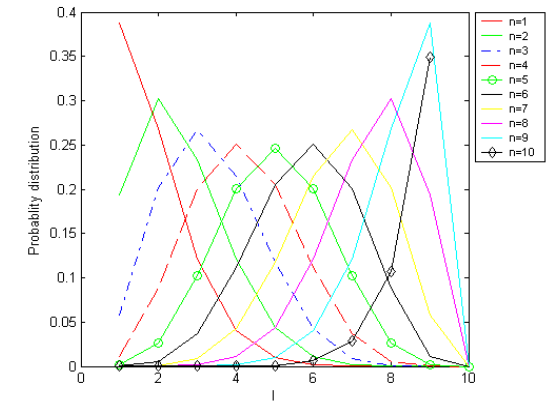
A numerical example: We assumed binomial probability distribution of the third order, with $n=3$, given by the following (Hwang, 2003):

$$\begin{aligned}&P_r(C,\overline{C}|\mathbf{Y}(k))=\\ &=\sum_{l^{(k)}=0}^{3}\binom{3}{l^{(k)}}\pi^{l^{(k)}}(1-\pi)^{n^{(k)}-l^{(k)}}=\\ &=\pi^3+3\pi^2(1-\pi)+3\pi(1-\pi)^2+(1-\pi)^3=1\end{aligned} \tag{31}$$

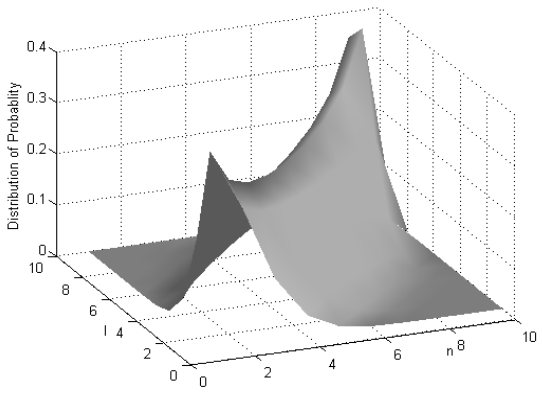
where:

$$\pi(k)=\Pr\left\{C\middle|\mathbf{Y}(k)\right\}=0.5 \tag{32}$$

The graphs of the probability density function at binomial distribution, for the total number of observed time intervals $n^{(k)}=1,2,...,10$ and with the probabilities of events $\pi(k)=0.25,\pi(k)=0.5$ $\pi(k)=0.75$ are given in Fig. 2a. The binomial distribution of probability with the number of observed time sequences and with a variety of probabilities of trials is given in Fig. 2b.



a)



b)

Figure 2 –

a) Binomial distribution of probability, with the number of time intervals $n^{(k)} = 1,2,...,10$,

b) 3D-binomial distribution of probability, with the number of observed time sequences and probabilities of trials

Рис. 2 –

а) Биномиальное распределение вероятностей с количеством временных интервалов $n^{(k)} = 1,2,...,10$,

б) Трехмерное биномиальное распределение вероятностей с количеством наблюдаемых временных последовательностей и вероятностей событий

Слика 2 –

а) Биномна расподела вероватноће са бројем временских интервала $n^{(k)} = 1,2,...,10$,

б) Тродимензионална биномна расподела вероватноће са бројем посматраних временских низова и вероватноћама догађаја

Simulation results

The performances of the implemented tracking filters and the corresponding neural network method are evaluated by Monte Carlo (MC) simulations over several representative test trajectories. The measure of performance is done using the Root Mean Square Error (Bar-Shalom & Li, 1999):

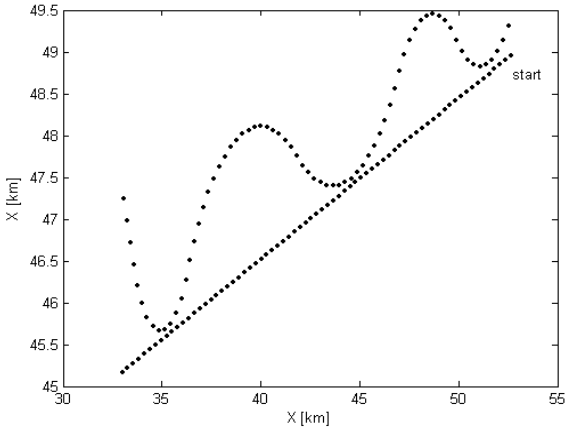
$$RMSE(k)=\sqrt{\frac{1}{N_{MC}}\sum_{i=1}^{N_{MC}}(\hat{\xi}^i(k)-\xi^i(k))^2+(\hat{\eta}^i(k)-\eta^i(k))^2} \tag{33}$$

where $\hat{\xi}^i(k),\hat{\eta}^i(k)$ are the position estimates (Cartesian coordinates) at the discrete time k, in MC run i and $\xi^i(k),\eta^i(k)$ are the measurement results. In the beginning, we assumed that both aircraft can have constant velocity (CV) or be in the coordinate turn (CT) mode (Fitzgerald, 1990). The tracking of two aircraft which interact in a period of time, is considered in this section. The observed aircraft is called the reference aircraft. The second aircraft, which enters the validation region of the reference aircraft, is called the stochastic aircraft. In order to test the efficiency of the proposed algorithm, two types of aircraft trajectories are formed. The first trajectory is without maneuver while the second trajectory has a maneuver with g acceleration. The test trajectories involve two aircraft flying along straight lines at an equal speed of 311 m/s. The flight data come from a radar sensor with a sampling interval $T=5\ s$. The duration of both simulations is 72 scans.

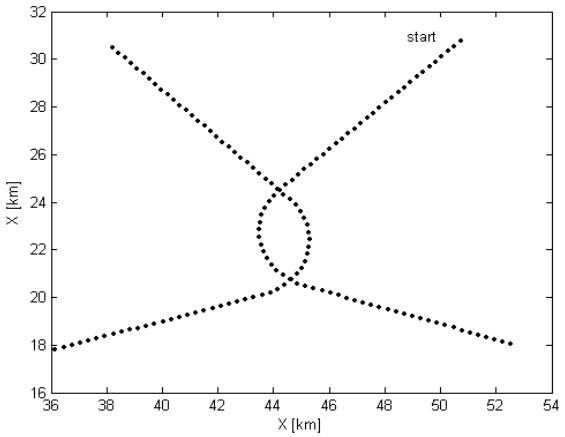
In the first test scenario, given in Fig. 3a, the reference aircraft is moving rectilinearly at a constant speed of $311\ m/s$ and at an angle of 45^0 in relation to the origin. The conflict aircraft performs full turn maneuvers with the intensities of g, $2g$, g and $3g$ during the scans 10-28, 37-45, 55-58, and 65-73, respectively.

The second test scenario, given in Fig. 3b, presents the trajectories of two aircraft at a constant speed of $311\ m/s$. The targets move towards each other. The first target is the reference aircraft flying towards the radar along the 45-degree line to the north while the trajectory of the second target (the conflict aircraft) is mirroring the first trajectory. At $k=34^{th}$ scan, both targets executed constant speed turns, of magnitude g that lasted for $k=8$ scans. During the maneuvers, the trajectories intersected and after the completions of the maneuvers, both targets

continued to move at constant speed. The radar is located at the origin, and cannot be shown. The trajectories from test scenario 1 intersected during scan 32, while the trajectories from test scenario 2 intersected during scan 44.

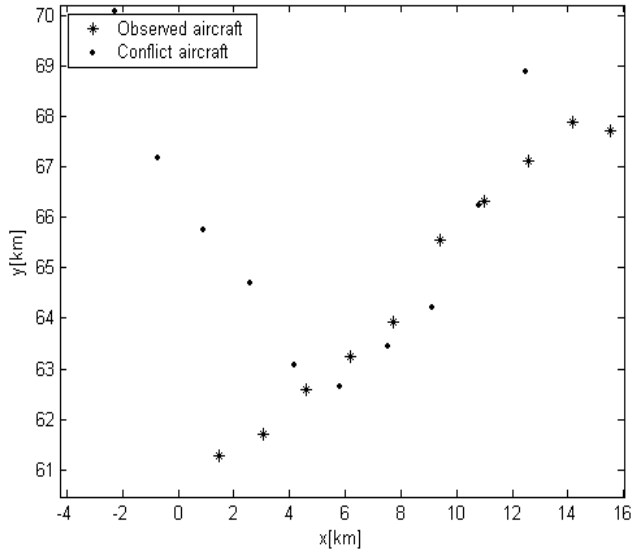


a)

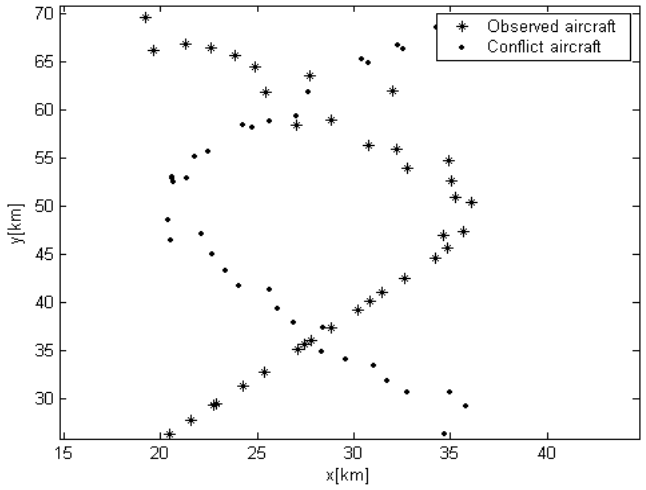


b)

Figure 3 – a) Trajectories from test scenario 1, and b) trajectories from test scenario 2
Рис. 3 – а) Траектории из тестового сценария 1 б) траектории из тестового сценария 2
Слика 3 – а) Трајекторије из тест-сценарија 1 и б) трајекторије из тест-сценарија 2



a)



b)

Figure 4 – Approaching the conflict in a) test scenario 1 and b) test scenario 2
Рис. 4 – Приближение столкновений в
а) тестовом сценарии 1 и б) тестовом сценарии 2
Слика 4 – Приближавање судара у а) тест-сценарију 1 и б) тест-сценарију 2

Consider the target moving in two dimensions, with two dynamic models and with process noise. For both trajectories, the constant velocity (*CV*) model is used, with the state vector defined as $\mathbf{x}(k) = [x\ \dot{x}\ y\ \dot{y}]'$. The matrices $\mathbf{F}_{cv}$ and $\mathbf{H}$ are defined by the equations:

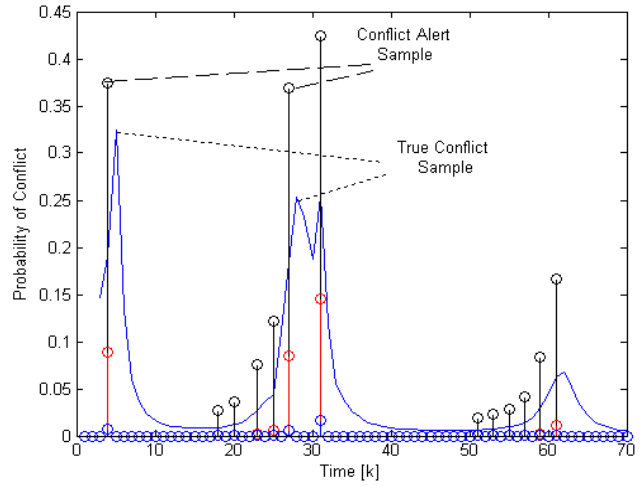
$$\mathbf{F}_{CV} = \begin{bmatrix} 1 & T & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & T \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad \mathbf{H}_{CV} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \tag{34}$$

respectively, where $q = 0.2,$ is the maneuver parameter (Song et al, 2012):

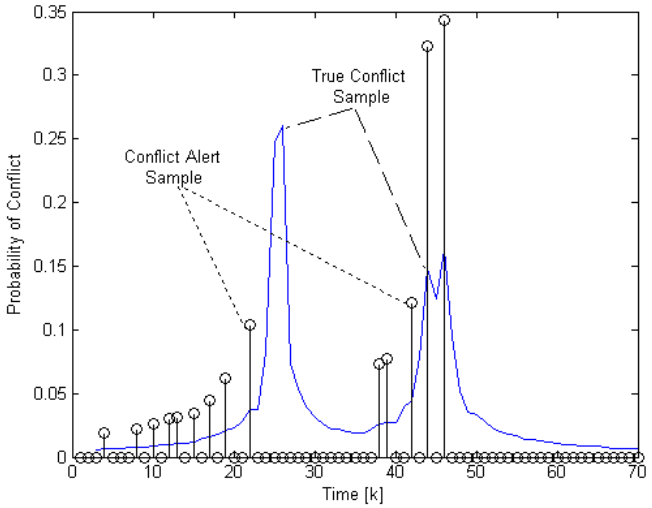
$$\mathbf{Q}(k) = q \begin{bmatrix} T^3/3 & T^2/2 & 0 & 0 \\ T^2/2 & T & 0 & 0 \\ 0 & 0 & T^3/3 & T^2/2 \\ 0 & 0 & T^2/2 & T \end{bmatrix}, \quad \mathbf{R} = \begin{bmatrix} \sigma_x^2 & 0 \\ 0 & \sigma_y^2 \end{bmatrix} \tag{35}$$

where $\sigma_x = \sigma_y = 20m$. The choice of the model set is of vital importance and must compromise computational load and target modeling flexibility. It has been found that the following two models: the constant velocity (*CV*) model (obtained for angular speed $\omega_0 = 0$) and the coordinated turn (*CT*) model (obtained for angular speed $\omega_0 > 0$), provide an adequate and self-contained model set for tracking purpose.

The conflict probability distributions for test scenario 1 and test scenario 2 are given in Figs. 5a and 5b, respectively. The time distributions of conflict prediction for the third-order binomial distribution for test trajectory 1 and test trajectory 2 are given in Figs. 6a and 6b. Similarly, the time distribution of conflict prediction for the fifth-order binomial distribution for test trajectories 1 and 2 are given in Figs. 7a and 7b.

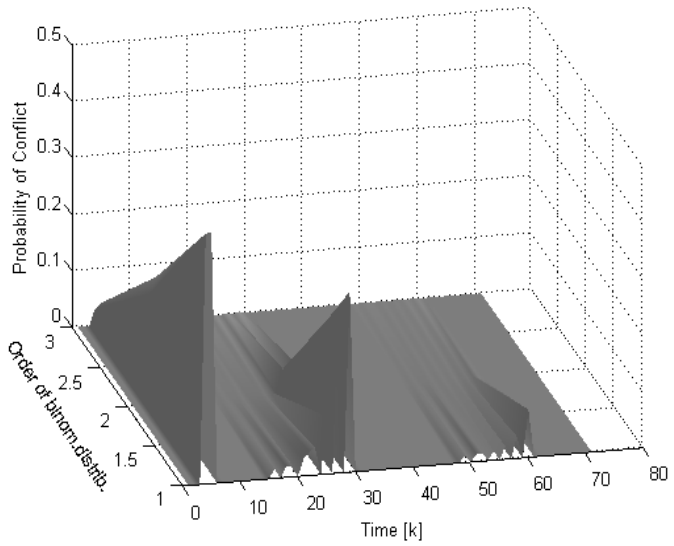


a)

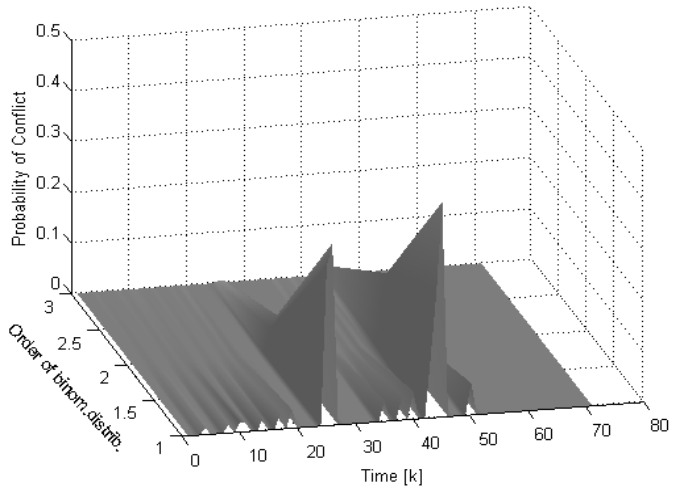


b)

Figure 5 – Time distributions of conflict probability at the noise variance $\sigma^2 = 0.04$
a) test scenario 1 and b) test scenario 2
Рис. 5 – Временные распределения вероятности столкновений при дисперсии шума
а) тестовый сценарий 1 и б) тестовый сценарий 2
Слика 5 – Временска расподела вероватноће судара при дисперзији шума $\sigma^2 = 0.04$*, а) тест-сценарио 1 и б) тест-сценарио 2*

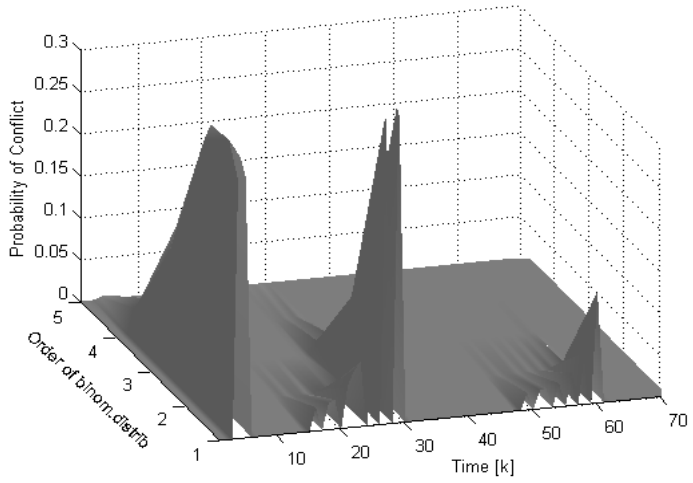


a)

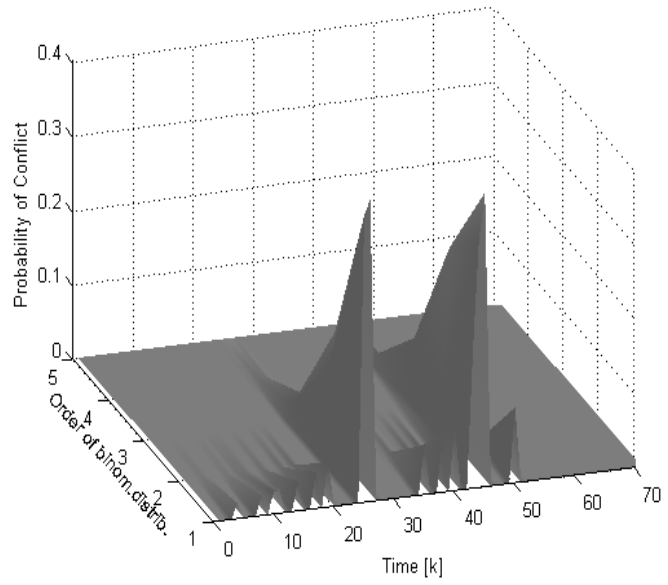


b)

Figure 6 – 3D conflict probability at the 3rd-order binomial distribution a) test scenario 1 and b) test scenario 2
Рис. 6 –Трехмерная вероятность столкновения при биномиальном распределении 3-го ряда
Слика 6 – Тродимензионална вероватноћа судара у биномној расподели 3. реда

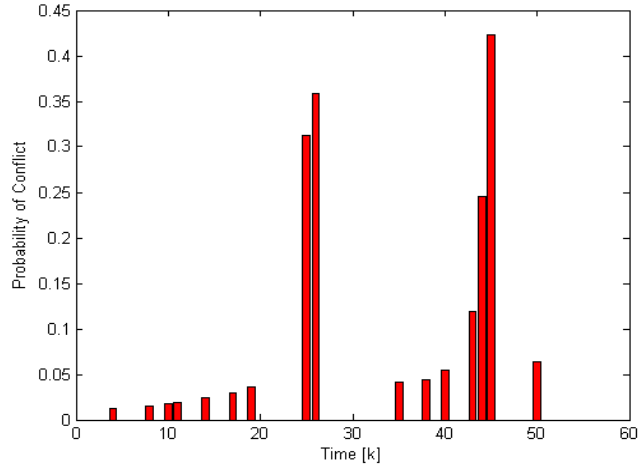


a)

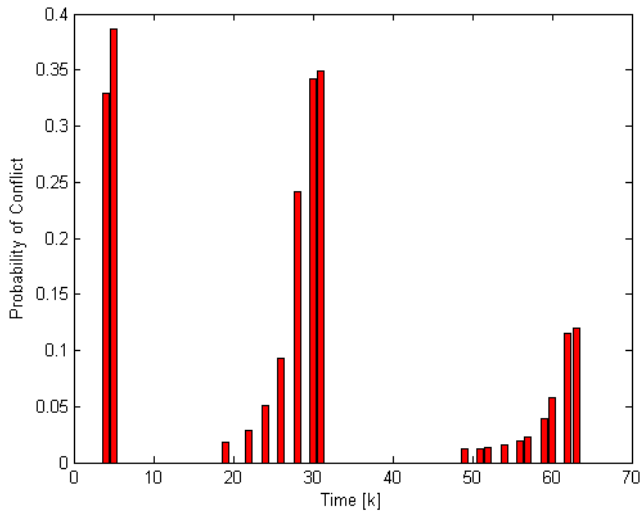


b)

Figure 7 – 3D conflict probability at the 5th-order binomial distribution a) test scenario 1 and b) test scenario 2
Рис. 7 – Трехмерная вероятность столкновения при биномиальном распределении 5-го ряда
Слика 7 – Тродимензионална вероватноћа судара у биномној расподели 5. реда



a)



b)

Figure 8 – 2D distributions of conflict probability at the noise variance $\sigma^2 = 0.02$
a) test scenario 1 and b) test scenario 2
Рис. 8 – Распределение вероятности столкновения при дисперсии шума $\sigma^2 = 0.02$ *а) тестовый сценарий 1 и б) тестовый сценарий 2*
Слика 8 – Расподела вероватноће судара при варијанси шума $\sigma^2 = 0.02$*,*
а) тест- сценарио 1 и б) тест-сценарио 2

The simulations results validate the probability data association algorithm, incorporated in the conflict detection method, and achieve good balance within two trajectories of flight. Finally, it could be easily observed that the conflict probability function rapidly increases into the validation region. The algorithm could be used to detect a conflict early enough to take a safe resolution maneuver if a neighboring aircraft starts a maneuver which might cause a conflict.

Conclusion

A new aircraft collision algorithm, by the use known PDAF algorithm, based on binomial distribution is presented in this paper. The common approach is calculating probabilities of all possible label-target assignments at each time step in the system. In that sense, we develop a probabilistic methodology, using track data association which can efficiently compute conflict probability. The proposed algorithm can detect a conflict early enough to take a safe resolution maneuver. For the track data association process, we proposed the PDA filter. In order to compute a function of conflict probability, we have constructed an algorithm based on binomial distribution which considers information about previously estimated states of positions. Based on the PDAF probability, the ATC system is able to send an alarm to the aircraft during a sampling interval.

For safety verification, we needed to apply the proposed algorithm to other types of radar sensors with a sampling interval shorter than the sampling interval of TWS radar sensors. Also, we will test the proposed method using other algorithms for hybrid estimation and data association such as IMMJPDA (de Feo et al, 1997), (Paielli & Erzberger, 2012), MHT (Nolan, 1998) or IMMPDAF.

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ПРОГНОЗ ВОЗМОЖНОСТИ СТОЛКНОВЕНИЯ ВОЗДУШНЫХ СУДОВ НА ОСНОВЕ БИНОМИАЛЬНОГО РАСПРЕДЕЛЕНИЯ

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РУБРИКА ГРНТИ: 27.43.00 Теория вероятностей и математическая статистика,
28.15.00 Теория систем автоматического управления
78.21.49 Военная электроника и кибернетика
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме

Введение/цель: На основе биномиального распределения функции плотности вероятности в данной статье представлена новая вероятностная модель для прогнозирования местоположения самолета.

Методы: Предложенный алгоритм состоит из трех составляющих: сбор данных, мониторинг / оценка гибридного состояния и расчет вероятности столкновения. Информация о текущем местоположении и траектории полета используется для получения алгоритма предупреждения возможности столкновения между воздушными судами. Прогнозирование ситуаций, в которых воздушное судно может приблизиться к другому на большом расстоянии, рассчитывается с высокой вероятностью. Оценка позиции и неопределенность относятся к идентификации данных целей, когда две траектории попадают в «окно» валидации с использованием фильтра идентификации данных по вероятности.

Результаты: Разработан и протестирован эффективный алгоритм для предупреждения столкновений при сопровождении групповой цели.

Выводы: Результаты моделирования предотвращения столкновений самолетов, выполненного по двум сценариям траекторий подтверждают эффективность предложенного алгоритма.

Ключевые слова: автоматическое управление, вероятность, отслеживание целей, идентификация данных.

ПРЕДИКЦИЈА СУДАРА АВИОНА НА ОСНОВУ БИНОМНЕ РАСПОДЕЛЕ

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ОБЛАСТ: математика, рачунарска техника, аутоматско управљање
ВРСТА ЧЛАНКА: оригинални научни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Увод/циљ: На основу биномне функције густине расподеле вероватноће, у овом раду је представљен нови вероватни модел предвиђања положаја ваздухоплова.

Методе: Предложени алгоритам састоји се од три различита блока: придруживање података, праћење/процена хибридног стања и израчунавање вероватноће судара. Информације о њиховим тренутним положајима и плановима лета користе се за добијање алгоритма за откривање могућих судара између ваздухоплова. Предвиђање ситуација у којима се ваздухоплов може приближити другом на већој удаљености израчунава се с великом вероватноћом. Процена положаја и неодређеност односе се на придруживање података циљева, када у „прозор" валидације падну два трага коришћењем филтра са придруживањем података по вероватноћи.

Резултати: Дизајниран је ефикасан алгоритам за откривање судара, који се тестира на многим вишеструким праћењима циљева.

Закључак: Резултати симулације превенције судара авиона у два сценарија путање потврђују ефикасност предложеног алгоритма.

Кључне речи: аутоматско управљање, вероватноћа, праћење циљева, придруживање података.

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IMPROVED CHEMICAL TREATMENT OF SUŠICA SURFACE WATER, ZLATIBOR AREA, AND SLUDGE APPLICATION

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FIELD: Chemical Technology
ARTICLE TYPE: Original Scientific Paper
ARTICLE LANGUAGE: English

Abstract:

Introduction/purpose: Sušica source surface water varies in natural organic and inorganic impurities, biological species and micro-organisms. This water is used instead of Vrutci lake water that has been stronglly affected by eutrophication. These waters need removal of pollutants with coagulants and polyelectrolyte. The aim of research was to improve the surface water treatment (coagulation and flocculation), to reduce sludge amount and to evaluate its quality, treatment and application.

Methods: The physical-chemical methods are developed for determining the quality parameters of water, sludge and compost. These parameters are: turbidity, $KMnO_4$ consumption, metals, total organic carbon, total nitrogen, and chlorophyll.

Results: Surface water quality has a strong impact on sludge. The concentrations of metals in the sludge were: 72200 mgkg-1 Al, 8550 mgkg-1 Fe, and 106 mgkg-1 Zn. The metals over the maximum limit were: Ni 169 mgkg-1, Cr 69.5 mgkg-1, Pb 5.7 mgkg-1, and they have to be reduced by zeolite. The „nutrients" concentrations were: 697 mgkg-1 P, 297 mgkg-1 K, 9.6 mgkg-1 total N, and 274 mgkg-1 of dissolved organic carbon. Escherichia coli and Salamonella are important for converting sludge to compost.

ACKNOWLEDGEMENTS: The researchers would like to thank the colleagues from the Public Health Institute Užice for peer support.

Conclusions: After maturation, compost can be used for Coriandrum sativum cultivation. In further work, this strategy should be applied to the water and sludge from Vrutci lake.

Key words: surface water, water flow, coagulation, flocculation, sludge, compost.

Introduction

Water is a public, renewable and easily accessible resource. Unfortunately, it is often not treated as a significant environmental, economic and social factor. United Nations experts estimate that in this year, 2020, two-thirds of people on Earth live in water-scarce areas. A large number of water bodies such as rivers, lakes, seas, and oceans are being affected by the eutrophication process. Due to geological aging and leaching from the surrounding catchment areas, the nutrient levels in water gradually increase and water bodies move from oligotrophic to eutotrophic. In this way, problems in Vrutci lake began. There was a significant decrease in dissolved oxygen concentration (DO) and increase in chemical oxygen demand (COD). Cyanobacteria bloom occurred, caused by eutrophication and global warming of these aquatic ecosystems. Similar results (Christophoridis et al, 2018.) were presented for algal blooms and the occurrence of cyanotoxins in 14 lakes in Greece, firstly determined by Elisa tests for several types of cyanotoxins (microcystins). Then the authors used microscopic identification with taxonomic keys, as well as liquid tandem mass spectrometry with electrospray ionization and chromatographic separation in multiple reaction monitoring mode (MRM) for the identification of all species and for their quantification. Cyanobacteria are photosynthetic prokaryotic organisms which reproduce rapidly, forming cyanobacterial "blooming" water. A prerequisite for the occurrence of cyanobacteria and their dominance is a decrease in the ratio of total nitrogen to total phosphorus (TN:TP) to a value of 10 or less. Phytoplankton has a great influence on the surface water quality, no matter which area – the Mediterranean area, the Marathonas Reservoir or Bubanj and Sumarice lakes - is a subject of investigation. Phytoplankton depends on the availability of CO_2, sun and nutrients. Phytoplankon degrading bacteria deplete water from oxygen and destroy living organisms. Phytoplankton is sizzling, but when it comes to water blooming, high concentrations of chlorophyll and other pigments appear as well as many species of algae (Katsiapi et al, 2011, pp .563–575), (Ranković et al, 2006, pp.107-114). The increase in phosphorus, an indicator of the occurrence of water blooming and the

development of phytoplankton, Planktothrix rubescens, from the Cyanobacteria group, was recorded in Vrutci Lake. Excessive contamination of the Vrutci lake water appeared as well as the development of pathogenic bacteria. As a result, the water treatment plant was not able to purify the modified water. Therefore, the Vrutci reservoir was disconnected from the water supply system and replaced with the surface raw water from the Sušica river source, Fig 1. The Sušica river is classified as type 6 of water and II-III surface water class, in accordance with the *Regulations on the parameters of the ecological and chemical status of surface waters and the parameters of the chemical and quantitative status of groundwaters* (Official Gazette of the Republic of Serbia, N^{o} 74/2011).

Figure 1 – Sušica river source
Рис. 1 – Исток реки Сушица
Слика 1 – Изворите реке Сушице

The water plant has been modernized: some lines have been reconstructed and some new lines have been built. In the process of treating surface raw water, besides the production of drinking water, waste water and sludge are generated as waste (including water with which filters have been washed and sludge after a sludge concentrator has been emptied). If drinking water is enriched with phytoplankton or other biological species as well as a lot of rainfall, it is necessary to use

more doses of chemicals such as Al-inorganic coagulants and organic flocculant, polyelectrolyte.

Figure 2 – Situation plan of the water supply plant
Рис. 2 – Ситуационный план для водоочистного сооружения
Слика 2 – Ситуациони план постројења за прераду воде

Figure 2 shows the situation plan (done by The Jaroslav Černi Institute for the Development of Water Resources, Belgrade, Serbia) and the reconstruction phases of the raw water treatment plant that operated in the "classical" way during 2017. At the very beginning of 2018, the first phase of reconstruction was released. This phase included the reconstruction of the part for the preparation of coagulants and laminar precipitators, as well as the construction of new objects: flocculation, ozone block and gas stations.

The sludge formation is mostly influenced by the quality of surface water, treatment processes (coagulation and flocculation), and the amount of water influx into the water treatment plant. The interdependence of raw water quantity in function of doses of chemicals was analyzed in the time before the technological reconstruction in 2017, with a classic water treatment and after the water plant reconstruction, with an improved treatment of the Sušica surface water in 2018. The technical improvement in the flocculation section included three speed mixing machines with reducer motors of different power that contribute to

more efficient flocculation. The „high quality“ flocculas are deposited on the laminar sedimentation tanks and after sapling sludge is obtained, undergoing dehydration by automatic dosing of polyelectrolytes. The reconstruction of the water plant also respected environmental principles and reduced the amount of generated sludge. Q. Malik dealt with similar issues (Malik, 2018.) He presented the method for reducing the generated sludge amount during the coagulation/flocculation process and for minimizing costs of deposition of by-products from the water treatment process. When surface water is treated with Al-sulphate, the pH of the treated water increases as a consequence of the high degree of basicity of this coagulant. Compared to other coagulants, Al-sulphate has lower efficiency. The optimal technological conditions for removing high turbidity are chosen. For example, for 250 NTU turbidity is removed with Al-sulphate doses of 0.25 g/l, pH 6, with the deposition time of 30 minutes. The similar concept of a physico-chemical treatment (coagulation-flocculation) is applicable (Aguilar et al, 2005, pp.47-56) to waste water, using anionic polyacrylamide as an additional chemical for improving coagulation, optimizing the rate of flocculation. The optimum rate and the mixing time for a given degree of flocculation were consistent with the pH and the doses of the coagulant/flocculant. Chemical oxygen demand (COD), biochemical oxygen demand for 5 days (BOD_5), and total suspended particulate matter (TSS) were determined at the beginning and the end of each experiment to monitor the process of waste water clarification. Once the optimal conditions were established, other parameters were also measured to evaluate the coagulation/flocculation process: number and size of particles, sludge volume, nutrients (ammonia, nitrogen, total Kjeldahl nitrogen, orthophosphate, total phosphorus), and residual Fe^{3+} and Al^{3+} concentrations in purified water. Anionic polyacrylamide, added with Fe-sulphate or polyaluminum chloride, led to a significant increase in the deposition rate.

The process of treating raw surface water involves bringing colloidal particles to a certain range, during the process of clarification, i.e. coagulation/flocculation of water, thereby reducing the content of colloidal particles, performing discharging and aggregation. The next phases in removing pollutants are the removals of chemicals in excess and metabolic products through the processes of precipitation and filtration**.** The most commonly used coagulants are aluminum salts (sulphates or polychlorides) or iron salts. The chemistry of aluminum in surface water is described by complexation reactions during the coagulation/flocculation process:

1. aluminum and inorganic ligands, sulphates, phosphates, hydroxyl ions,

2. aluminum and organic ligands, aluminum-humic matter,

3. reactions of formation, monomers, polymers and precipitation formation:

- monomeric types of aluminum, Al^{3+}, $Al(OH)^{2+}$, $Al(OH)_2^{+}$, $Al(OH)_3$, $Al(OH)_4^{-}$
- polymer species, $Al_2(OH)_2^{4+}$, $Al_3(OH)_4^{5+}$, $Al_{13}O_4(OH)_{24}^{7+}$
- precipitate $Al(OH)_3$, (s).

Cvijović and Djurdjevic in some papers (Cvijović et al, 2012, pp.1087-1097), (Cvijovic et al, 2012, pp.313-322), (Djurdjevic et al, 2005, pp.1615-1629) presented the results of studing monomeric species, polymeric species that form during complexation and hydrolysis of Al^{3+} ions and amino acids and antibiotics. By varying a degree of neutralization, metal-organic ligand ratio, temperature, pH, the aging time of the Al-solution, mixing speed, different equilibrium species of aluminum and organic molecules are formed and with different yields. The amino acids and antibiotics ligands, in a similar way, bond to Al^{3+} ion as polyelectrolite, anionic polyacrilamide $(CH_2CHC{=}ONH_2)n$ across carbonyl oxygen and amino N. The experimentally obtained species formed between L-histidine (HHis) ions and Al^{3+} ions in aqueous solution, detected by UV spectrophotometry at 298 K were: $Al(HHis)^{3+}$, $Al(His)^{2+}$, $Al(HHis)His^{2+}$ or dimmer $Al_2(OH)His_2^{2+}$ with complex formation constants, indicators of complex stabilty: $\beta_{p,k,r}$, $\log \beta_{1,1,1} = 11,90 \pm 0,04$, $\log \beta_{1,1,0} = 7,25 \pm 0,08$, $\log \beta_{1,2,1} = 20,1 \pm 0,1$ and $\log \beta_{2,1,1} = 5,92 \pm 0,12$ (p, k, r are the stoichiometric indices of metals, ligands, and protons). The formed species detected by ^{27}Al NMR spectroscopy were: $Al(HHis)^{3+}$ and $Al(HHis)(His)^{2+}$ or $Al(OH)(HHis)_2^{2+}$ and Al_{13} polymer. The polymer $Al_{13}O_4(OH)_{24}^{7+}$, a major species formed in water solution of polyhydro aluminum chloride is more effective in water clarification (coagulation / flocculation), than Al- sulphate. Speciation occured similarly in fresh water with Al^{3+} or Fe^{3+} ions, most probably with similar complex formation constants. The species formed of Al^{3+} ion and antibiotics were investigated in water solution by tandem mass spectroscopy (Cvijovic et al, 2012, pp.313-322). The antibiotics ligands are often waste water contaminants.

This paper presents the results when the surface water from Vrutci lake was replaced with the surface water from the neighboring Sušica river source, i.e. the comparison of the amounts of chemicals used before and after the reconstruction of the water treatment plant; it also

presents the amount of sludge in a conventional water treatment and improved technical–technollogical water treatments with reduced quantities of chemicals, which reduced sludge amount and resulted in higher efficiency and economical results.

The improvement also concerned the validation of physico-chemical methods based on instrumental techniques in the laboratory of the water treatment plant. The methods were applied for the analyses of surface water and generated sludge, assessing whether such sludge can be used for composting or growing medicinal plants or other species, in accordance with standard SRPS Z.T1.100:2017 (Institute for Standardization of Serbia, 2017), which prescribes clear requirements for the composting process, the selection of input materials and the minimal quality of the composted materials.The treatment of this sludge involves the removal of aluminum, because Al is considered to be a detrimental element. Sludge needs removal of toxic metals that are above the maximum permissible value. The treatment should be done by zeolite, as a real time removal of toxic metals (Kerkez, 2014) or by fitoremediation that is a long-standing way of treating metal-contaminated soil or sludge (Čudić et al, 2016, pp.229-239).

The environmental and economic effects of coagulation were also the focus of authors (Keeley et al, 2014, pp.2675-2719), as well as a possibility of recovery, separation of the coagulant and its re-use in drinking water treatment.

The aim of the research was to improve the Sušica source surface water treatment especially through coagulation and flocculation processes, to reduce chemical dosing amounts and generated sludge amounts, as well as to evaluate sludge quality, treatment and application. Instead of piling up waste by being taken to a landfill (used as land breeder), the generated sludge from Sušica will be converted into compost for growing medicinal herbs as a permanent solution after its treatment (toxic metal removal by zeolites as the fastest removal method and conditioning sludge).

The same strategy is intended to be applied to the surface water sludge from the Djetinja river, accumulated in Vrutci Lake, if sludge is not hazardous. But if the quality of surface water is deteriorating because the concentration of blue-green algae increases, the so-called cyanobacterial blooming occurs and sludge becomes dangerous, loaded with cyanotoxins, different strategy must be applied.

The experimental part

Within the experimental part, some standard methods were used and some were developed as „new“ ones for the analysis of the most useful physico-chemical and biological parameters for surface water, treated water and sludge: turbidity, pH, electroconductivity, $KMnO_4$ consumption, total organic carbon (TOC), total Kjeldalh nitrogen (TKN) phosphates, and chlorophyll a,b,c (biological parameter). The microbiological parametres were determined by standardised methods. These parameters are "common" for achieving the higher objective of respecting green environmental chemistry principles, assessing the management of the process of coagulation and flocculation with aluminum sulphate (or polyaluminum chloride) and polyectrolyte during the removal of natural organic matter (NOM), inorganic matter, pollutants, metals and sludge. Crops are estimated to be capable of growing on sludge converted to compost, but only after toxic metal overrange reduction and maturation. The investigated biological parameters were: phytoplankton, qualitative and quantitative, Chlorophyll a, b, c, nematodes, and zooplankton. The microbiological parameters were: total coli, fecal coli, fecal enterococci, and the total number of aerobic mesophiles.

Reagents

The chemicals of p.a. purity or ultra pure, of the world's most trusted manufacturers, were used.

Al strip, 99.997%, Merck, Darmstadt, Germany.

Hydrochloric acid , HCl, 36,5-38 %, p.a, J.T.Baker, USA.

Sulphuric acid, H_2SO_4, p.a, 98%, Fisher, USA.

Aluminum by the Eriochrome Cyanine method reagent set contains ECR-20 Reagent, Hexamethylenetetramine Buffer Reagent F20 and ECR Masking Reagent Solution, Hach, USA.

Ultra pure water, UPW voda, TOC ≤0.1 mg/l, Sigma Aldrich, USA.

Potassium permanganate, $KMnO_4$, p.a., Merck, Darmstadt, Germany.

The reagent stock solution is a concentrated mixture of phosphoric acid and ammonium persulphate, Hach, USA.

Nickel, metal pieces, 99.995 %, Merck, Darmstadt, Germany.

Lead, metal pieces, 99.995%, Merck, Darmstadt, Germany.

Chromium, metal pieces, 99.995% , Merck , Darmstadt , Germany.

Hydrochloric acid HCl, 30%, suprapure, Merck, Darmstadt, Germany.

Oxalic acid, $H_2C_2O_4$ x$2H_2O$, p.a. , Reagecon, Ireland.

Nitrogen, gas, 5.0, without CO_2, 200 bar, Messer, Serbia.

Sodium Hydroxide, NaOH, p.a., granules, Carlo Erba Reagents, France.

Boric acid, powder, p. a., Carlo Erba Reagents, France.

Tahiro indicator, Carl Roth, Germany.

The stock solutions: The stock solution of Al chloride 0.1 mol/L was prepared by dissolving the shredded aluminum strip, weighing 0.53974 g with 5 ml HCl and 1-2 ml redistilled water, with heating in a sand bath for several hours. The solution was dilluted with bidistiled water up to the 1 dm^3 mark of the volumetric flask. The solution concentration was precisely determined by the gravimetric analysis, so the concetration of Al was 0.1020 mol/L.

The stock solution of Ni 0.1 g/L was obtained by dissolving .0.1 g of Ni pieces in 10 ml of HNO_3 conc. acid, oxide removed and cooled down. Then the solution was dilluted with bidistiled water up to the 1dm^3 mark of the volumetric flask.

The stock solution of Pb 0.1 g/L was obtained by dissolving 0.1 g of Pb in 10 ml of concentrated nitric acid, after dissolution, evaporated to dryness and then redissolved with redistilled water up to the 1 dm^3 mark of the volumetric flask.

The stock solution of Cr 0.1 g/L was obtained by dissolving .0.1 g of Cr in 10 ml of concentrated HCl acid; after cooling, the solution was dilluted with bidistiled water up to the 1dm^3 mark of the volumetric flask.

$KMnO_4$ standard solution (0.02M) was prepared by dissolving 3.160 g $KMnO_4$ in 200 ml of redistilled water, supplemented up to the 1 dm^3 mark of the volumetric flask. It is stored in a dark bottle.

The standard solution of oxalic acid (0.1M) was prepared by dissolving 6.303g of oxalic acid with a little of redistilled water, added 50 ml of sulfuric acid (1:3) to conserve and dilluted with bidistiled water up to the 1 dm^3 mark of the volumetric flask.

The working solutions were made by diluting the stock or standard solutions with bidistiled water.

Instruments

1. Hach 2100N turbidimeter for turbidity measurement with calibration standards based on formazionic polymer: <0.1 NTU, 20 NTU, 200 NTU and 1000 NTU, Hach.

2. Stirrer, Velp scientifica, T range 0-350°C and rpm range: 0-1500

3. pH-meter, Infolab WTW, with glass electrode, pH range 0-14, resolution 0.01 pH; pH accuracy ± 0.01pH units, with buffers for calibration pH 4.00 (phthalate), pH 7.00 (phosphate), pH 9.00 (borate) Hach

4. Conductometer, HQ 440 d, multi with CRM standard 100 μS / cm ± 1 μS / cm, NIST

5. Automatic burette, Tirette 50 ml, Class A, Brand,

6. Spectrophotometer, Lange DR 6000, Hach, with Hach software, vers. 11, with UV and VIS lamp, 1cm and 5cm quartz and glass cells, for the analysis of true and apparent water color (in Co-Pt units) and Al concentration (using manufacturer's method with commercial reagents and methods with „classical" solutions of eriochrome-cyanine and aluminon, after forming calibration curves). The compared results of different methods showed good agreement. The instrument was also used for the determination of UV extinction at 254 cm^{-1}, chlorophyll a, b, and c (where absorbances were measured on two wavelengths: 665 and 750 nm), nitrogen compounds and ortho–phosphates and total phosphorous .

7. TOC analyzer. (total organic carbon analyzer) Qbd 1200 with autosampler, Hach, with a UV lamp, a burette for persulphate reagent addition and a non-dispersive IC detector, NDIR. The measuring range is from 0.4 μg/L to 100mg/L, with the accuracy of 3%, calibration standard, manufacturer's cuvettes, and nitrogen gas 5.0.

8. Gerhardt analytical system for the determination of total nitrogen from different matrix (water, sludge, food) by Kjeldah (with three units Gerhardt Turbotherm with 4 digestion cells, for sample destruction, Turbosoq, centrifugal rinse for inorganic gases and vapors and Gerhardt Vapodest 200, unit for distillation and a volumetric titration burette of the resulting solution after digestion and distillation. The reference material (RM) solution is prepared of histidine nitrogen, conc. 5 mg/l. The sample with 2 drops of Tahiro indicator is titrated with 0.1M hydrochloric acid until the color changes from slightly green to pink.

9. Laboratory mini plant, Jar Test FC6S, Velp Scientifica, consisting of four $2dm^3$ jars with supernatant sample taps, with programmable speed and time settings and a possibility to adjust coagulant and flocculant doses.

10. ICP-OES spectrometer, ICAP Pro for metal concetration analysis, Rf generator, 27 MHz, 167-852nm wavelength range, 7 ppm resolution, multi-element analysis, 99.999% argon used as carrier, nebulization and plasma forming gas, with a nebulizer, a torch (burner),

quartz or glass, depending on the acids used for sample preparation, Thermo Scientific.

Sample preparation

a) The procedure for raw surface water sample preparation

A preferably fresh raw water sample is taken in a specified volume in accordance with the method. Some samples were filtered through 0.45μm filter before measuring.

b) Procedure for sludge sample preparation

1 dm^3 of sludge is taken, the liquid part is decanted and the rest dried at 104°C for 5 hours. Most analyses were done from dry sludge calculated for the mg/kg weight, and a few analysis were done from decanted liquid.

c) Procedure for compost sample preparation

1 kg of compost is taken and put to dry till constant mass for most analyses and the results are calculated for the weight in mg/kg. Sampling and sample preparation were carried out in accordance with the appropriate standards (SRPS or EPA).

d) Kjedalh total nitrogen is determined by a modified method adapted for this type of samples using standard SRPS ISO 1871:2013 (Institute for Standardization of Serbia, 2013) and Gerhard methods for total nitrogen in water, adapted for given samples and conditions, with all tests for method validation.

e) TOC/DOC is determined by standard SRPS ISO 8245, 2007 (Institute for Standardization of Serbia, 2007) adjusted for water samples and for dissolved organic carbon (DOC) from sludge, where samples are filtered through a 0.45μm size filter. The method was developed by validation principles.

f) Aluminum concetrations in surface water, water from different stages of the treatment process, waste water, residual, and sludge were determined spectrophotometrically. The method with commercial reagents was compared with classical methods with solutions of eriochrome cyanine and hexamethylenetetramine, as well as with aluminon, with six standard solutions. The calibration curve equation was C =0.015+0.8217A. The linearity coefficient was R^2=0.9997. The three

compared aluminum quantification methods give results in very good agreement, no matter the sample matrix.

Water Treatment Plant - Chemicals

The following chemicals of technical purity were used in the water treatment: Coagulant $Al_2(SO_4)_3X18H_2O$, class A, Marking ltd, or $Al_nCl_{(3n-m)}(OH)_m$, Impuls hemija ltd, used occasionally**,** Polyelectrolyte anionic, Settafloc AP -17, SNF s.a.s

Water Treatment Plant – Part for coagulation and flocculation

I * Saturator for aluminum sulphate stock solution preparation, with centrifugal pumps for mixing a solution, Technique KB, Belgrade

* Pools, where the stock solution of Al-sulphate dilutes with water, after aging, up to a required concentration, and the pumps (piston-membrane) for pumping the Al-sulphate solution, Technique KB, Belgrade

* Dosage unit for Al-sulphate with the ProMinent pump Heidelberg, Germany, power 0.55 κW, and a dosing speed of 1033 l/h with an Omron frequency control for speed adjustment

II * Flocculation Part with Prominent instruments for making a solution of polyelectrolyte and dosing it into water, and with spectra type Prominent pumps with a capacity of 650 L/h. The preparation of a solution of polyelectrolyte with ultrasonic control of the added polyelectrolyte amount, with a Siemens control unit and 3-speed flocculation mixers: a small mixer rated at 3kW, 11 rpm, a medium one at 2.2 kW and 5.7 rpm (turnover per minute) and a large mixer driven by an engine of rated power of 1.1 kW, with 2.7 rpm, Strojna, Maribor

III * Precipitator automated and cotrolled by SCADA software, ver 2.0, for remote and process control; sludge discharge valves towards the lagoons, where closing and opening of the valves is carried out from the Schneider Electric substation

Results and discussion

The paper deals with the treatment of surface water and the amount of sludge generated in the case of using surface water from the Sušica river, before and after technically-technologically upgrading the water treatment plant. The treatment of raw water also includes ozonization and filtration processes with sand, quartz filters and activated carbon filtration. Water treatment also includes disinfection with chlorine gas.

In the extended physical-chemical analysis of the surface water from the Sušica sources (Small and Large Source), the following was determined: 0.026mg/l of aluminum, 0.027mg/l of iron, 0.013mg/l of barium, and 0.079 mg/l of strontium. The concentration of phosphorous is 0.015 mg/l while that of boron is 0.04mg/l. The quality of raw water is continuously monitored to assess which chemicals (and how much of them) should be added to produce hygienically safe drinking water. During the jar tests at the laboratory conditions, the coagulant and flocculant doses were adjusted, in accordance with the surface water quality and the optimal speed for stable flocule formation and then transferred to the water treatment plant. In the flocculation section in the water plant, the 3-speed mixer helped to better manage the process. The pollutants removed by coagulation & flocculation are: turbidity (removal efficiency over 95%), alkali metal ions (calcium, removal efficiency 29%), dissolved silica, bacteria, algae, apparent, true Pt-Co dye, organic compounds, oxidized iron, manganese, clay particles, and aluminum ions (Nishat Ashraf et al, 2018, pp.187-199).

These compounds undergo alkaline hydrolysis in the alkaline medium, producing positively charged, insoluble, voluminous hydroxides. The hydroxides have a large adsorption surface and attract oppositely charged (negative) colloids, thus neutralizing their charge (aluminum ions). During flocculation, polyelectrolytes increase the volume and cohesion properties of colloidal particles, accelerate coagulation and improve its effects.

The presented graphs show the dose dependence of aluminum as a coagulant on the amount of raw water discharged to the water plant treatment during 2017 when water treatment was still classical, and in 2018, when water treatment was improved. In both cases, raw water comes from the Sušica sources.

Sušica River, classical method of water treatment - February 2017

The amounts and doses of coagulants and flocculants depend on the amount of water entering the plant and the quality of raw water which depends on climatic conditions (such as season, temperature, rainfall, snow, global warming, and imbalance in aquatic ecosystems). In the tables given below, the parameters present the quality of surface raw water in the selected month. Using this data, jar tests are used to adjust coagulant and flocculant doses as efficiently as possible (Nishat Ashraf et al, 2018, pp.187-199). The goal is to compare the amounts of sludge generated during 2017 and 2018 and to evaluate a possibility of its

application (for composting) in the case of the surface water from the Sušica sources. The water treatment plant doubled its capacity after the reconstruction. Owing to the improvement in the key processes, i.e. in coagulation and flocculation, the amount of waste sludge was reduced. Then, after checking its quality and after dehydration and removal of toxic compounds, sludge could be applied in agriculture.

Table 1 – Results of physico-chemical analysis of surface water, February 2017.
Таблица 1 – Результаты физико-химических анализов поверхностных вод в феврале 2017 года
Табела 1 – Резултати физичко-хемијских анлиза површинске воде у фебруару 2017. године

	Parameter	Units	Water		
			Raw	Treated	MPV*
1.	Temperature	°C	7.7	8.7	8-12
2.	Turbidity	NTU	6.1	0.4	1
3.	pH	-	7.7	7.5	6.8-8.5
4.	Total alkalinity ($CaCO_3$)	mg/L	210	190	-
5.	KMnO4 cosumption	mg/L	17.1	10.9	8
6.	Electroconductivity	µS/cm	376	371	1000
7.	Aluminum	mg/L	0.026	0.032	0.2
8.	Chlorides	mg/L	14	16.5	100
9.	Sulphates	mg/L	17	49	250
10	TOC	mg/L	-	-	5.0**
11.	Total hardness ($CaCO_3$)	mg/L	236	233	-

MPV*- refers to II-III surface water class - type 6, Official Gazette of the Republic of Serbia, No 74/2011, Regulations on the parameters of the ecological and chemical status of surface waters and the parameters of the chemical and quantitative status of groundwaters.

MPV** - maximum permissiblle (concentration) value, according to the Official Gazette of the SRJ, No 42/1998, 44/1999, Official Gazette of the Republic of Serbia 28/2019, Rulebook on the Hygienic Safety of Drinking Water.

During the winter period, the turbidity of the Sušica source water increased 6 times over the MPV and the consumption of $KMnO_4$

increased up to 2 times, which indicates the burden on natural organic matter. In order to make this water hygienically correct, it was treated with chemicals. The dosage of Al-sulphate and polyelectrolyte, as a function of the amount of inlet water per day, is shown graphically for February 2017, Figure 3a. The coagulant dose is low because the water was of average quality from the physico-chemical point of view (average and uniform total carbonate hardness, i.e total alkalinity for the Sušica source) and from the biological point of view. This water periodically requires more chemicals because the spring is variable due to rainfall and water temeperature that cause variations of biological species and their abundance. The microbiological Sušica water status during February 2017 required higher doses of disinfectants, because Coliform, total coliform bacteria of fecal origin and total aerobic mesophilic bacteria were above the maximum prescribed. The nitrate concentration was 7.2 mg/l. The used coagulant was aluminum sulphate that binds efficiently with pollutants.

The treatments of raw water in February 2017 and February 2018 are compared and graphically presented as a relationship of the doses of Al- sulphate, i.e polyelectrolyte as a function of the amount of raw water per day, Figures 3a, 3b.

Turbidity indicated an increase in suspended matter: clay, silt, well-arranged organic and inorganic particles. Phytoplankton and microorganisms and ranged from 2.9 to 6.1, so the doses of Al-coagulant and polyectrolyte were higher for medium hard Sušica source water, between 5 and 7 days of February 2017. After the treatment of the Sušica water of this quality, drinking water, waste water and sludge were produced in the plant. In February, out of the total amount of raw water of 480,418 m^3 introduced into the water treatment plant, the amount of generated sludge was 6,586 m^3. During the autumn and winter months, especially in November and December 2017, more sludge was generated because turbidity and organic and inorganic pollutants in water increase due to low water temperatures of 7.7 °C which causes the solubility of gases (oxygen and carbon dioxide). So, oxygen increases in water, due to the increased degradation of organic matter and the development of living organisms, as well as the increased photosynthetic processes, which is also confirmed by the increased $KMnO_4$ consumption (atmospheric pressure also influences the rise in oxygen content). Based on Henry's law, decreasing temperature leads to an increase in the solubility of gases in water (O_2, CO_2) as well as in turbidity (due to more rainfall). At lower T, the coagulation process is slower and with less efficiency.

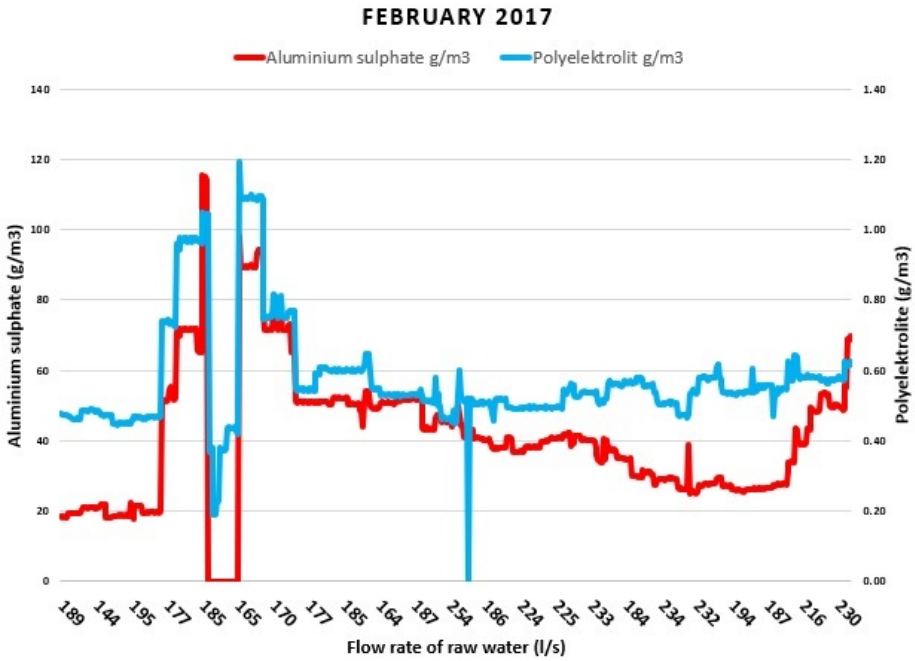

Figure 3a – Dependence of the concentration of added aluminum sulphate and polyelectrolyte on the flow rate of raw water during February 2017
Рис. 3а – Взаимозависимость концентрации добавленного сульфата алюминия и полиэлектролита и протока сырой воды в течение февраля 2017 года
Слика 3а – Међусобна зависност концентрације додатог алуминијум сулфата и полиелектролита од протока сирове воде у току фебруара 2017. године

Sušica River, after the water supply plant reconstruction - February 2018

During February 2018, the same Sušica source water was used, but the flocculation and deposition part of the water treatment plant was improved after reconstruction, so it was expected that the amount of sludge generated would be lower as the flocculation process was improved with 3 stirring speeds and lamellar precipitators as well. However, during February 2018, the facts were opposite to the expectations, because the quality of raw water was "above" the technical improvement of the water plant functioning (physico-chemical characteristics, microbiological and biological status deteriorated). Figure 3b shows that the amount of added polytherolite increased almost twice, 1.2 g/m^3 in comparison to February 2017. Raw water coloration was 10 Co-Pt units, effectively removed by the coagulant. The coloration was

most likely derived from nutrient enrichment of water, eutrophication, at low water temperatures which stimulate the production of algae and also increase turbidity (1.6 NTU), increased $KMnO_4$ consumption and nitrates up to 5.2 mg/l. Algae contain chlorophyll in their cells, determined as chlorophyll a, b, and c on the DR 6000 UV-VIS spectrophotometer. In cold water, more decomposed organic matter accumulates at greater depths, thus leading to a reduction in the quality of fish life conditions. An increased amount of polyelectrolyte up to 2 times, caused by the deterioration of raw water quality, for almost the same amount of water inlet of 473,418 m^3, generated an increased amount of sludge up to 7,274 m^3 when compared to February 2017(when it was 6,586 m^3). The microbiological status indicated that total coliform bacteria were over 161 and that coliform bacteria of fecal origin were present in the number higher than 161; streptococci of fecal origin and Citrobacter spp were also isolated – therefore, water purification and desinfection were intensified.

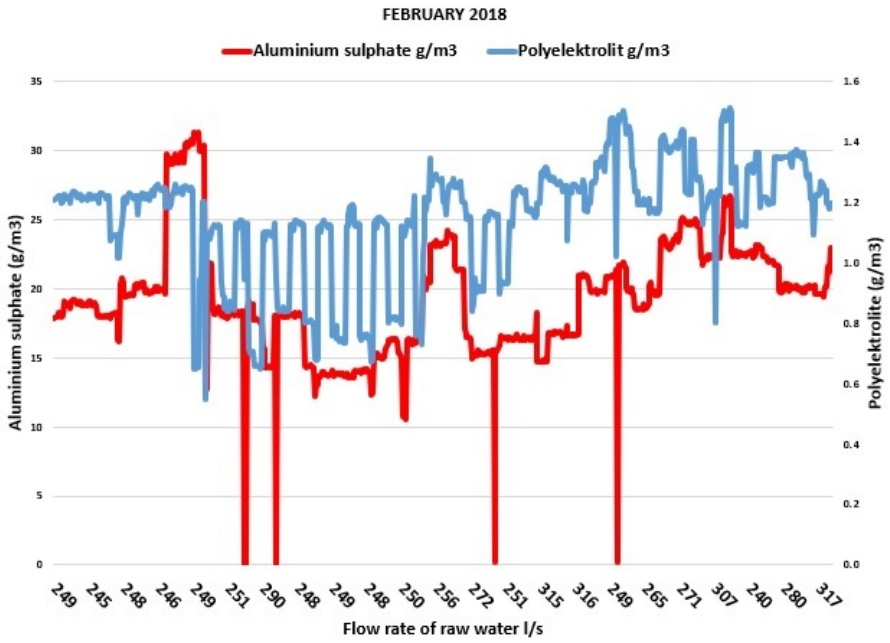

Figure 3b – Dependence of the concentration of added aluminum sulphate and polyelectrolyte on the flow rate of raw water during February 2018
Рис. 3б – Взаимозависимость концентрации добавленного сульфата алюминия и полиэлектролита и протока сырой воды в течение февраля 2018 года
Слика 3б – Међусобна зависност концентрације додатог алуминијум сулфата и полиелектролита од протока сирове воде у току фебруара 2018. године

Sušica River, classical method of water treatment - April 2017, extended analysis

Table 2 gives the results of the extended analysis of the surface water during April 2017. The parameters relevant for water and sludge quality are: TOC, UV extinction at 254 nm, total Kjedalh nitrogen, chlorophyll a, total phosphorus, and ortophosphates.

Table 2 – Results of the physico-chemical analysis of surface water, April 2017, extended analysis
Таблица 2 – Результаты физико-химических анализов поверхностных вод в апреле 2017 года (расширенный анализ)
Табела 2 – Резултати физичко-хемијских анлиза површинске воде у априлу 2017. године (проширена анализа)

N	Parameter	Units	Water		
			Raw	Treated	MPV*
1.	Temperature	C	8	9.2	8-12
2.	pH	-	7.4	7.3	6.8-8.5
3.	Electroconductivity	µS/cm	538	415	1000
4.	Turbidity	NTU	1.5	0.2	1
5.	Total hardness ($CaCO_3$)	mg/l	270	265	-
6.	Total alkalinity (CaCO3)	mg/l	245	220	-
7.	Chlorides	mg/l	13	14	100
8.	Sulphate	mg/l	12	35	250
9.	Aluminum	mg/l	0.018	0.032	0.2
10.	$KMnO_4$ cosumption	mg/l	8.8	6.4	8.0
11.	TOC	mg/l	3,63	1.22	5.0 **
12	UV extinction at 254 nm	1/cm	0.124	0.021	
13	Total Kjeldalh nitrogen	mg/l	2.54	-	
14	Ortophosphates	mg/l	0.06	-	0.10**
15	Total phosphorus	mg/l	0.032	-	0.15**
16	Chlorophyll a ,b, c	µg/l	2.92	-	
17	Potassium	mg/l	1.0	-	

These parameters and metals are important in the compost quality evaluation. Some instrumental methods were developed on the basis of standards, adapted and improved, as well as tested according to the principles of accredited methods (repeatability, accuracy, potential sources of errors tested, limit of detection, limit of quantification, and measuring uncertainty).

The determination of total organic carbon (TOC) is the most valid indicator of organic matter in surface water, because there is a complete degradation of a sample caused by the reagent stock solution, i.e. a concentrated mixture of phosphoric acid (to aid in removal of CO_2 from solution) and ammonium persulphate (to aid in oxidizing organic compounds) and UV radiation. The TOC method was developed for water samples and used for sludge, as well. Firstlly, the calibration curve was constructed after measuring the peak area (of total organic carbon) as a function of the TOC concentration in the calibrated standards. Every calibration standard was with 3 times repeated measurement, for the concentration range from 1000 to 5000 ppb. The calibration curve equation is $Y = 9.23x + 25.92$. The linearity coefficient is $R^2=0.9997$. Blank was analyzed before each analysis. Tests for reproducibility, precision, as well as limit of detection and limit of quantification were done. Distilled, redistilled water and ultra pure water (upw) were analyzed before the samples of interest. There were some variations with distilled and redistilled water regarding the TOC results. When distilled, redistilled and ultra pure water were analyzed, it was observed that distilled water flowing through the ion exchange resin showed higher and variable values of TOC, because the resin was saturated, impured. The impurity of resin was noticed to affect the TOC results, as well as the electroconductivity results for distilled water. This problem was solved by replacing the ion exchange resin.

The TOC samples of surface water and sludge as well as the samples from the water treatment process were randomly analyzed with repetition, day by day. The effects of larger diameter particles present in water during treatment with coagulants and flocculants were also analyzed. The formed particles of aluminum sulphate and polyelectrolyte with impurities from the precipitate, over 100 μm, (where the concentration of Al was in a range of 0.78-0.92 mg/l) had difficulty in degrading by the action of UV radiation and a mixture of phosphoric acid and ammonium persulphate reagent. On the contrary, during the total organic carbon analysis, the degradation of the surface fresh water samples was easy and repeatable. Besides the contamination of distilled water, redistilled water can be contaminated with CO_2, if a vessel

remains open. Other sources of contamination have also been investigated. After removing a contamination source, the methods were rigorously tested up to the level of in-house validation and then accepted for the analyses of different samples. Upw water with 0.07 ppm TOC, redistilled water, and destilled water were first measured before other samples. Some samples were tested many times and after receiving valid results, they were conserved and accepted as an internal standard.

The literature data has shown similar problems with contamination and variable TOC results for destilled water chosen by other researchers (Meyers, 1998).

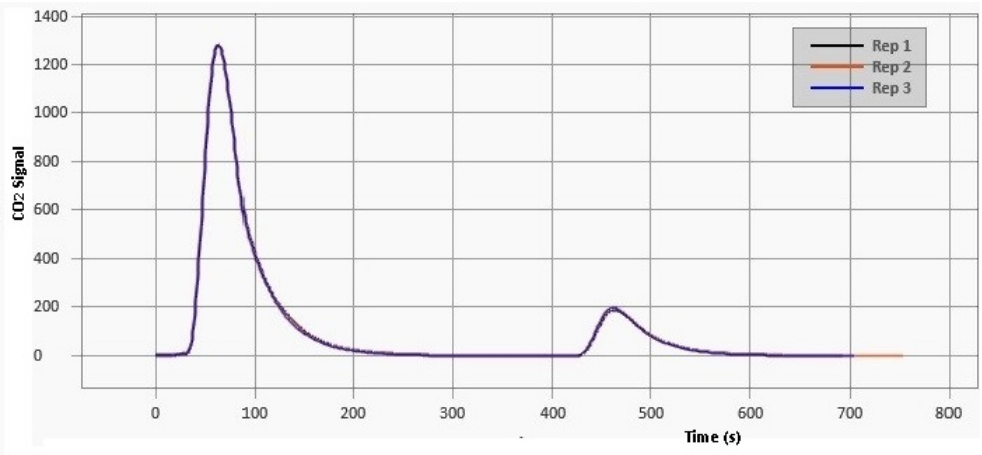

Figure 4 – TOC spectrum of surface water: the left high peak belongs to total inorganic carbon (TIC), the lower right one belongs to total organic carbon (TOC)
Рис. 4 – Спектр ТОС поверхностных вод: левый верхний пик относится к общему неорганическому углероду (TIC), нижний правый пик относится к общему органическому углероду (TOC)
Слика 4 – Спектар ТОЦ површинске воде, леви виши пик припада укупном неорганском угљенику (ТИЦ), а нижи десни пик укупном органском угљенику (ТОЦ)

The TOC method is developed by using standard SRPS ISO 8245 2007 (Institute for Standardization of Serbia, 2007) as basic literature, after many tests, improvements, and statistical evaluations for different matrix samples.

Chlorophyll a,b,c is an indicator of the biological status of raw surface water (photosynthesis and present algae). Chlorophyll a,b,c was determined spectrophotometrically by a DR 6000 device, as the difference of the measured absobances at 750 and 665 nm, from an ethanol solution. This method is validated with some improvements. The comparative method is formed on the basis of the standard and the

chlorophyll calculated by a formula as a difference in measuring absorbance at 634 and 675 nm and from a methanol and acetone solution, as well. The results are in good agreement, and in accordance with the results for similar samples, published by R.J. Ritchie (Ritchie, 2006, pp.27-41).

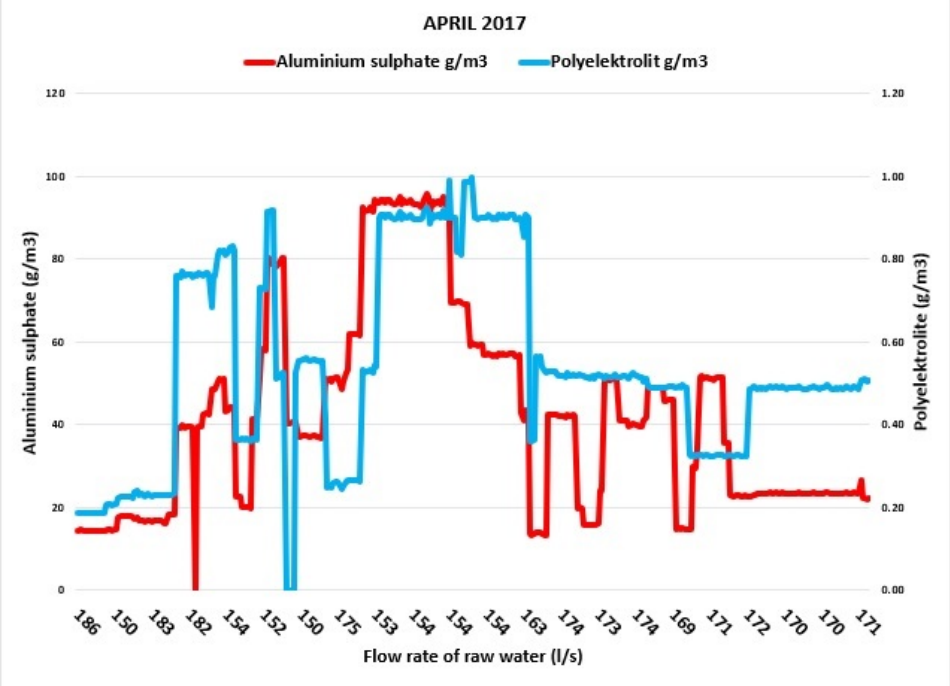

Figure 5a – Dependence of the concentration of added aluminum sulphate and polyelectrolyte on the flow rate of raw water during April 2017
Рис. 5а – Взаимозависимость концентрации добавленного сульфата алюминия и полиэлектролита и протока сырой воды в течение апреля 2017 года
Слика 5а – Међусобна зависност концентрације додатог алуминијум сулфата и полиелектролита од протока сирове воде у току априла 2017. године

Bearing in mind that the doses of chemicals are dependent on the quality and quantity of raw water, it can be seen that, during April 2017, the doses of Al-sulphate and polyelectrolyte varied, in accordance with April climatic variations: periods with sunny days, periods with snowy days when snow melted quickly and caused high turbidity of raw surface water. The temperature was low, i.e. variable, so the doses of chemicals were variable. The maximum chemical doses were from 12 to 15 (17) days of month. The quantity of 426,998 m^3 of raw water yielded 9,314 m^3 of sludge during April 2017.

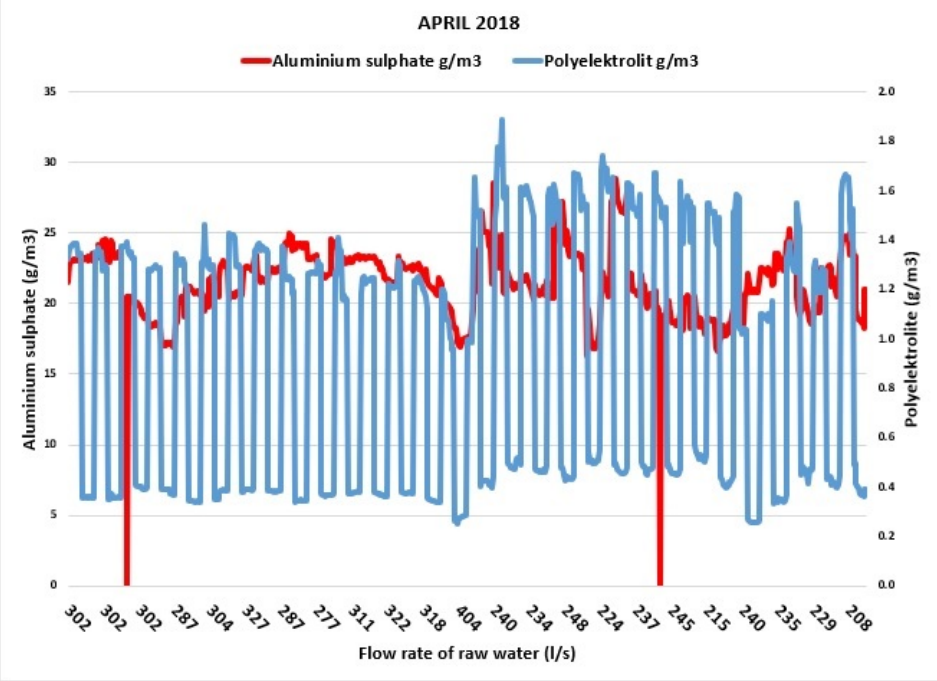

Figure 5b – Dependence of the concentration of added aluminum sulphate and polyelectrolyte on the flow rate of raw water during April 2018
Рис. 5б – Взаимозависимость концентрации добавленного сульфата алюминия и полиэлектролита и протока сырой воды в течение апреля 2018 года
Слика 5б – Међусобна зависност концетрације додатог алуминијум сулфата и полиелектролита од протока сирове воде у току априла 2018.године

During April 2018, the average doses of Al-sulphate were 24 g/m^3, and those of polyelectrolytes were 0.4-1.4 g/m^3. The chemical doses were less variable because both climatic and other parameters were more constant. The amount of 4,977m^3 of sludge was produced out of 681,193 m^3 of raw water during april 2018, which is about 2 times lower than in the same month during 2017. A smaller amount of sludge was generated in the reconstructed plant as expected. The microbiological status indicated that the number of coliform bacteria of fecal origin was over 24 in 100ml, above the maximum allowed value. E. Coli was also found.

During summer, July of 2017 and 2018, the water temperature increased and ranged between 13-14° C, contributing to a decrease in the solubility of oxygen and other gases in water according to Henry's law. The reduction of oxygen concentration inhibits oxidative processes, and, consequently, degradation of organic substances and development

of living organisms in surface water. This caused a decrease in the $KMnO_4$ consumption. Therefore, the average doses of chemicals in summer are reduced as well as the amount of sludge generated in summer 2017 and 2018.

A detailed physico-chemical analysis of sludge collected during 2017 and 2018 was carried out and some data is presented in Table 3.

Table 3 – Results of the physico-chemical analysis of sludge
Таблица 3 – Результаты физико-химических анализов ила
Табела 3 – Резултати физичко-хемијских анализа муља

N	Parameter	Units	Value	MPV***
1.	Humidity	%	87.18	-
2	Solids content	%	12.82	
3	Total Kjeldah nitrogen	mg/kg	9.6*	
4.	Phosphorous	mg/kg	697	
5.	TOC /DOC	mg/kg	274	
6.	C/N ratio	w/w	28.5	<20
7.	Potassium	mg/kg	297	-
8.	Aluminum	mg/kg	72200	-
9.	Copper	mg /kg	8.9	25
10.	Total Chromium	mg/kg	69,5	5
11.	Nickel	mg/kg	169	20
12.	Lead	mg/kg	5.7	5

*MPV*** - Official Gazette of the Republic of Serbia, No. 56/2010, 93/2019, Regulation on categories, testing and classification of waste, Attachment 10*
C/N = Carbon Content $mgkg^{-1}$/Nitrogen Content $mgkg^{-1}$ = TOC $mgkg^{-1}$/TKN $mgkg^{-1}$

As the maximum permissible values were exceeded for Ni, Pb, total Cr, and toxic metals, this sludge needed treatment for the removal of these metals (Kerkez, 2014), especially if there is intention to use it in composting or postponement (land breeder). Aluminum should also be removed, regardless of the fact that it is not over the maximum permissible value since it is categorized as a detrimental metal. So, the sludge generated from the Sušica surface water should be used as compost, but only after metal removal with zeolites and maturation. The

minimal conditions for composting are also tested in accordance with the Serbian legislation (Institute for Standardization of Serbia, 2017). An opportunity is thus provided to use treated sludge as a material for growing Coriandrum sativum. The medical effect of Coriandrum sativum is compared to the effect of ciprofloxacin, gentamicin and other antibiotics. It is useful as a spice plant and in cosmetics. In further work, this strategy should be applied to a treatment of the Djetinja (Vrutci Lake) surface water and its generated sludge.

Conclusion

The obtained results confirmed the next findings:

After the reconstruction of the water treatment plant, especially the lines for coagulation and flocculation, the quantity of the formed sludge decreased due to the technical plant improvements such as 3-speed strirrers during flocculation and one new polyelectrolite.

Before the reconstruction, the pH-values were adjusted and doses of coagulants such as aluminum sulphate or polyaluminum chloride were based on jar testing every day. After the improvement of the water plant treatment, the addition of coagulants is better controlled, drinking water is, according to standards, „easily“ received, and the amount of sludge is minimized.

The formation of „high-quality“ floccules was more efficient when the system with three stirring rates was used.

The sludge formed during 2017 and 2018 contained metals such as Ni, total Cr, and Pb, and they exceded their maximum permissible values. Therefore, the sludge treatment was required.

Eutrophication as a process of enriching water with nutrients results in increased organic compounds and primary production of aquatic plants. This increased organic content is bacterially decomposed, consuming available oxygen and affecting the development of other aquatic organisms. The nutrients-enriched water stimulates the production of algae, thereby increasing turbidity, water color and total organic carbon.

The quality of the Sušica surface water is strongly affected by season, water temperature, dissolved gasses (O_2 and CO_2), level of rainfall, as well as living organisms in water.

The generated sludge quality is strongly affected by the quality of the Sušica surface water and the amount of water inlet to the water plant.

Generated sludge should be used as compost, but only after metal removal with zeolites and maturation.

The minimal conditions for composting are also tested and provide the opportunity to use treated sludge as compost for growing Coriandrum sativum.

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УЛУЧШЕННЫЕ ПРОЦЕССЫ ХИМИЧЕСКОЙ ОБРАБОТКИ ВОДЫ ИЗ РЕКИ СУШИЦЫ ЗЛАТИБОРСКОГО ОКРУГА И ПРИМЕНЕНИЕ ПОЛУЧЕННОГО ИЛА

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РУБРИКА ГРНТИ: 61.00.00 ХИМИЧЕСКАЯ ТЕХНОЛОГИЯ. ХИМИЧЕСКАЯ ПРОМЫШЛЕННОСТЬ;
61.13.21 Химические процессы
61.01.94 Охрана окружающей среды
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Введение/цель: Концентрация природных органических и неорганических примесей, биологических видов и микроорганизмов в поверхностных водах истока реки Сушица изменчива. Эта вода заменила воду из озера Врутци, на которую сильно повлияла эвтрофикация. Данные воды нуждаются в очистке от загрязнения с помощью коагулянтов и полиэлектролитов. Целью исследования являлись: улучшение очистки поверхностных вод (коагуляция и флокуляция), уменьшение количества ила, оценка его качества, обработка и применение.

Методы: Разработаны физико-химические методы определения параметров качества воды, ила и компоста. Исследуемые параметры: мутность, расход $KMnO_4$, металлы, общий органический углерод, общий азот и хлорофилл.

Результаты: Качество поверхностных вод сильно влияет на содержание осадка. Концентрация металлов в иле составляет: 72200 мгкг-1 Al, 8550 мгкг-1 Fe, 106 мгкг-1 Zn. Параметры металлов, превышающие предельно-допустимую концентрацию в воде: Ni 169 мгкг-1, Cr 69,5 мгкг-1, Pb 5,7 мгкг-1 и должны быть снижены за счет цеолитов. Концентрации «питательных веществ»: 697 мгкг-1 P, 297 мгкг-1 K, 9,6 мгкг-1 общего азота, 274 мг-кг растворенного органического углерода. Eserihia coli и Salamonella необходимы для преобразования ила в компост.

Выводы: После созревания компост можно использовать для выращивания Coriandrum salivum. В следующем исследовании данная стратегия будет применяться по отношению к воде и илу из озера Врутци.

Ключевые слова: поверхностные воды, проток воды, коагулация, флокулация, ил, компост.

УНАПРЕЂЕНИ ПРОЦЕСИ ХЕМИЈСКОГ ТРЕТМАНА ВОДЕ ИЗ РЕКЕ СУШИЦЕ У ЗЛАТИБОРСКОМ ОКРУГУ И ПРИМЕНА ЊЕНОГ МУЉА

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ОБЛАСТ: хемијске технологије
ВРСТА ЧЛАНКА: оригиналан научни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Увод/циљ: У површинској води изворишта реке Сушице варира концентрација природних органских и неорганских нечистоћа, биолошких врста и микроорганизама. Ова вода заменила је воду из језера Врутци, на коју је снажно утицала еутрофикација. Тим водама неопходно је уклањање загађивача коагулантима и полиелектролитом. Циљ истраживања био је да се побољша третман површинске воде (коагулација и флокулација), смањи количина муља, процени његов квалитет, третман и примена.

Методе: Физичко-хемијске методе развијене су за одређивање параметара квалитета воде, муља и компоста. Ти параметри су: замућеност, потрошња $KMnO_4$, метали, укупни органски угљеник, укупни азот и хлорофил.

Резултати: Квалитет површинске воде увелико утиче на садржај муља. Концентрације метала у муљу су: 72200 мгкг-1 Al, 8550 мгкг-1 Fe, 106 мгкг-1 Zn. Метали преко максималне границе су: Ni 169 мгкг-1, Cr 69,5 мгкг-1, Pb 5,7 мгкг-1, и морају се редуковати зеолитима. Концентрације „хранљивих састојака" су: 697 мгкг-1 P, 297 мгкг-1 K, 9,6 мгкг-1 укупног N, 274 мгкг-1 раствореног органског угљеника. Eserihia coli и Salamonella битне су за претварање муља у компост.

Закључак: Након сазревања компост се може користити за гајење Coriandrum salivum. У наредном истраживању ова стратегија ће се применити на воду и муљ из језера Врутци.

Кључне речи: површинска вода, проток воде, коагулација, флокулација, талог, компост.

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ПРЕГЛЕДНИ РАДОВИ

ОБЗОРНЫЕ СТАТЬИ

REVIEW PAPERS

RECOVERY OF COBALT FROM PRIMARY AND SECONDARY MATERIALS - AN OVERIEW

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Abstract:

Introduction/purpose: Cobalt is a strategic metal for industrial application. Cobalt recovery from oxidic ores such as laterite and sulphidic ores, and from secondary materials during acidic treatment and precipitation is a highly used strategy ensuring different products such as cobalt hydroxide, cobalt oxide, and finally metallic cobalt.

Methods: Familiarity with cobalt behavior in hydrometallurgical processes such as dissolution at atmospheric and high pressure, precipitation, neutralization, filtration and hydrogen reduction is most important for cobalt recovery from ores and secondary materials. Pyrometallurgical methods such as roasting and flash smelting are applied for the treatment of sulphidic ores combined with solvent extraction and electrolysis in order to obtain cathodic cobalt.

Results: Powders of nickel-cobalt hydroxide were obtained from ores using sulphuric acid under high pressure in an autoclave and after precipitation with MgO. Solvent extraction was used to separate cobalt from nickel. The final step of cobalt recovery from a solution is using electrolysis. Cobalt and cobalt compounds such as cobalt carbonate and cobalt hydroxide can be obtained from secondary materials in hydrometallurgical operations.

Conclusion: Hydrometallurgical and pyrometallurgical processes are mostly applied for cobalt recovery from primary ores (oxidic and sulphidic

compounds) and from secondary materials (cemented tungsten carbide, polycrystalline diamond blanks, and waste cathodic materials from lithium-ion batteries).

Key words: cobalt, hydrometallurgy, cobalt hydroxide, powder, recycling.

Introduction

Cobalt, an element with atomic number 27, is a ferromagnetic transition metal located between iron and nickel in the periodic table of elements. Because of its application in lithium-ion batteries, cemented carbides and catalysts, and high demands in future, cobalt belongs to critical metals. The latter has especially influenced several worldwide economies due to a rising demand for electric mobility and green energy buffering (Wang, 2006, pp.47-50). Future demand for cobalt is likely to increase - even the importance of cobalt recycling – not only because of cobalt positive influence on wear resistance and thermal stability of superalloys and cemented tungsten carbides but also due to its value and rising demand in the field of advanced alloys, entertainment electronics, and Li-ion battery technology.

Cobalt production processes are usually energy-intensive because cobalt often comes as a passenger in copper and nickel bearing ores and has to be refined and purified by the methods of successive solvent extraction, electrowinning, and/or precipitation, for instance (De Graaf, 1979, pp.47-65).

Another aspect of cobalt is the location of resources versus the location of production. In most cases, production sites are far from mines. For example, while large quantities of cobalt are mined in the Democratic Republic of Congo in the form of *Coltan* (columbite-tantalite, linked to conflict minerals) the metal is produced in China, Finland or Norway. Long supply chains and socioeconomic issues have already contributed to smuggling and armed conflicts connected to the value of cobalt in the past and present times (Wakenge et al, 2018, pp.497-522).

Cobalt is usually available in lateritic ores with approx. 0.1-0.2 % (Moskalyk & Alfantazi, 2002, pp.593-605). Processing of lateritic nickel ores was performed in an electrowinning process for metal winning. Studies on the kinetics of dissolution of the Nigerian lateritic soil in acid media including hydrochloric, nitric and sulphuric acids have been undertaken (Olanipekun, 2000, pp.9-14). The elemental and mineralogical characterization, the loss of mass on ignition, the moisture content and the pH value of material suspension in water were determined in order to study the content of nickel and cobalt with

impurities. The effects of the acid concentration, the process temperature, the stirring rate and the particle size on the dissolution rate were investigated. Experimental results indicated that laterite dissolution was greatly influenced by hydrogen ion concentration and the leaching data fitted a diffusion model.

Beneficiation of laterites to enrich cobalt, besides recovery of associated chromite, is not only important to countries totally devoid of nickel bearing sulphides but is also of a significance to other countries, since laterites account for a greater percentage of these metals in the world (Narasimhan et al, 1989, pp.425-429). Unfortunately, primary resources were highly treated in the last century and connected with environmental problems and high production costs. On the other hand, small amount of cobalt in primary ores and their very complex mineralogical and chemical compositions are the reason for using secondary materials in cobalt recovery. Therefore, recycling is a chosen strategy for metal recovery in contrast to traditional primary metallurgy (Stopić & Friedrich, 2016, pp.1033-1047). The recycling of cemented carbide WC-Co was performed using dissolution with nitric acid and subsequent ultrasonic spray pyrolysis (Gürmen et al, 2006, 1882-1890). An increase of ultrasound frequency from 0.8 to 2.5 MHz decreases an aerosol diameter of cobalt nitrate to 2.2 μm, which leads to the formation of submicron particles after drying and precipitation in a furnace above 500°C in hydrogen atmosphere.

Other important secondary materials for recovery of cobalt are waste nickel metal hydride and lithium-ion batteries (Müller & Friedrich, 2006, pp.1498-1509). The recycling processes of waste Li–ion batteries were performed using three strategies: pyrometallurgical, hydrometallurgical, and pure mechanical treatment (Georgi-Maschler et al, 2012, pp.173-182). More than 10 companies are recycling thousands of metric tons of spent portable and industrial Li–ion batteries annually. The companies, such as Umicore (Belgium), Xstrata Nickel (Canada), Accurec (Germany), Inmetco (USA), S.N.A.M (France) and Sony-Sumitomo (Japan) use the pyrometallurgical strategy as the main recycling process to recycle rechargeable portable and industrial Li–ion batteries also including NiMH and NiCd batteries. Valuable metals, such as Co and Ni, are fully recovered in the form of alloy at high temperature in contrast to Al, Li and Cd, which stay in slag or flue dust (Wang & Friedrich, 2015, pp.68-178).

The third secondary material for recovery of cobalt is polycrystalline diamond (PCD) in blanks. Diamond is the hardest material put to use on commercial and industrial scales. It is used, for example, for working edges of cutting tools or for grains in the hardest abrasives. Due to

advancements in the field of high strength steels and super alloys, the demand for hard cutting and forming tools is highly increased (Strong & Chrenko, 1971, pp.1838-1843). Industrially used diamonds can be found in the form of a naturally grown and mined crystal or as a man-made product with mono- or polycrystalline microstructure. PCDs are made at high temperature and during a high pressure process which requires cobalt (Co) as a solvent catalyst. Cobalt is incorporated in the final product resulting in a multi-phase-compound that is PCD. This multiphasic character renders PCD vulnerable to thermal stress since cobalt and diamond have different thermal expansion coefficients. The only way to make these PCDs stable for industrial applications at high temperatures, such as hot forming of metals, is to remove inclusions from the cavities in the framework of diamond grains. This study will include some results concerning an optimization of the leaching process of cobalt from polycrystalline diamond blanks using a conventional leaching method augmented with ultrasound.

The main purpose of this study is to present some processes and results regarding cobalt recovery from primary materials (lateritic and sulphidic ores) and secondary materials such as WC-Co, lithium-ion batteries and polycrystalline diamond blanks.

Thermochemistry of cobalt dissolution in acidic medium

The Pourbaix diagram (potential Eh-pH) of cobalt in water solution at room temperature confirms the presence of cobalt in the form of Co^{2+} and Co^{3+} in the pH-area below 0 (very acidic systems), as shown in Figure 1. At an increased potential between 2.0 and 3.0 V, cobalt is available only as Co^{3+}.

Huang et al (2004, pp.77-90) conducted experiments on the precipitation of cobalt and molybdenum from effluents and used HSC software to compute potential-pH-diagrams for the system Co-H_2O at temperatures of 20°C, 40°C, 60°C, and 80°C. An increase in temperature did not show any influence on the presence of cobalt-ions. Using a mixture of hydrochloric acid and nitric acid (“aqua regia”), namely without external potential, Eh = 0, and at pH values close to zero, the stable form of cobalt is a divalent cation within this temperature range. It was reported that the equilibrium for this reaction should be on the right side of the balance, since the divalent cobalt cation is a stable form at pH<<1 and without external potential. In many cases, the most cost- and energy-efficient way to extract metal from gangue or scraps is to oxidize and

dissolve it in a leaching solution, which means this method is useful for hydrometallurgical treatment as well as recycling.

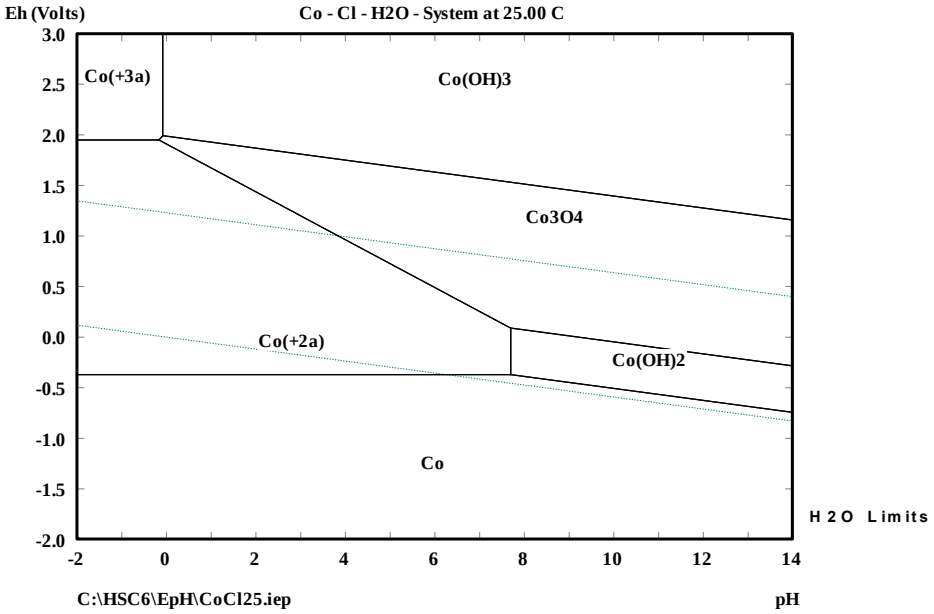

Figure 1 – eH-pH diagram of Co-Cl-H2O at 25°C
Рис. 1 – Потенциал – pH диаграмма в системе Co-Cl-H2O на 25°C
Слика 1 – Потенцијал – pH дијаграм у систему Co-Cl-H2O на 25°C

Regarding cobalt leaching, Han & Meng (1993, p.709) found that cobalt dissolution is dependent on diffusion while the dissolution of divalent oxides is reaction controlled. They reported that the leaching rate of cobalt is generally faster than that of their respective oxides.

Cobalt extraction refers to the techniques used to extract cobalt from its sulphidic ores (cobaltite) and oxidic ores (nickel laterite) based on final separation of cobalt from copper and nickel and other elements. The chosen processes for cobalt recovery from primary and secondary materials are presented in this review.

Recovery of cobalt from primary materials

Recovery of cobalt from complex sulfidic concentrates

Over 91 % of cobalt and 84 % of copper were recovered from cobaltite concentrate by a process that included: 1) Oxidative pressure leaching, 2) Jarosite precipitation, 3) Ferric arsenic precipitation, 4)

Selective solvent extraction of copper with a mixed hydroxyamine-extractant, 5) Electrowinning of copper from recirculating acidic strip liquor, 6) Selective solvent extraction of cobalt from copper solvent extraction raffinate with an alkyl phosphinic acid extractant, and 7) electowinning of cobalt from recirculating weak acidic strip liquor (Dannenberg et al, 1987, pp.1-20). The electrowon copper was 99.89 % pure, and the electrowon cobalt was 99.8 % pure, as shown in Figure 2.

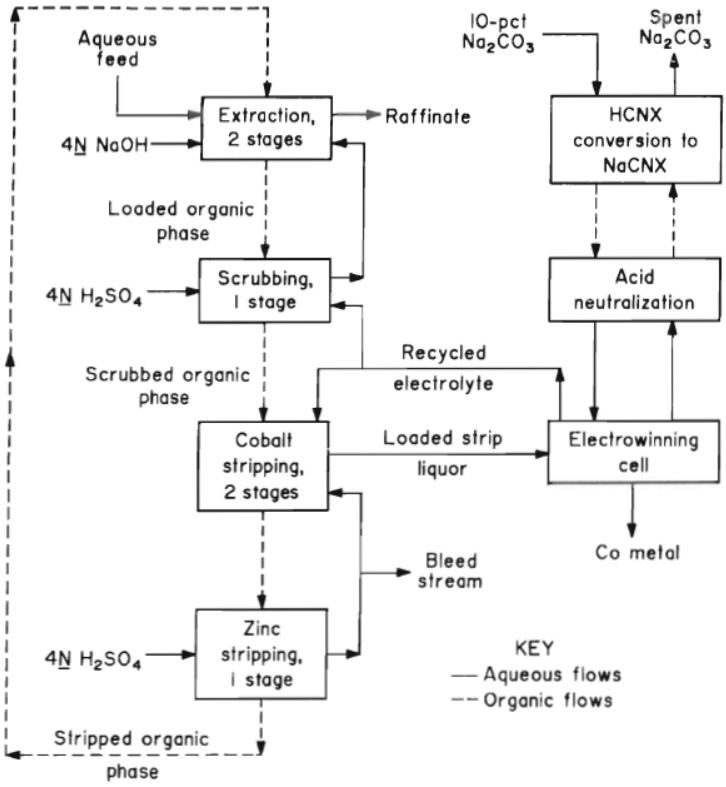

Figure 2 – Conceptual flow diagram for cobalt solvent extraction and electrowinning
Рис. 2 – Концептуальная диаграмма экстракции кобальта в растворе и извлечения электролитическим путем
Слика 2 – Концептуални дијаграм тока производње кобалта помоћу раздвајања течно-течно и електролизе

The cobalt solvent extraction with its many recicirculating streams takes more time at steady state conditions, where any bildup of impurities in these streams can cause serious problems. These batch experiments have confirmed that scale-up is possible only by using a continuous feed reactor.

In the Sheritt-Gordon process of nickel, sulfide concentrates can firstly be treated by either roasting or flash smelting to produce matte from which nickel and cobalt can be recovered hydrometallurgically, or they may be treated by an ammonia solution pressure leach. The chemistry of the ammonia pressure process for leaching Ni, Cu, and Co from Sherritt Gordon sulphide concentrates was described by the laboratory and pilot plant studies carried out by Sherritt Gordon Mines Ltd., Metallurgical Research Div. (Forward & Mackiw, 1955, pp.457-463)

Bioleaching of cobalt from an arsenidic ore is a new reseach subject, where an addition of citric acid can improve cobalt liberation and result in a more stable activity. In Australia, the BIOX-process was developed regarding the tank bioleaching of sulphidic concentrate.

Meta Nickel Cobalt Process for the treatment of lateritic ores, Turkey

Turkey Meta Madencilik Ltd. Şti. was founded in 2000 by a group of professional engineers and it developed Turkey's first nickel-cobalt project from lateritic ores with approx. 0.1-0.2 % Co. The following operations are used: 1) Ore preparation and classification of ore particles, 2) High Pressure Acid Leaching (HPAL) -a leaching method to extract nickel and cobalt, 3) Primary Iron Removal & Re-Leach Area Solid Liquid Separation (CCD or SX), 4) Secondary iron removal (secondary neutralization), 5) MHP (Mixed Hydroxide Product) Precipitation-1, 6) MHP (Mixed Hydroxide Product), Precipitation-2, 7) Manganese removal, and 8) final neutralization.

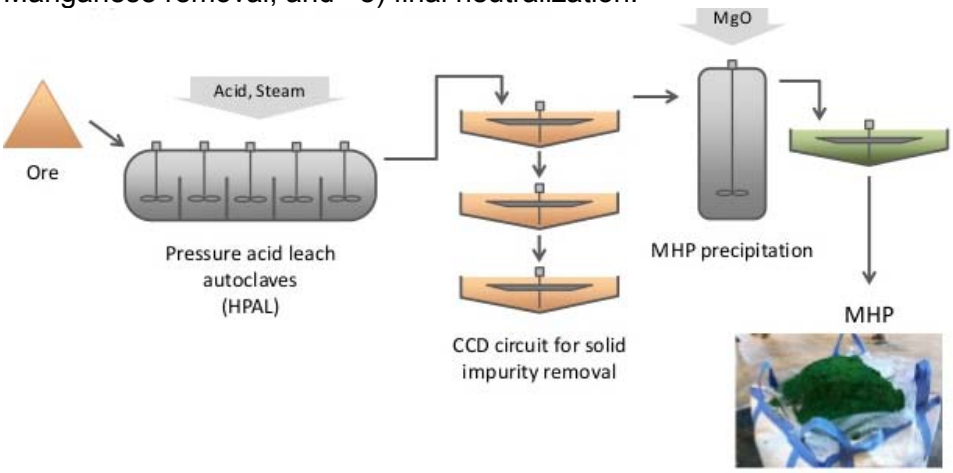

Figure 3 – Flowchart of the META Cobalt Nickel Process
Рис. 3 – Схема META Cobalt Nickel Process
Слика 3 – Шема за META Kobalt Nikal Proces

Recovery of cobalt from secondary materials

Treatment of cemented tungsten carbide

The chemical composition of cemented tungsten carbide used in this work was as follows (wt %): 75.86 W, 8.14 Co, and 6.07 C. The process used is shown in Figure 4.

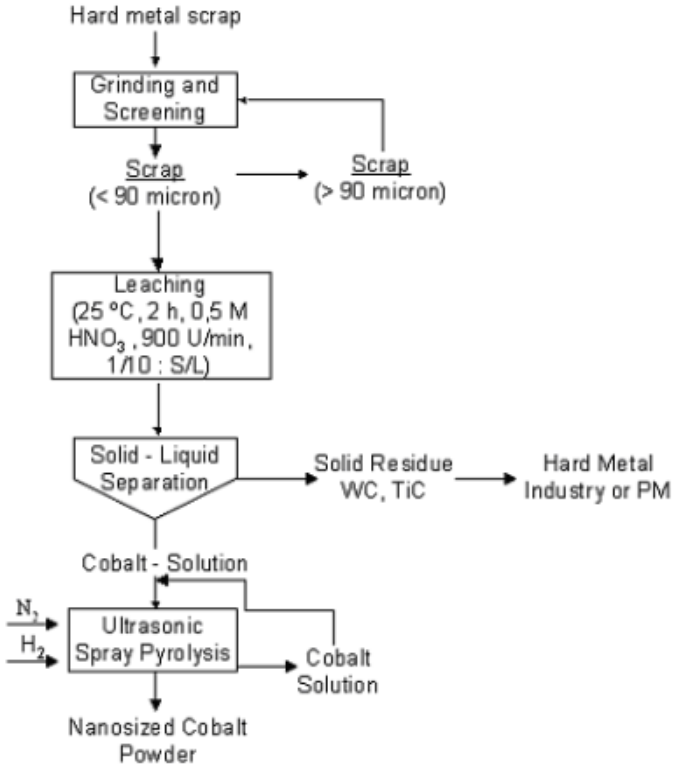

Figure 4 – Recovery of cobalt from cemented tungsten carbide
Рис. 4 – Извлечение кобальта из цементированного карбида вольфрама
Слика 4 – Издвајање кобалта из цементираног волфрам карбида

After grinding and sieving, the chosen fraction below 90 μm was treated with nitric acid. The leach solution of nitric acid leaching of cemented tungsten carbide scrap was used as the starting material for this strategy. After leaching and purification of the cobalt-nitrate solution, the final concentration of cobalt amounted to 0.08 mol Co/l. This solution was used for cobalt production by the ultrasonic spray pyrolysis (USP)

method in hydrogen atmosphere after leaching and the purification of cobalt-nitrate solution was used for cobalt production by the ultrasonic spray pyrolysis method in hydrogen atmosphere. The particle size of the produced cobalt powder can be controlled by the change of reaction temperature. Partly-agglomerated spherical cobalt particles with a mean diameter below 500 nm were obtained at 800°C using a concentration of cobalt nitrate of 0.4 mol/l, as shown in Figure 5.

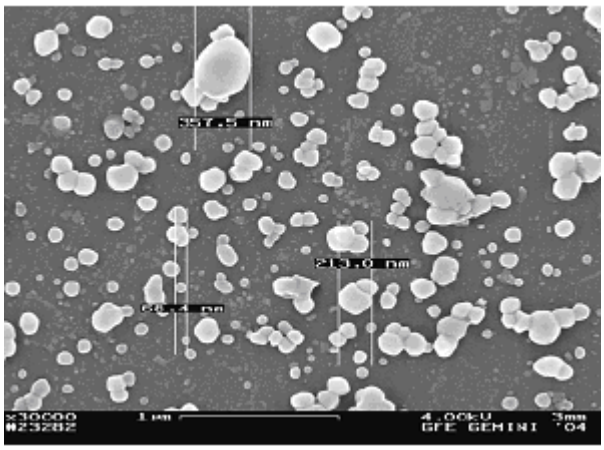

Figure 5 – Cobalt powders obtained at 800 °C, C =0.04 mol/l by USP
Рис. 5 – Кобальтовые порошки, полученные при 800 ° С, с = 0,04 моль / л, ультразвуковым распылением раствора
Слика 5 – Прахови кобалта добијени на 800°C, c=0,04 mol/l, ултразвучним распршивањем раствора

Hydrometallurgical treatment of polycrystalline diamond (PCD) blanks with a grain size of 5µm

This strategy developed at the RWTH Aachen University focuses on polycrystalline diamond blanks made by Redies Deutschland GmbH & Co. KG, Aachen a manufacturer of wire drawing dies. Cobalt is incorporated in the final product (max. 1.6 % Co) resulting in a multi-phase-compound. This study was performed at between 60°C and 80°C aiming at optimizing the process of leaching cobalt and cobalt compounds from polycrystalline diamond blanks using the mixing of nitric and hydrochloric acid (aqua regia) in a conventional leaching method augmented with ultrasound. The reactor used is shown in Figure 6. The experiments were carried out in two reactors simultaneously set up in a fume cabinet. The reactor vessels were three-necked round bottom flasks with a capacity of 500 ml. Below the aforementioned setup,

ultrasonic baths of Bandelin Sonorex RK 52H type were placed on the lab jacks so they could be lowered for sampling and batch changes. This arrangement made disassembly easier and did not require readjusting the upper structure with every batch change. These ultrasonic baths have an effective nominal frequency of 35kHz and 60W output while their maximum power output is in the range of 240W. Ultrasonic irradiation, solid-to-liquid-ratio, temperature and particle size are the varying parameters in this study. Ultrasound has been found to enhance leaching processes and is varied from zero to intermittent to permanent. The results from this study have suggested that the leaching of used fraction does not require 80°C bath temperature but can be done at 60°C. Ultrasound can accelerate the leaching process so much that PCD can reach a desaturated state with less than 10% of metallic inclusions remaining after three to four days if they are leached at low solid-to-liquid-ratios close to 15g/L.

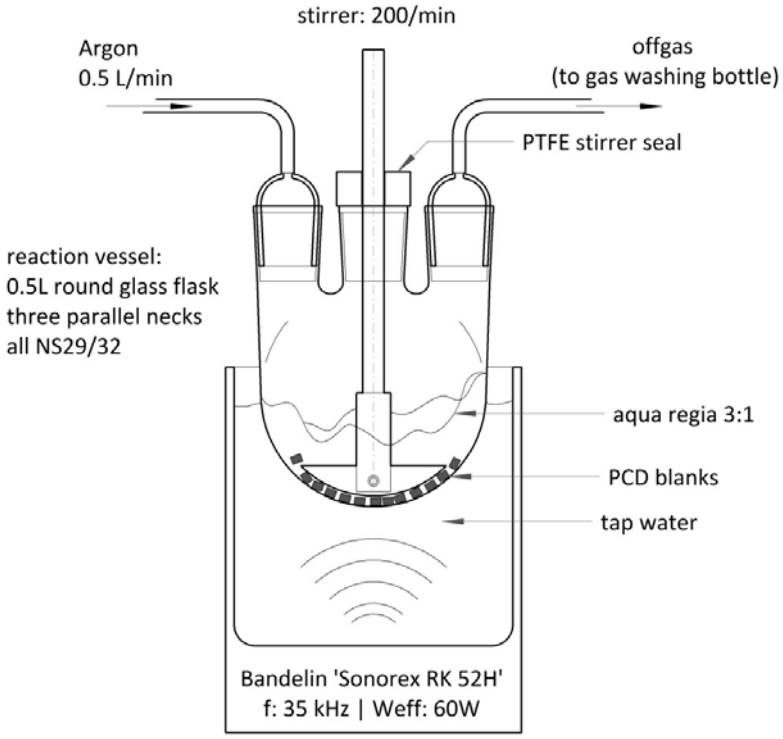

Figure 6 – Reaction vessel in an ultrasound bath
Рис. 6 – Реакционный сосуд в ультразвуковой ванне
Слика 6 – Реакциони суд у ултразвучном купатилу

Some problems are present since the mixing of aqua regia involves volatile or gaseous species such as chlorine gas or hydrochloric vapor. It is possible that hydrochloric acid evaporated rapidly from the hot freshly-mixed solution while also forming NOCl. Applying neutralization with NaOH at the end of the experimental setup can solve this problem. The scale-up of this process can be a challenge in the future work.

Highly efficient hydrometallurgical recycling process for automotive Li–ion batteries

A highly efficient hydrometallurgical recycling process including pre-treatment for used automotive Li–ion batteries has been developed at the RWTH Aachen University, showing the possibility of using a unique process to recover high-grade graphite, cathode metal salts and lithium carbonate, as shown in Figure 6.

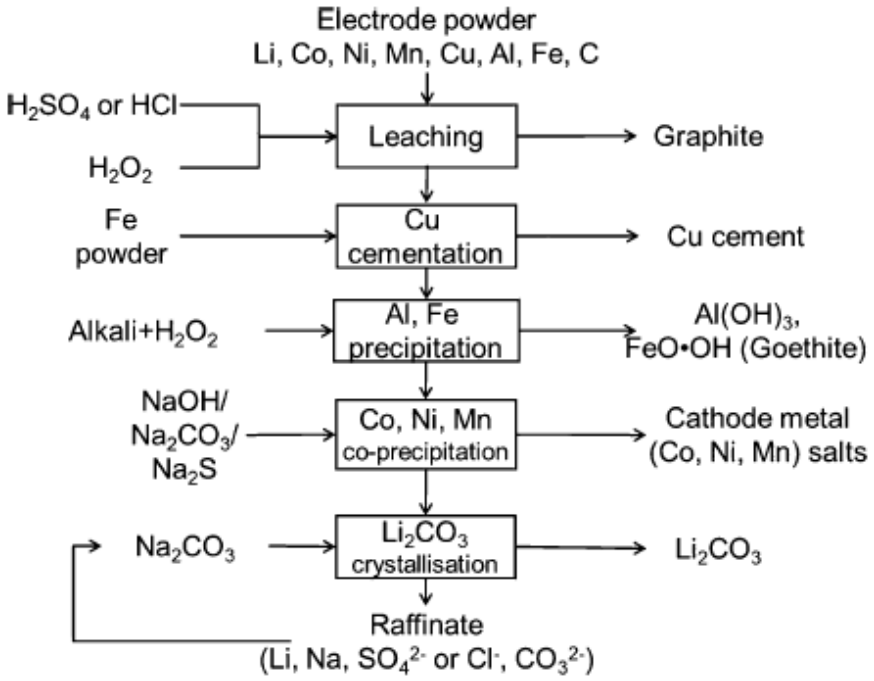

Figure 7 – Developed hydrometallurgical recycling process for Co (Wang & Friedrich, 2015, pp.168-178)
Рис. 7 – Разработанный гидрометаллургический процесс переработки Co (Wang & Friedrich, 2015, pp.168-178)
Слика 7 – Развијени хидрометалуршки процес за рециклирање кобалта (Wang & Friedrich, 2015, pp.168-178)

The chemical composition of the electrode powder is assayed by the ICP–OES method, showing very high Co and Ni of about 22 and 9.9 %, respectively. Al, Fe, Mn and Cu have low content values, in the range of 0.2–1.18 %. The cathode metal (Co, No, Mn) compounds such as carbonates, sulphide and hydroxides are very valuable products obtained from this precipitation process. The recycling rates of Co, Ni and Mn can reach 95 % in the developed hydrometallurgical process. Regarding the application, the cathode metal salt could serve as a raw material (precursor) to prepare a new cathode material.

Potential-controlled selective recovery of manganese and cobalt from a cobalt slag leaching solution

Cobalt separation from other metals was usually performed using solvent extraction. Another strategy is a method based on an electrochemical study where manganese and cobalt were selectively separated from zinc in a leaching solution of cobalt slag by potential-control oxidation with ozone as shown in Figure 8.

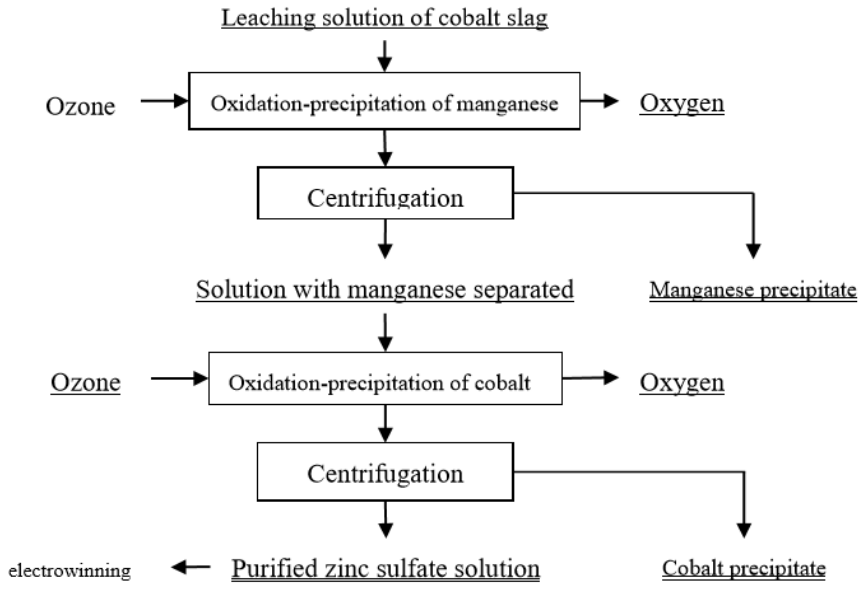

Figure 8 – Flowsheet of the two-stage method for manganese & cobalt recovery by ozone (Tian et al, 2017, pp 201-206)
Рис. 8 – Двухступенчатый метод извлечения марганца и кобальта с помощью озона (Tian et al, 2017, pp 201-206)
Слика 8 – Двостепени метод за издвајање мангана и кобалта коришћењем озона (Tian et al, 2017, pp 201-206)

When ozone was pumped into the solution in ordert o increase the oxidation potential, manganese (II) was oxidized and precipitated firstly, and then cobalt(II) was separated from the solution in the same way. Partial zinc was lost in the precipitates in the form of encapsulated inclusions. The effects of the dilution rate, the solution pH value and the system temperature on the manganese and cobalt separation were investigated, and high-grade cobalt precipitate and highly purified liquid were obtained in certain conditions.

Conclusion

Hydrometallurgical and pyrometallurgical processes are mostly applied for cobalt recovery from primary ores (oxidic and sulphidic compounds) and from secondary materials (cemented tungsten carbide, polycrystalline diamond blanks, waste cathodic materials from lithium-ion batteries and slag from zink metallurgy). Hydrometallurgical operations such as dissolution at atmospheric and high pressure, precipitation, neutralization, filtration and hydrogen reduction are most important for the recovery of cobalt from secondary materials. Additionally, ultrasonic spray pyrolysis with hydrogen reduction leads to the formation of nanosized cobalt powders. The final product of the acidic leaching of lateritic ores under high pressure in an autoclave after precipitation and filtration is mixed nickel-cobalt hydroxide. The influence of the parameters such as temperature, solid/liquid ratio, pressure, acid pH-value and concentration is of high importance for the reaction kinetics. The techniques for cobalt separation from other elements such as nickel, manganese, and zinc are solvent extraction and potential-controlled selective leaching and precipitation. Finally, the main advantages of cobalt recovery from secondary materials are higher content of cobalt (approx. 1 to 20 % in contrast to 0.1-0.2% in ores), higher selectivity, and a smaller number of required operations. However, these recycling processes are not industrially developed in comparison to traditional primary metallurgy. Therefore, the scale-up of these processes is a big challenge in future.

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ИЗВЛЕЧЕНИЕ КОБАЛЬТА ИЗ ПЕРВИЧНЫХ И ВТОРИЧНЫХ МАТЕРИАЛОВ - ОБЗОР

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РУБРИКА ГРНТИ: 61.13.21 Химические процессы
ВИД СТАТЬИ: обзорная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Введение/цель: Кобальт является стратегическим металлом в промышленном применении. Извлечение кобальта из оксидных руд, таких как латеритные и сульфидные руды, а также из вторичных материалов во время кислотной обработки и осаждения является широко используемым методом, обеспечивающим получение различных соединений, таких как гидроксид кобальта, оксид кобальта и металлический кобальт.

Методы: Гидрометаллургические процессы, такие как растворение при атмосферном и высоком давлении, нейтрализация, осаждение и извлечение водородом, использовались для выщелачивания кобальта из руд и вторичных материалов. Пирометаллургические процессы, такие как обжиг и автогенная плавка сульфидных руд, сочетались с экстракцией растворителем и электролизом при получении катодного кобальта.

Результаты: Порошки гидроксида никеля и кобальта получены из руды с использованием серной кислоты при высоком давлении в автоклаве и осаждением оксидом магния. Никель и кобальт

разделяли с помощью экстракции растворителем. Конечный раствор с кобальтом использовали в процессе электролиза для получения кобальта. Кобальт и его соединения, такие как карбонат кобальта и гидроксид кобальта, получены из вторичного сырья с помощью гидрометаллургических операций.

Выводы: Гидрометаллургические и пирометаллургические процессы в основном используются для выделения кобальта из первичных руд (оксидных и сульфидных соединений) и вторичных материалов (цементированные карбиды вольфрама, поликристаллические алмазные пластины и отходы катодных материалов литий-ионных аккумуляторов).

Ключевые слова: кобальт, гидрометаллургия, гидроксид кобальта, порошок, вторичная переработка.

ИЗДВАЈАЊЕ КОБАЛТА ИЗ ПРИМАРНИХ И СЕКУНДАРНИХ МАТЕРИЈАЛА – ПРЕГЛЕД

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ОБЛАСТ: хемијске технологије
ВРСТА ЧЛАНКА: прегледни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Увод/циљ: Кобалт је стратегијски метал у индустријској примени. Његово издвајање из оксидних руда, званих латерити, и сулфидних руда, као и секундарних материјала третирањем киселином и преципитацијом најчешће је коришћен метод који обезбеђује различите продукте као што су кобалт хидроксид, кобалт оксид иметални кобалт.

Методе: Хидрометалуршки процеси, као што су растварање при атмосферском и високом притиску, неутрализација, преципитација и редукција водоником коришћени су за издвајање кобалта из руда и секундарних материјала. Пирометалуршки процеси, као што су пржење и аутогено топљење сулфидних руда, комбиновани су са солвент екстракцијом и електролизом за добијање катодног кобалта.

Резултати: Прахови никал-кобалт хидроксида добијени су из руда коришћењем сумпорне киселине при високом притиску у аутоклаву и преципитацијом са магнезијум оксидом. Никал и кобалт раздвајани су коришћењем солвент екстракције. Финални раствор са кобалтом коришћен је у процесу електролизе за добијање кобалта. Кобалт и његова једињења као што су кобалт карбонат

и кобалт хидроксид добијају се из секундарних сировина помоћу хидрометалуршких операција.

Закључак: Хидрометалуршки и пирометалуршки процеси већином су примењени за издвајање кобалта из примарних руда (оксидна и сулфидна једињења) и секундарних материјала (цементирани карбиди волфрама, поликристалне дијамантске плочице и отпадни катодни материјали из литијум- јонских батерија).

Кључне речи: кобалт, хидрометалургија, кобалт хидроксид, прах, рециклирање.

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RADIATION EXPOSURE OF THE ARMY OF THE FR YUGOSLAVIA IN KOSOVO AND METOHIA DURING THE NATO AGGRESSION OF 1999

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Abstract:

Introduction/purpose: The paper indicates the radiation doses the military personnel of the Federal Republic of Yugoslavia were exposed to, and in particular the military personnel of the motorized brigades in the territory of Kosovo and Metohia on the Albanian-Yugoslav border.

Methods: Gammaspectrometry measurements have confirmed that round penetrators contained depleted uranium, and the presence of alpha, beta and gamma radiation was determined by the method of dosimetric measurement.

Results: The use of ammunition with ^{238}U depleted uranium, with added plutonium, pollutes the environment, water, and soil in the long term, causing various disorders and diseases, primarily malignant ones. The radioactivity of ^{239}Pu, compared to its toxicity, is several thousand times higher and the inhalation of plutonium dust is harmful and causes cancer. Uranium is a pyrophoric metal, toxic, radioactive and easy to ignite. Its oxides are toxic and partially soluble in water. After ignition, the round releases radioactive aerosol particles which burn in contact with the air causing short or long term damage wheninhaled. In Kosovo and Metohia, a large amount of radioactivity was measured during the NATO aggression against the FR Yugoslavia. In Metohia, radioactivity was 1,100 times that of natural background radiation.

Conclusion: During the war, the Army of the FR Yugoslavia was exposed to high radioactive doses, so that among the members of the army after

the war there was an increased incidence of various malignancies, many of them lethal.

Keywords: chemical warfare, depleted uranium ammunition, increased radioactivity, chemotoxicity, plutonium, exposure of the Army of the FR Yugoslavia to radiation, disease, malignancy.

Introduction

The 78-day NATO aggression on the Federal Republic of Yugoslavia in March 1999 represents one of the most shameful pages in the history of international relations and the modern-day civilization of the second half of the 20th century. It is a crime against peace, human health and the environment. It caused an increase in various malignancies, difficulty in conceiving, sterility,the number of miscarriages, thyroid diseases, and an increased occurrence of asthma in children as well as in the elderly.

The use of ammunition with depleted uranium caused a large increase in various malignancies after the war, and thus the number of deaths in the FR Yugoslavia during the aggression can be added to the number of deaths which is increasing daily, since in most cases they died from radiation. During the 1999 aggression against the Federal Republic of Yugoslavia, enormous material damage and irreparable loss of life were inflicted on people and the eco system. Besides the destruction of cities and infrastructure by various missile types, a great tragedy was caused by depleted uranium (DU) rounds (uranium depleted in ^{235}U isotope), fired from Gatling-type guns ofthe A-10 aircraft.

The exposure of the Army of the FR Yugoslavia and the civilian population to radiation was particularly increased in the territory of Kosovo and Metohia and southeastern Serbia, the surroundings of Vranje and the near-by villages. However, the radiation from Kosovo and Metohia also reached the surrounding countries, so Bulgaria and Greece reported increased radioactivity in their countries. Radioactivity from Kosovo and Metohia spread to other parts of the country, so the incidence of various tumors throughout Serbia has increased.

By the decision of the Government of the Republic of Serbia, on June 12, 2018, the Commission for Determining the Consequences of NATO Bombing was formed in order to establish all relevant facts and inform the public about it.

Number of uranium depleted rounds fired on the Federal Republic of Yugoslavia

The countries that directly attacked FR Yugoslavia were 228 times larger than the FR Yugoslavia, had 67 times bigger population, their economic potential exceeded that of Yugoslavia by 679 times, and they were 37 times more technically superior. The exact number of fired DU rounds will never be known, because NATO, and above all the USA, keep this information secret; they do not want to admit how many missiles they fired, as it would show that they had genocidal intentagainst the Serbian (but also the Albanian) people. There are three reports on the amount of depleted uranium ammunitionused during the 1999 aggression on the FR Yugoslavia:

- The first report is the one compiled by NATO, which states the number of 31,000 missiles.
- The second is the report of the Army of the FR Yugoslavia, according to which about 50,000 pieces of DU ammunition were fired, and
- The third is from Russian sources which estimate that about 90,000 DU missiles were fired in the territory of FR Yugoslavia.

Most DU rounds targeted the territories of Kosovo and Metohia and southern Serbia.

However, retired Major General Božidar Delić, on the basis of his observations while commanding the 549th Motorized Brigade in Kosovo and Metohia, then in the rank of colonel, believes that the number of used DU rounds is much higher. According to the General's estimate, 225 tons of depleted uranium were dropped on the territory of Kosovo and Metohia. The Army of the FR Yugoslavia has data about approximately 15 tons, which is almost 15 times less than the General's estimation (Delić, 2019). The 549th Brigade, commanded by then-colonel Božidar Delić, and the 125th Motorized Brigade, commanded by then-colonel Dragan Živanović, were located on the Yugoslav-Albanian border. The 549th Motorized Brigade was stationed in Prizren and within its area of responsibility was the territory of Paštrik, and in the area of responsibility of the 125th Motorized Brigade, stationed in Kosovska Mitrovica, was the territory of Košare.

The data collected by the FRY Army and the NATO data can be summarized as follows: a total of 112 air strikes with DU ammunition occurred at 91 locations, 12 strikes at 9 locations in the Republic of

Serbia, 2 strikes at one location in the Republic of Montenegro and 98 strikes at 81 locations in Kosovo and Metohia.

In the south of Serbia, according to the data from the FRY Army, four areas in Serbia were confirmed with recorded radiological contamination. These are:

1. Pljačkovica Hill – about four kilometers north of Vranje, DU activity in soil samples 5.580 - 235.000 (Bq / kg)
2. Borovac - two locations southeast of Bujanovac for about six kilometers, DU activity in soil samples 250 - 17.490 (Bq / kg)
3. Bratoselce – northeast of Preševo for about 10 km, the activity of DU in soil samples 1.800 - 23.400 (Bq / kg)
4. Reljan - two locations, east of Presevo for about 10 km, DU activity in soil samples 70 - 200 (Bq / kg)

The Pljačkovica hill top near Vranje where the relay station was located, was hit by a large number of DU rounds. The base of the hill is hard, rocky and made it possible for roundsto ignite and scatter radioactive aerosol over long distances (Anđelković-Lukić, 2015a).

There are bigger or smaller differences (depending on the source) between this and the data collected by the Army of the FR Yugoslavia, but it is important to note that a total of 49 strikes (or 44%) of the DU ammunition attacks were carried out after the agreement had been reached to end the aggression, in the last 10 days of the war (Jovanović et al, 2012). Depleted uranium was used not only in 30 mm rounds but also in cruise missiles (with 300 kg stabilizer rods). It is no accident that Tomahawk cruise missiles are explicitly mentioned in the manual titled "KFOR International Brigades West / MNB-W / Depleted Uranium / Informatiom Book". They are used to destroy fortified concrete bunkers and underground hangars (Accame, 2006, p.15).

Responsibility zone of the 125th Motorized Brigade

The area of responsibility of the 125th Motorized Brigade is shown in Figure 1, marked in yellow. The combatants from the 125 Metohia Motorized Brigade and the protective battalion that was part of the brigade were exposed daily to heavy enemy fire. The task of the Defense Battalion of the 125 Motorized Brigade was to protect Klina, Dečani, Srbica, and Vučitrn from possible attacks by the paramilitary-terrorist KLA from the direction of Drenica, or the Čičavica mountain, where there was a large concentration of terrorist forces. In addition to protecting civilians, the task of the Defense Battalion of the 125 Motorized Brigade was to, in

cooperation with the forces of the Serbian police, provide travel routes and convoys carrying food stuffs. During the war, the Brigade was in Metohia in the area of Kosovska Mitrovica, Drenica, Podujevo, Peć, Đakovica, and Klina.

Figure 1 – Responsibility zone of the 125th Motorized Brigade (Đurović & Petrušić, 2016, pp.137-138)
Рис. 1 – Зона ответственности 125-й моторизованной бригады (Đurović & Petrušić, 2016, pp.137-138)

Слика 1 – Зона одговорности 125. моторизоване бригаде (Đurović & Petrušić, 2016, pp.137-138)

Figure 2 shows the sites in Kosovo and Metohia targeted by DU ammunition, according to the NATO map. It is clearly shown that not only the territory of Kosovo and Metohia was targeted but also the territory of North Macedonia and Albania.

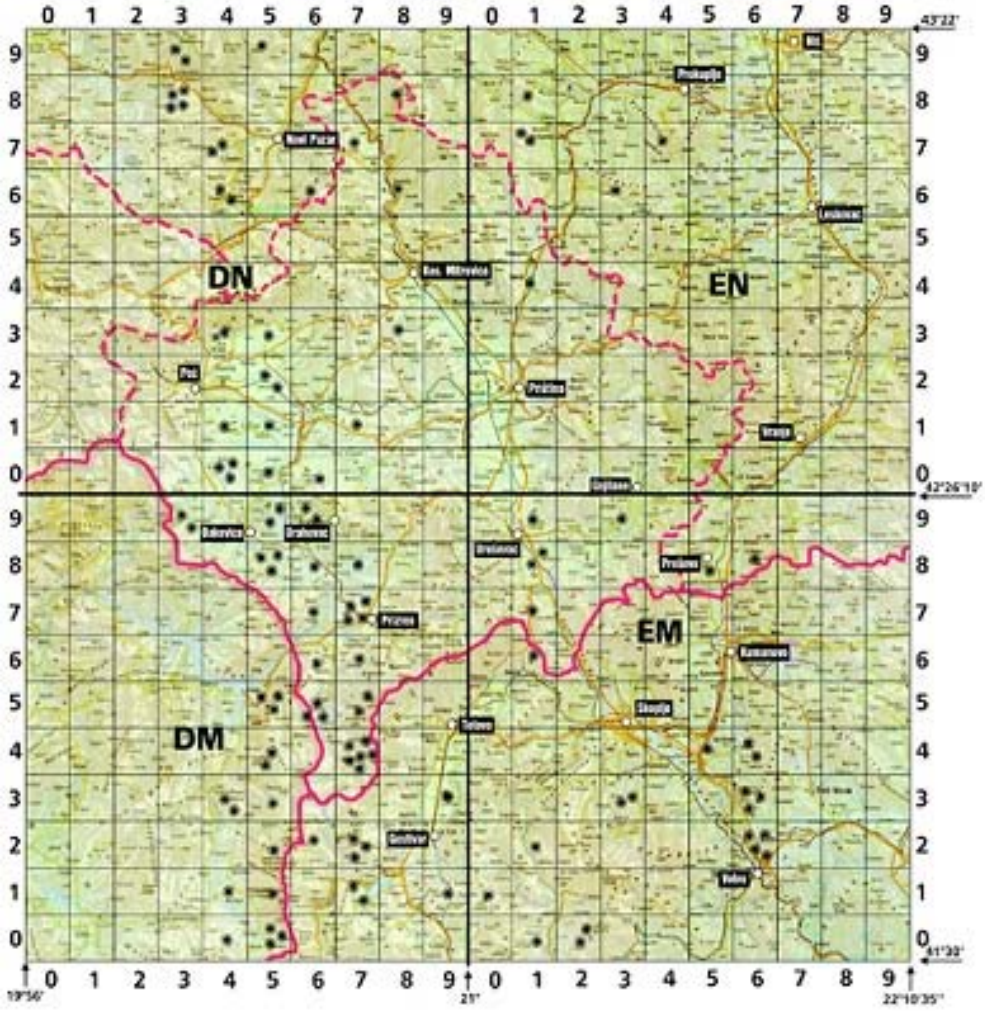

Figure 2 – Sites in Kosovo and Metohia that were targeted by DU ammunition based on NATO data (Ajdačić & Jakšić, 2001, p.341)

Рис. 2 – Точки в Косово и Метохии, пораженные снарядами с обедененным ураном на основе документов НАТО (Ajdačić & Jakšić, 2001, p.341)

Слика 2 – Места на КиМ која су гађана муницијом са ОУ базирано на НАТО документима (Ajdačić & Jakšić, 2001, p.341)

Figure 3 illustrates the deployment of the KFOR (International Forces in Kosovo and Metohia) after the Kumanovo Agreement had been signed.

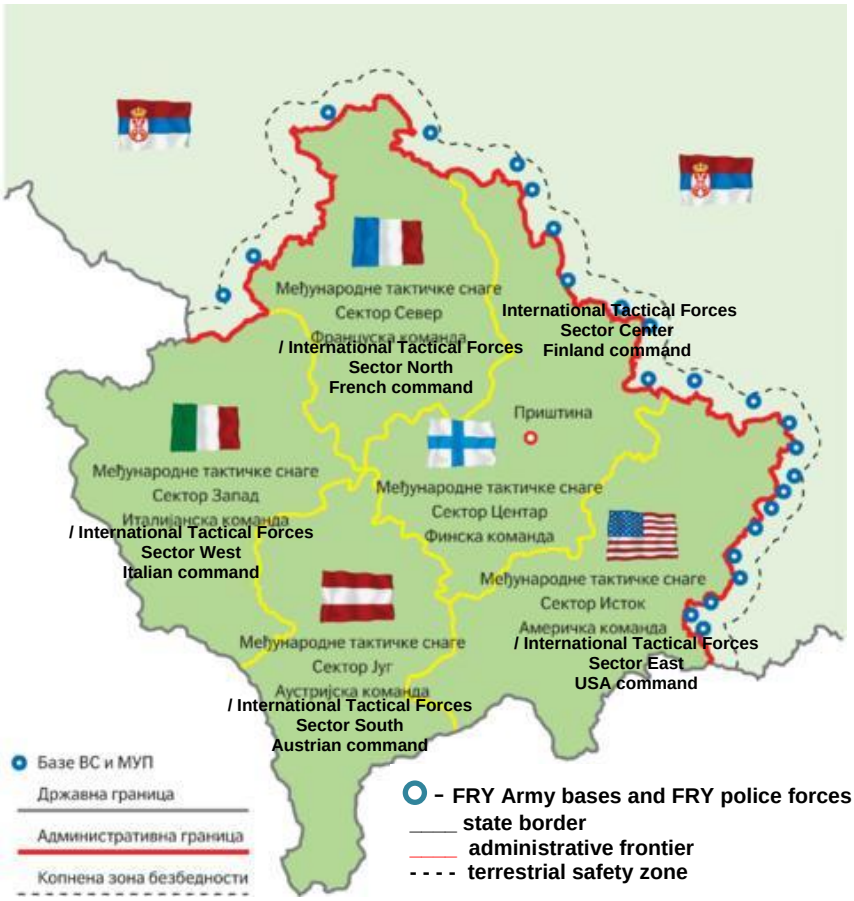

Figure 3 – Deployment of international forces after the signing of the Kumanovo Agreement (Ocić, 2019)
Рис. 3 – Дислокация международных сил после подписания Кумановского соглашения (Ocić, 2019)
Слика 3 – Распоред међународних снага после потписивања Кумановског споразума (Ocić, 2019)

Figure 3 shows that the KFOR's Italian and French battalions were deployed in the area that was within the area of responsibility of the 125th Motorized Brigade. Some members of the KFOR international forces, soldiers from the Italian Battalion, fell ill with malignant tumours

and many died after returning from Kosovo and Metohia. The surviving soldiers sued the Italian Ministry of Defense for failing to inform them of the health hazards they might encounter in the field and the case resulted in a verdict in their favour with adequate material compensation. The positive court decision also applied to those soldiers who died and had previously been in the wars in both Bosnia and Herzegovina and Kosovo and Metohia (Tagliazucchi & Leggiero, 2019).

Characteristics of the 30 mm DU round for a Gatling gun

With its classic shape and appearance, the DU round belongs to sub-caliber ammunition that penetrates without explosive, due to its kinetic energy and mass, releasing high temperature.

It weighs about 727 g and consists of a cartridge case with initial and propulsion charges for ejecting a DU projectile. Inside an aluminium alloy casing, there is a DU core – cylindrical gray armour piercing penetrator with a dominant presence of ^{238}U.

The core contains 2.2 grams of titanium.

The diameter of the DU round penetrator is 16 mm and the length is 95 mm.

The DU core weight is 298 g and the calculated density is 19.05 g/cm3.

The total length of the DU projectile without a protective cap is 114 mm.

Figure 4 shows a round fired in the FR Yugoslavia in 1999. The figure shows a complete DU round and a penetrator as well as a damaged round casing. The DU round kinetic energy of 157 kJ penetrates 60 mm thick armor at 500 meters and 38 mm thick armor at 1,000 meters. The nucleus is radioactive and emits 11,198 alpha and 35,914 low energy beta particles per second.

According to the report of the Nuclear Biological Chemical Defense Department Expert Group of the Army of Serbia and Montenegro HQ, the presence of alpha, beta and gamma radiation was determined by dosimetry measurements. The reports from April 23, 1999 and May 21, 1999, of the Vinča Institute of Nuclear Sciences, among other things, stated: "Based on the results of gamma spectrometric measurements and the identification of radionuclides present, it can be claimed with certainty that the sample contains depleted uranium" (Jovanović et al, 2012, pp.37-41).

In the case of touching apenetrator with bare hands,various pathogenic changes occur on the skinafter only 80 hours.

Figure 4 – DU rounds used in the territories of the FR of Yugoslavia in 1999, exhibited at the Military Museum in Belgrade
Рис. 4 – Фотография снарядов с обедненным ураном, поразивших СР Югославию в 1999 году, выставлены в Военном музее в Белграде
Слика 4 – Метак са ОУ којим су гађани простори СР Југославије 1999. године, изложен у Војном музеју у Београду

Functioning of a depleted uranium round after hitting a target

Depleted uranium has the same chemical properties as natural uranium and is equally chemically toxic. Natural uranium has three isotopes: ^{234}U, ^{235}U, and ^{238}U. Their mass fraction in natural uranium is: 0.007%, 0.72%, and 98.28%, respectively. Only ^{235}U is used for nuclear power plants. ^{235}U is extracted from natural uranium to a content of 0.2 – 0.3%. and it is a by-product in the preparation of fuel for nuclear reactors and nuclear weapons.

Therefore, ^{238}U is uranium depleted in the ^{235}U content. Uranium is pyrophoric metal, easy to ignite and radioactive. Its external radioactivity is not significant, but the danger is high when inhaling or ingesting combustion products after a round has hit a hard target.

When DU projectiles hit hard targets releasing high temperature, about 10% of the uranium penetrator burns into uranoxide and 70% goes into the aerosol state, the remainder being larger round fragments scattered around the impact site. When DU projectiles hit a hard ground or an armored vehicle, uranium, being easily flammable, ignites at about 700^{o}C and develops a temperature of 3,000^{o}C, penetrating through the hardest armor, and with a small proportion of added plutonium, the temperature increases by another 400^{o}C so that it reaches a combustion temperature of 3400°C. After hitting a target, the round ignites and releases smoke-sized particles that burn in contact with the air causing short-term or long term damage to those who inhale them. The size of uranium aerosol particles is about 5 μm and less, i.e. that of nanoparticles.

These particles contaminate the environment, can enter the body by inhalation or oral route, and depending on meteorological conditions, can be spread over long distances (40 to 300 km and beyond). Uranium oxides are toxic and partially soluble in water, so they can contaminate groundwater and reach thehuman food chain through plants (Anđelković-Lukić, 2015b, pp.39-50).

The 549th and 125th Motorized Brigades had tanks and armored fighting vehicles, which was a military objective for NATO aviation. In relation to the other parts of the Province, the area of Metohia was exposed to heavy NATO air strikes as it can be seen from Figure 2, and due to everyday bombing fromthe A-10 aircraft, there was high radioactivity on that front. According to the data of the FRY Army, the territory of Kosovo was targeted with 30-50 thousand DU projectileswhile 5,000 to 10,000 DU projectiles hit the locations outside the Province. In the 85 days during which the 125th Motorized Brigade was in Kosovo and Metohia, an average of 353 to 588 rounds were fired per day. The half-life of ^{238}U is 4.5 x 10^{9} years (4.5 billion years). Analyses of the contaminated material samples from several Kosovo and Metohia sites revealed that the specific DU activity in individual samples ranged from several hundreds to 235,000 Bq/kg per samples from Metohia, where was the 125th and 549th Motorized Brigades' area of responsibility. This is 1,100 times over the lower limit. For the purpose of calculation, the number of A-10 aircraft strikes was taken, where thecombat load for the 30 mm AN / GAU-8A Gatling gun is about 1100 to 1200 rounds, out of which about 880 rounds are with a DU core weighing about 300 grams. The natural background of uranium in soil is 5 to 125 Bq/kg of soil. The most intense air strikes were in the Dečane, Uroševac and Đurakovac regions (Jovanović et al, 2012, p.56).

Health effects of increased radioactivity and the toxicity of depleted uranium and plutonium

DU particles can enter the body by inhalation or with food and water. They are deposited for years in the lungs, kidneys (up to 12% of DU), lymph glands, muscles, testicles, bones (up to 20% of DU), brain, liver, pancreas and spleen (up to 20% of DU). Regardless of the pathways of contamination of the body, these particles bind to the proteins and the erythrocyte membranein the blood, which is most damaging. After the war had ended, combatants who were in high-risk situations were invited for examinations. The greatest danger to human health is staying close to the target at the time of the hit. The medical check program lasted for 5 years and then was terminated. Over 1,500 members of the FRY Army were examined at three FRY Army establishments, but the program did not give the expected complete picture because the examined group was relatively small in relation to the number of exposed individuals, so that was not a representative sample (Đurović et al, 2011, pp.182-183).

The danger of DU is compounded by the fact that analyses of some projectile fragments have shown, in addition to DU, traces of americium, neptunium, technetium, and ^{236}U uranium. The UNEP teams that came to Kosovo and Metohia after the end of the war also detected the presence of plutonium, ^{239}Pu, which increases the risk for humans. Its toxicity can be compared to that of cyanide and arsenic. When compared to toxicity, radioactivity is several thousand times higher, so plutonium dust of only 1 mg is enough to endanger a dozenof people inhaling it, and only 0.1 mg is enough to cause cancer. Plutonium is a light-white metal with a density of 19.8 g/cm3, with a half-life of 24,000 years, and it melts at about 639°C. It is a dominant alpha emitter. It was used to produce the first atomic bomb, dropped on August 9, 1945, on Nagasaki (Jovanović et al, 2012, p.61).

The presence of plutonium increases the radiotoxicity of samples, which increases the risk for the exposed individuals. The main radiation doses of DU particles come from alpha and beta radiation, which is dangerous for human tissue even in small amounts, so if inhaled or ingested it would certainly give values over the permitted dose. Alpha radiation of DU particles causes significant primary direct radiation injury, mainly to tissues in direct contact with them, while beta and gamma radiation can damage other tissues as well. It is also collected in semen, where toxic and radiation effects lead to changes in genetic material resulting in numerous changes and processes: chromosomal

aberrations, genetic mutations, genomic instability, cell inactivation or cell death (Đurović et al, 2011, pp.127-128).

NATO indirectly acknowledges the dangers of depleted uranium particlesafter hittingan obstacle

According to US sources and knowledge, radiological weapons with DU cause lasting effects on the population even after the end of hostilities, as DU particles contaminate soil and water for thousands of years to come. According to the resolution of the SubCommission on Prevention of Discrimination and Protection of Minoritiesof the UN Commission on Human Rights of 1996 and 1997, the use of these weapons of mass and nonselective destruction is against the norms of international humanitarian law. The first NATO member state, Belgium, despite having the NATO headquarters in Brussels, passed a law in 2009 to ban the production, storage, sale, transportation and use of depleted uranium weapons. The law came into force in mid-June 2009 (Vukmirović, 2019).

The members of the West Multinational Brigade upon KFOR's entry into the Kosovo and Metohia in November 1999 were given a nuclear-chemical-biological manual entitled “KFOR International Brigade West / MNB-W / Depleted Uranium / Information Book”. The manual was signed by Col Osvaldo Bizzari on 22 November 1999 and published in 2006 by retired NATO Admiral of the Mediterranean fleet, Falco Accame in his book *Uranio impoverito. La verità/Depleted Uranium: The Truth* (Accame, 2006). On the cover of the manual, besides the title, there is a skull which warns of radioactive danger. The manual was written as a warning of what type of danger the brigade members would face in the field and how to handle it. In the section called *"The Golden Rules"* it says: *“Stay away from tanks, vehicles and buildings affected by missiles or cruise missiles with depleted uranium (DU). Wear a protective mask if you are operating within 500 meters of a tank or building hit by missiles or missiles with DU. Inhalation of insoluble uranium dust particles has long been associated with health consequences including cancer and neonatal deformities. These consequences can only be seen a few years later.”* In order to avoid contamination, soldiers are recommended, among other things, to wash their clothes frequently, and in the section entitled *"Warning",* among other things, it says: *“Food and water will become unusable due to contamination with dust from DU. Do not eat food that is not controlled. When inhaled, particles can cause long-term damage.“* And the

recommendations for dealing with the damaged or destroyed weapons of the Serbian army are the following:

"...Vehicles and materials of the Serbian army can be a danger to soldiers and civilians who come in close contact with them. Only qualified personnel must inspect destroyed or damaged vehicles and materials (....) and should absolutely avoid the proximity of vehicles suspected of being hit by a missile with DU. There should be no distance less than 50 meters. If you are forced to be closer, you must wear a protective mask and gloves to prevent uranium dust from entering your body."

This guide clearly confirms the fact that before the start of the bombing of FR Yugoslavia, NATO and the USA knew that weapons with DU were dangerous, carcinogenic and genotoxic; however, despite knowing what kind of dangerous weapons they had, they used them in the territory of Serbia. They knew that such irradiation of air, land, and water would certainly have far-reaching consequences for human health and their offspring. They warned their own members of the danger, while the civilian population was never warned of the dangers – on the contrary, they are still publicly claiming that there is no danger of DU particles.

The Manual refers to objects *"hit by missiles or cruise missiles with DU"* which clearly indicates that NATO Pact forces in Kosovo and Metohia and elsewhere in Serbia also used cruise missiles with DU. The US military regulations in the field of radiation protection require every soldier wear a protective suit during training and wear a protective mask for any activity within 20 - 50 meters of an object struck by ammunition with DU (Accame, 2006, pp.8-11). The danger of radioactive dust from DU particles in the United States has long been known. Thus, a US military document emphasized the dangers of DU*: "The major danger associated with depleted uranium is the harmful effect it can have if it enters the body. If the particles are inhaled or ingested, they can be chemically toxic and cause considerable and long-lasting irradiation of the internal tissues."* (Anđelković-Lukić, 2015a, pp.225-226)

During the aggression, the members of the FRY Army in Kosovo and Metohia did not wear protective suits or masks, so the likelihood that they could inhale or swallow radioactive particles from uranium dust generated by the combustion of DU munition was VERY HIGH.

In the immediate aftermath of the war, many works and professional conferences were dedicated to this military conflict. In 1999, the complete issue No 12 of the French journal "Défense nationale" was dedicated to the war in Kosovo and Metohia and in the conference presentation entitled *"First lessons from the war in Kosovo"(Les premières leçons de*

la guerre au Kosovo") there is the following statement: "*After the end of the Kosovo War, historians will give their judgment in a few months or years, but it can already be said that there was no capitulation of the Serbian army or the Serbian state; television has confirmed this in the best sense. Some regret it, but it's true."* (David, 1999, p.39).

Conclusion

After the aggression had ended, mortality among veterans from Kosovo and Metohia increased. Many soldiers who were not injured in the war died from radiation received in Kosovo and Metohia, so that the death toll during the war subsequently increased by the number of deaths from various types of malignancies. Unfortunately, today, nothing seems to be done in Serbia to investigate and prove the damage caused by the bombing, thus denying the dominant effects of depleted uranium and chemical agents on cancer growth in Serbia.

There is no centralized statistics to accompany the increase in the number of people suffering from malignancies among members of the military and police who were deployed in Kosovo and Metohia. The radiation in Kosovo and Metohia was high during the aggression, in some cases as much as 1,100 times that of the natural background.

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РАДИАЦИОННОЕ ОБЛУЧЕНИЕ ВОЕННОСЛУЖАЩИХ СР ЮГОСЛАВИЯ В КОСОВО И МЕТОХИИ ВО ВРЕМЯ АГРЕССИИ НАТО В 1999 ГОДУ

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РУБРИКА ГРНТИ: 78.00.00 ВОЕННОЕ ДЕЛО;
78.25.12 Химическое, биологическое и зажигательное оружие. Вооружения и средства радиационной, химической и биологической защиты
61.00.00 ХИМИЧЕСКАЯ ТЕХНОЛОГИЯ. ХИМИЧЕСКАЯ ПРОМЫШЛЕННОСТЬ;
61.01.94 Охрана окружающей среды
ВИД СТАТЬИ: обзорная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Введение/цель: В данной статье приведены данные о стадиях облучения, которому подвергались военнослужащие армии Союзной Республики Югославия и особенно члены моторизованных бригад в районе Косово и Метохии на албанско-югославской границе.

Методы: С помощью гамма-спектра было выявлено, что снаряды содержали обедненный уран, а наличие альфа, бета и гамма излучений было определено методом дозиметрических измерений.

Результаты: Использование боеприпасов с обедненным ураном ^{238}U, к которому добавлен плутоний, наносит долгосрочный ущерб окружающей среде, в виде заражения воды и почвы, вызывая различные расстройства и злокачественные заболевания у людей. Радиоактивность ^{239}Pu в несколько тысяч раз превышает его токсичность, а вдыхание плутониевой пыли ставит под угрозу здоровье и вызывает рак. Уран является токсичным пирофорным металлом, легко воспламеняющимся и радиоактивным. Его оксиды токсичны и частично растворимы в воде. Во время взрыва снаряда освобождаются радиоактивные аэрозольные частицы в виде дыма, которые воспламеняются при взаимодействии с воздухом, вызывая кратковременные или долговременные повреждения у вдыхающих. Во время агрессии НАТО против СР Югославия при измерениях на территории Косово и Метохии был выявлен высочайший уровень радиации. В районе Метохии радиоактивность была в 1100 раз выше естественного радиационного фона.

Выводы: Выявлено, что во время войны военнослужащие армии СР Югославии подвергались воздействию высоких радиоактивных доз, вследствие этого количество различных злокачественных новообразований и смертельных исходов возросло в несколько раз.

Ключевые слова: химическая война, снаряды с обедненным ураном, повышенная радиоактивность, гемотоксичность, плутоний, радиактивное заражение военнослужащих армии Союзной Республики Югославия, болезни, злокачественные опухоли.

ОЗРАЧЕНОСТ ПРИПАДНИКА ВОЈСКЕ СР ЈУГОСЛАВИЈЕ НА КОСОВУ И МЕТОХИЈИ У ТОКУ НАТО АГРЕСИЈЕ 1999. ГОДИНЕ

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ОБЛАСТ: хемијске технологије
ВРСТА ЧЛАНКА: стручни рад
ЈЕЗИКЧЛАНКА: енглески

Сажетак:

Увод/циљ: У раду се указује на дозу озрачености којој су били изложени припадници Војске СР Југославије, а посебно припадници моторизованих бригада на подручју Косова и Метохије на албанско-југословенској граници.

Методе: Гамаспектрометријским мерењима утврђено је да пенетратор у метку садржи осиромашени уранијум, а методом дозиметријског мерења утврђено је присуство алфа, бета и гама зрачење.

Резултати: Употреба муниције са осиромашеним уранијумом ^{238}U, коме је додат и плутонијум, на дуги рок загађује околину, воду и земљиште, а код људи изазива различите поремећаје и болести, пре свега малигне. Радиоактивност ^{239}Pu је неколико хиљада пута већа од његове токсичности, а удисање плутонијумске прашине угрожава здравље и изазива канцер. Уранијум је пирофоран токсичан метал, лако се пали и радиоактиван је. Његови оксиди су отровни и делимично растворљиви у води. После паљења метак ослобађа радиоактивне аеросолне честице димензије дима, које сагоревају у додиру са ваздухом, изазивајући код онога ко их удахне краткотрајна или дуготрајна оштећења. За време агресије НАТО-а на СР Југославију на Косову и Метохији је измерена велика радиоактивност. У метохијском подручју она је била 1100 пута већа од природног фона.

Закључак: Припадници Војске СР Југославије су током рата били изложени великим радиоактивним дозама, што је довело до повећаног оболевања од разних малигних болести и смртних исхода.

Кључне речи: хемијски рат, муниција од осиромашеног уранијума, повећана радиоактивност, хемотоксичност, плутонијум, озрачености припадника Војске СР Југославије, болести, малигнитет.

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СТРУЧНИ РАДОВИ
ПРОФЕССИОНАЛЬНЫЕ СТАТЬИ
PROFESSIONAL PAPERS

APPLICATION OF GEOINFORMATION SYSTEMS IN THE ARMED FORCES AND OTHER MILITARY FORMATIONS IN THE REPUBLIC OF KAZAKHSTAN

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FIELD: IT, Geoinformation Technology
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Abstract:

Introduction/purpose: The purpose of the paper is to present the importance of geoinformation systems (GIS) in the process of geotopographic support to all levels of command as well as the necessity of developing the GIS platform concept based on geoinformation data as a support to decision making.

Methods: Besides an analytical approach to some of foreign experiences in developing GIS and a sample analysis, the authors give the content and the architecture of the adopted program named „Development of a special GIS platform for the defense and security of the Republic of Kazakhstan".

Results: The paper presents the structures and the level achieved in the development of the single geographic information platform (SGIP) which aims at helping the state to create modern army and efficiently use geoinformation technologies in the support to the armed forces of Kazakhstan.

Conclusion: The importance of creating, at the state level, a unique geographic information space based on the integration of geospatial data at all levels of command has been pointed out as well as the importance of eliminating overspending while creating geoinformation data. In addition, efficient usage of geoinformation technologies will contribute to better combat control of troops and armament thus creating a modern and ready military.

Keywords: geotopographic and cartographic support, geoinformation, geoinformation system, visualizations, geographic overview, aviation maps, city plan, electronic photographic plan, matrix of terrain properties, automated system, remote sensing.

Introduction

Recently, geographic information systems (GIS) are considered as an effective tool for analyzing various types of data in the study of regional development and the development of integrated solutions. Currently, GIS occupy one of the leading places among various information technologies in the field of management and planning.

A geographic information system (GIS) is a hardware-software human-machine complex that provides for the collection, processing, display and distribution of spatial coordinate data, the integration of information and knowledge about the territory for their effective use in solving scientific and applied problems associated with inventory, analysis, modeling, forecasting, environmental management and territorial organization of society.

GIS is a management tool. It is generally accepted that geographic data represent about 70% of the total volume of circulating GIS information. (Goodchild & Kemp, 1990)

The structure and implementation of GIS

Geographic information systems include five key components: hardware, software, data, performers and methods.

Hardware

This is the computer on which the GIS is running. The GIS currently runs on various types of computer platforms, from centralized servers to single or networked desktop computers.

Software

GIS software contains the functions and tools necessary for storing, analyzing and visualizing geographic (spatial) information. The key components of software products are:

- tools for entering and operating the geographic information database management system (DBMS or DBMS); - tools for supporting spatial queries, analysis and visualization (display);

- Graphical user interface (GUI or GUI) for easy access to tools and functions.

Data

Data is probably the most important component. Spatial location data (geographic data) and associated tabular data can be collected and prepared by the user or purchased from suppliers. In the process of managing spatial data, a geographic information system combines (or rather, combines) geographic information with data of other types. For example, already accumulated data on the population, soil character, proximity of hazardous objects, etc. (depending on the task that will have to be solved with the help of the GIS) may be associated with a specific piece of the electronic map.

Moreover, in complex, distributed systems for collecting and processing information, there is often no data associated with an object on the map, but only its source, which allows real-time monitoring of the state of such an object. This approach is used, for example, to deal with emergencies such as forest fires or epidemics.

Performers

Performers are people who work with software products and develop plans for their use in solving real problems. It may seem strange that people working with software are considered to be part of the GIS, but this makes sense. The fact is that for the geographic information system to work effectively, it is necessary to comply with the methods provided by the developers; therefore, without trained performers, even the most successful development can lose all meaning.

GIS users can be both technical specialists who develop and maintain the system, and ordinary employees (end users), whom the GIS helps to solve current everyday affairs and problems.

Methods

The success and effectiveness (including economic) of the use of the GIS in many respects depends on a correctly drawn up plan and

work rules, which are compiled in accordance with the specifics of the tasks and work of each organization.

GIS subsystems

The GIS structure, as a rule, includes four mandatory subsystems:

1) Data input, providing input and / or processing of spatial data obtained from maps, remote sensing materials, etc .;

2) Storage and retrieval, allowing quick receipt of data for appropriate analysis, data update and data adjustment;

3) Processing and analysis, which makes it possible to evaluate parameters, solve computational and analytical problems;

4) Presentation (issue) of data in various forms (maps, tables, images, block diagrams, digital terrain models, etc.)

Application and charcteristics of the GIS

Thus, the creation of maps in the circle of “responsibilities” of the GIS is far from the first place, because to get a hard copy of the map most of the GIS functions are not needed at all, or they are used indirectly. Nevertheless, both in world and in domestic practice, the GIS is widely used, precisely for preparing maps for publication and, to a lesser extent, for analytical processing of spatial data or managing the flow of goods and services (Tikunov, 2004).

The GIS allows making decisions based on geographic information. Unlike other types of information processing tools, the GIS understands the concept of location, as it is based on information tied to the coordinates on the map, and allows the information presentation in a graphical form for interpretation and management decisions.

Geoinformation technologies are inextricably linked with the GIS. Geoinformation technologies can be defined as a combination of software and technology tools for obtaining new types of information about the world. Geoinformation technologies are designed to increase efficiency: management processes, storage and presentation of information, processing and decision support (Tikunov, 2004).

The main feature of the GIS, which determines its advantages in comparison with other AIS, is the presence of a geographic information base, i.e. digital maps (DM), giving the necessary information about the earth's surface. In this case, the DM must ensure:

- exact binding, systematization, selection and integration of all incoming and stored information (single address space);
- comprehensiveness and visibility of information for decision making;

- the possibility of dynamic modeling of processes and phenomena;
- the ability to automatically solve problems associated with the analysis of the features of the territory;
- the ability to quickly analyze the situation in emergency cases.

GIS experience

Geoinformation technologies, offering new effective approaches to the analysis and solution of territorial problems, continue to gain more and more popularity and official recognition in our country, and digital spatial information begins to play an increasingly important role in the tasks of socio-economic, political and environmental development and environmental management, production and labor potential in the national interest.

Foreign experience in operating various GIS indicates that the need to analyze the geographical location of phenomena and objects, their quantitative and qualitative characteristics using a map arises among representatives of armed forces and various sectors of economy (Kapralov et al, 2005).

An analysis of the forms and methods of combat use of troops (groupings of troops) in special operations in Chechnya allows us to conclude that the goal of topographic and geodetic support (hereinafter TGO) should be the preparation and timely delivery of accurate and reliable topographic and geodetic information in the required volume to headquarters and troops, contributing to the creation of necessary conditions for solving the following tasks:

- maintaining troops (forces) in constant combat readiness;
- timely covert deployment (creation) of force groupings;
- accomplishment of assigned tasks by troops;
- ensuring the effective use of weapons and military equipment.

The process of organizing topographic support for the combat operations of troops in modern conditions, taking into account the experience of counter-terrorism operations in Chechnya, Afghanistan and Iraq, necessarily includes the following aspects:

- timely and complete provision of command and control bodies with topographic and special maps, early production of topographic plans of cities;
- preparation of initial astronomical and geodetic data on the positional areas of the missile forces and artillery and bringing them to the appropriate command and control agencies;

- providing staffs and troops with additional information about the terrain in the form of special photo documents of the terrain, with other reference materials made in direct preparation for hostilities and during their conduct;

- providing appropriate systems for command and control, reconnaissance and guidance with digital electronic maps, digital terrain models;

- organization and timely communication to the troops of the results of topographic reconnaissance of the terrain of objects and the enemy (Evgievsky & Morozov, 2005, pp.39-43).

An analysis of the provision of geospatial information of the Armed Forces of the Republic of Kazakhstan in everyday life, during preparation and during exercises, indicates a serious lag in these matters from the armies of developed countries. The command and control bodies of the troops receive information about the area in the form of the same topographic map and according to the same procedure as fifty years ago. After the application has been sent to the relevant authority, the data of archived topographic maps are processed, then separate sheets are issued, combined and filled in with official symbols and descriptions.

At the same time, it should be noted that the topographic map in an analog form is the main working document of the commander and staff used in planning operations and combat operations, when setting up tasks for subordinate troops and exercising control over the progress of the troops in fulfilling assigned tasks.

The experience of armed conflicts of foreign countries shows that topographic maps on a paper basis, under the conditions of active influence on the weapons and equipment of electronic means of suppressing the enemy, are the main information document. Consequently, activities to create, store and bring to the troops a paper map will retain its significance along with the creation of a digital cartographic database.

Geoinformation support

The development of a modern army, as well as the development of modern society as a whole, is based on the introduction and development of information technology. The most important component of most technologies is the processing of digital terrain information in conjunction with diverse data about the enemy and their troops.

Now that the world is entering the new millennium with an understanding of the benefits of digital imaging, sound and

communications, topographic and geodetic support simply cannot be left out of technological progress.

It becomes obvious that geoinformation support is the topographic and geodetic support of the 21st century. It includes aerospace, optoelectronic reconnaissance, satellite communications, digital computer technology and classical methods of geodesy, cartography and photogrammetry. An analysis of the tasks solved by the topographic services of the associations of the Armed Forces of the Republic of Kazakhstan during the preparation and during operations and combat operations, as well as the means and methods of solving them, indicates that there is a serious lag in these issues from the armies of developed countries.

Geoinformation support assumes the circulation of terrain data through channels connected to databases of geographical information systems (GIS). Actually, they are the basis of geoinformation support. At its core, the GIS is a combination of a geographic or topographic map and an extensive array of digitally expressed heterogeneous information, systematized and linked to the corresponding point in the cartographic image. Digital information about the terrain can be presented in the form of an electronic topographic, geographic, aviation map, city plan, diagram, electronic photographic plan, elevation matrix, matrix of terrain properties, etc.

The GIS performs two important functions: creating a digital map of the area, integrated with an expanded database, and turning a digital map into electronic - visualization - with the possibility of interactive work with the user. Based on these two functions implemented with the GIS, many others are based (Ivanov & Markus, 1999, pp.42-45).

Geospatial information, formed on the basis of the collection and analysis of cartographic, geographical, climatic, hydrological, aerological, administrative data and information on the infrastructure features of the territories, plays an increasingly important role in ensuring the military and public security of the state.

Modern technologies make it possible to generalize and link geospatial data, provide the possibility of their visualization and interactive access to them, and provide support for management decisions.

An analysis of the development of modern systems of geospatial support for armies of foreign countries and the prospects for their development allows us to conclude that the practical effect of increasing the combat capabilities of troops is achieved not only by increasing fire, maneuverability and other characteristics of weapons platforms, but also

primarily by the reduction of the combat command cycle and decision-making on the basis of geographic information components of the combat space.

For example, in the armed forces of the NATO countries, the implementation of a new concept for providing geospatial information, denoted by the term Situational Awareness, is made possible through the use of the neogeography method, which assumes, in particular, the location of the user “inside the data” in real spatial time continuum, instead of the obligatory mediation of cartographic conventions.

The problem of determining a single special geographic information platform arose due to the heterogeneity of geospatial information used in the Armed Forces, other troops and military units. Issues within departmental information interaction and analytical decision support based on geoinformation data were implemented using various software tools.

Currently, the ArcGIS software platform has partially created geospatial data:

- in the Ministry of Internal Affairs of the Republic of Kazakhstan as part of the deployment of the “module of the geographic information system” of the Operational Management Center,
- in the emergency committee of the Ministry of Internal Affairs of the Republic of Kazakhstan as part of the deployment of the GIS subsystem of the "corporate information and communication system" (presentation attached),
- a large volume of cartographic materials in the Mapinfo format has been created in the Ministry of Defense of the Republic of Kazakhstan.

So, from 2002 to 2016, by the order of the Ministry of Defense of the Republic of Kazakhstan, plans and topographic maps were produced in analog and electronic formats on a scale of 1:10 000 - 1: 1000 000 on the territory of the Republic of Kazakhstan, border states, military training grounds, as well as on the territory of regional centers and large cities, covering 8034 nomenclature sheets.

In addition, single materials of large-scale topographic maps were produced on the territory of military training grounds in the ArcGIS format on 164 nomenclature sheets. At the same time, the conversion of geospatial data from one format to another was carried out with a loss of quality of materials.

In addition, the implementation of the SGIP project acquires special relevance in connection with the sanction ban on the provision of ArcGIS and MapInfo software licenses, as well as the provision of technical

support services (including the delivery of software updates as part of the existing technical support) to a number of defense and oil and gas enterprises.

At the same time, ESRI GIS refers to the relevant order of the Department of Foreign Assets Control of the US Department of the Treasury and the Bureau of Industry and Security of the US Department of Commerce.

Program: Development of a special GIS platform for the defense and security of the Republic of Kazakhstan

To solve all of the above tasks and programs, officers of the National Defense University named after the First President of the Republic of Kazakhstan, the Leader of the Nation, took part in the implementation of the both scientific and scientific and technical program as part of targeted funding for the topic of a both scientific and scientific and technical program (hereinafter - the program): “Development of a special GIS platform for the defense and security of the Republic of Kazakhstan” which will be based on the integration of large arrays of cartographic materials, other geospatial data, infrastructural information on operational equipment of the territory and mobilization resources by sectors of the economy, detailing materials for the certification of terrorist vulnerable objects, and will be the basic platform of information systems for decision-making support of the Armed Forces, other troops and military units, government bodies and organizations, the joint activities of which rule in the solution of tasks of ensuring military security of the Republic of Kazakhstan.

Research Objectives

- development of a prototype of a unified software platform for collecting, accumulating and visualizing GDB, with the functions of performing GIS applications that solve the range of tasks of terrain analysis, with the possibility of creating geospatial products for various purposes and publishing topographic and special maps;
- creation of an electronic geospatial information bank;
- development of geospatial engineering products;
- development of converters for re-issuing DTMs into a single format of the SGIP platform.

At this stage of the study, the goal was to analyze the views of domestic and foreign experts on the development of geographic

information platforms and to develop the structure of a special geographic information platform for the Armed Forces of the Republic of Kazakhstan.

Based on the goal, the following tasks were identified:

- study of world experience in the development of geographic information platforms;
- the formation of the structure of a special geographic information platform;
- development of technical specifications for the development of a special program of the SGIP.

Fulfillment of the tasks set and achievement of the goal at this stage provides the basis for further research and helps substantiate the novelty and significance of the study.

Scientific novelty and relevance of research

The SGIP will be a domestic software product based on the integration of a large number and scale cartographic materials, geospatial data of the military state and operational infrastructure information.

The formation of the SGIP structure, the development of technical specifications, the acquisition of the necessary software equipment and the development of special programs will allow to:

- promptly display and use in work any requested area of the terrain from a large volume of source geospatial information databases (satellite images, cartographic materials);
- along with electronic maps, create geographic information products that are visualized in the form of layers of maps and tabular information;
- ensure the uniformity of requirements for protocols for the exchange of geospatial information between users of the GIS;
- ensure the formation of electronic documents (orders, directives, orders) and the issuance of commands when changing environmental conditions;
- and, on the whole, create a single information space based on the integration of generally applicable data and their descriptions by types of functional activity at all levels (links) of the Armed Forces command.

The development of the SGIP will contribute to the achievement of the goals of creating a modern combat-ready army, the effective use of geographic information technologies in the implementation of combat control of troops and weapons.

Analysis of foreign specialists of the development of geoinformation platforms

Due to the variety of GIS platforms, only the most common ones were selected for the analysis.

ArcGIS platform

The ArcGIS platform is the optimal solution for building a corporate GIS, the foundation of an information system for the effective management of large state and commercial organizations (Raklov, 2011).

The ArcGIS - produced by the American corporation ESRI, one of the few GIS platforms supports full-fledged work with a topological model of data representation, as well as storage, processing and visualization of three-dimensional representation of spatial data. It has an open architecture (more than 800 standard additional target applications), but source codes are not transmitted to users.

The use of this GIS platform will require the conversion of the entire range of maps to the ArcGIS format, while the work will require a lot of manual labor and financial costs.

Price policy: for one ArcView license - 600 000 tenge, ArcEditor-1 - 2 000 000 tenge, ArcInfo-2 - 1 500 000 tenge, time libraries completion - 300 000 tenge, development tools - 2 100 000 tenge for one year. The GIS price is not fixed.

MapInfo

MapInfo was produced by the American company Pitney Bowes Software and is intended for the collection, storage, display, editing and analysis of spatial data. MapInfo is used in 130 countries. Due to its ease of development, rich functionality and moderate cost, MapInfo has become the most popular GIS.

Based on this program, the entire range of electronic cards for the Armed Forces of the Republic of Kazakhstan has been created. Price policy: GIS MapInfo Professional for Windows - 900 000 tenge, GIS MapInfo Professional for Windows (Russian version) including technical support for 1 year - 600 000 tenge.

The ArcGIS and MapInfo have an open architecture; however, since the source codes of these GIS platforms are not transmitted to users, it is not possible to check for the presence of undeclared functions.

Functionality, usability and adequate technical support are at the highest level; however, it is difficult to use it due to the fact that not all modules and instructions are translated into Russian.

Free legitimate distribution is practically impossible. There is a high level of technological dependence on foreign manufacturers.

Analysis of Russia and Belarus specialists of the development of geoinformation platforms

Due to the lack of ready-made GIS solutions on the domestic market, the GIS developments of Russia and Belarus, which have in-CIS GIS platforms of their own design, were examined.

In order to make the analysis objective, the opinions of both the GIS manufacturers themselves and competent users were taken into account.

In the post-Soviet space, the most common are the developments of Russian manufacturers.

GIS Integration

GIS Integration. Developed by the closed joint stock company KB Panorama for FGUP NII TP.

Positive sides:

- adopted by the Armed Forces of the Russian Federation and is a military product.

Negative sides:

- does not meet security criteria due to the impossibility of transferring source codes to check for the presence of non-declared functions;
- there is low-level technical support, the system is underdeveloped, and since the last update was carried out in 2005, there is a discrepancy between the system and the requirements of the troops;
- all system improvements can only be made by the developer; and
- there is a threat of technological dependence on foreign manufacturers.

Despite the decisions taken by the Council of Ministers of Defense of the Commonwealth of Independent States on the Concept of creating a unified GIS for years, appeals to the General Staff of Russia on the transfer or sale of GIS Integration were ignored.

GIS Operator

The geographic information system Operator was accepted for supply to the RF Armed Forces by order of the Minister of Defense of the Russian Federation No. 598 dated August 15, 2013. The set of programs developed by the closed joint stock company KB Panorama allows organizing topographic and geodetic support based on the principles of network-centric technologies in advanced automated systems and controls in power departments. (KB Panorama, 2020)

Positive sides:

- according to the results of comparative tests of geographic information systems, the GIS Operator in 2012 was recognized as the most fully meeting the requirements of the armed forces for military GIS and in 2013 it was adopted by the Armed Forces of the Russian Federation;
- the ability to transfer source codes to check for the presence of non-declared functions;
- the system is constantly evolving, the developer promptly responds to user requirements;
- cards created through the VTU General Staff of the Armed Forces of the Russian Federation are produced on the software complexes of closed joint stock company KB Panorama.

Negative sides:

- impossibility of free distribution, i.e. expansion of the user structure entails additional costs for licenses, and all system improvements can only be made by the developer;
- the product is quite complicated to learn and maintain, focused on the professional use of the system;
- there is a threat of technological dependence on foreign manufacturers.

Price policy: GIS Map 2011 - 95 000 tenge, professional GIS Map 2011 with development tools - 270 000 tenge.

GIS Horizon

Developed by FGUP NIIIAA and named after Semenikhin.

Positive sides:

- the ability to transfer source codes to check for the presence of non-declared functions;

- the possibility of "free distribution of GIS", i.e. the user's right to freely run, copy, distribute, study, modify and improve it;
- the possibility of creating a domestic GIS on a ready platform, i.e. technological independence from foreign and private producers of GIS;
- there is an official partner in the Kazakhstan market.

Negative sides:
- the system has not been adopted by the Armed Forces of the Russian Federation;
- there is no information that the system is being updated and developed.

"GIS for military use"

Despite the fact that Russia is a strategic partner not only politically, but also militarily, in addition to the operation of Russian GIS platforms, Belarus is actively developing its own GIS - "GIS for military use", created on the basis of the closed joint stock company KB Panorama software core.

It is developed by the Joint Institute for the Study of Informatics Problems of the Belarusian Academy of Sciences.

Positive sides:
- adopted by the Armed Forces of the Republic of Belarus;
- the ability to transfer source codes to check for the presence of non-declared functions;
- the possibility of "free distribution of GIS", i.e. the user's right to freely run, copy, distribute, study, modify and improve it;
- the possibility of creating a domestic GIS on a ready platform.

Negative sides:
- it is not a complete GIS, it is used as a tool to support decision making.

Pricing policy: no information.

Types of GIS in use in other armies

Out of all the listed programs, the following ones are actually adopted and used as GIS platforms of automated control systems of the armed forces:

In the NATO countries, including: the United States of America, France, Germany, as well as in Ukraine (from the CIS countries) - ArcGIS.

Turkey, as a member of NATO, simultaneously with ArcGIS uses a proprietary GIS platform - Netcad.

Sweden uses ArcView GIS and MapObjects, derived from ArcGIS.

In Russia and Armenia, the GIS Integration is used, and in return the GIS Operator is being prepared.

In addition to the GIS Integration, Belarus uses a GIS platform of its own design - military GIS.

Israel - ArcGIS, Adlib;

Uzbekistan uses ArcGIS in the field of communications and information technology;

China - no data;

In the Republic of Serbia, as a neutral country, the Serbian Armed Forces are developing a GIS project called "Universal User Software Platform (UKSP) of the Serbian Armed Forces GIS". This GIS is a modular software platform intended for spatial support in the decision-making process at all levels of command in all missions of the Serbian Armed Forces, which is in the final stages of adopting into the arms and equipment of the VS.

In the Republic of Kazakhstan, among government agencies, the situation is as follows:

ArcGIS is operated in the National Security Committee, Ministry of Emergencies, MEP, KTZ, and KMG;

Mappinfo is operated in the Ministry of Defense, and the Interior Ministry.

Transition to a single GIS platform

One of the ways to solve the problem of heterogeneous software products is to create uniform standards for the language for describing the modeling space (Konovalova & Kapralov, 1997).

However, the lack of work to standardize objects of the operational-tactical situation, control languages, and other elements of information support does not allow solving this problem. The choice of a single basic GIS platform should be the first step in creating a single information space of the state.

A distinctive feature of military conflicts of a new type, at the end of the twentieth and the beginning of the twenty-first century, is that the role of informational aspects in ensuring the actions of armed forces has

grown. This was facilitated by the rapid development of information technology, which began to invade all areas of human activity, including the military sphere. Ensuring information superiority over the enemy has become one of the decisive factors for achieving success in the war.

Modern information and network technologies in military affairs are the basis for the integration of geographically dispersed command and control bodies, reconnaissance, surveillance and target designation systems, military groups and weapons in a highly adaptive gliding system.

At present, new tools that reflect the current level of geoinformatics are increasingly used. These include the means of complex multivariate spatial analysis and the preparation of high-quality synthesized images based on maps, images, and the operational environment (Lurie, 2000).

Geoinformation technologies make it possible to move to a unified planning system, form a single picture of situational awareness, develop modern methods of control and management of weapons of war, including unmanned and robotic systems, increase transparency and operational efficiency of the rear and reduce the level of advanced presence through the formation of virtually remote headquarters and other bodies management.

To determine the feasibility of using a specific GIS, it is necessary to consider how much it meets the requirements stipulated by the specifics of the tasks to be solved when processing geospatial information shown in the modules of the geographic information system (Fig. 1).

The spatial analysis and modeling module is one of the key GIS. The functional completeness of the analysis and modeling tools mainly determine the versatility and effectiveness of a particular GIS (Berlyant, 1997).

Basic operations include groups of operations such as measuring operations, polygonal operations (overlaying polygons, determining whether a point belongs to a contour, and others), transformation of coordinate systems and projections, analytical and modeling operations (selection of objects according to specified criteria, network tasks, processing of geodetic survey data, construction of buffer zones and others), surface analysis, digital processing of Earth remote sensing data, and other operations.

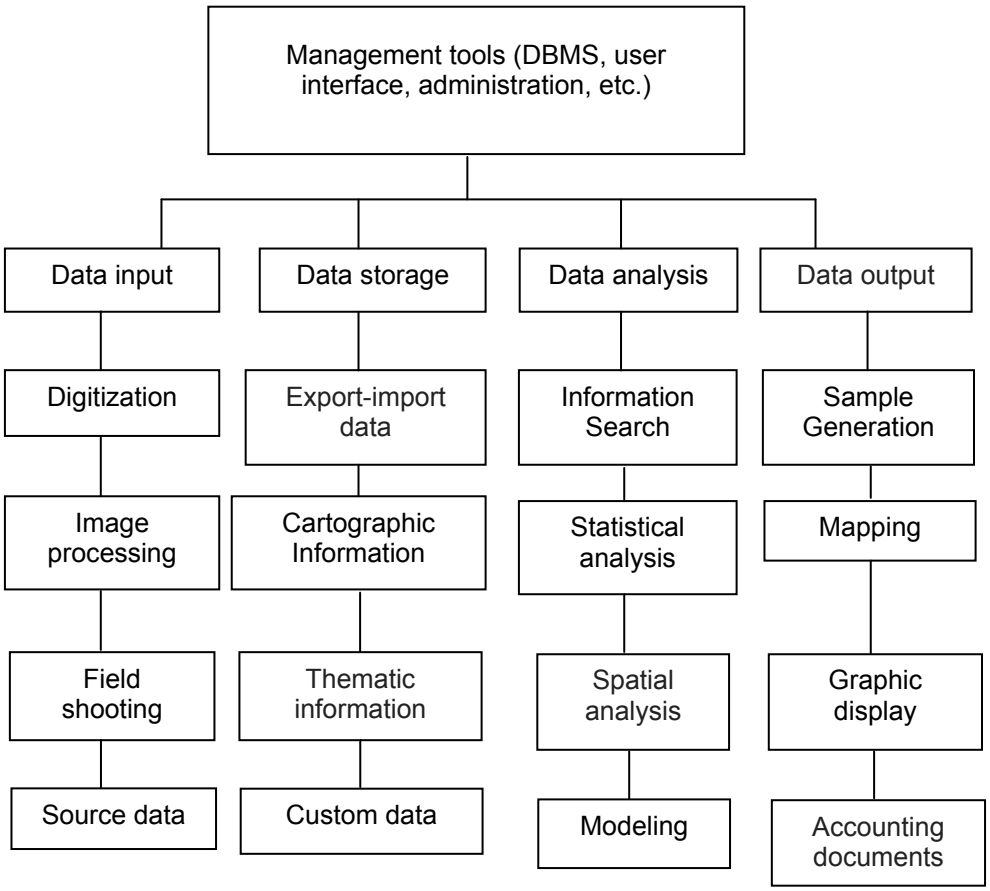

Figure 1 – Module of a geographic information system
Рис. 1 – Модуль геоинформационной системы
Слика 1 – Модел географског информационог система

The GIS management tools include access operations to internal and external databases, a user interface, a system for organizing access to the system's functional procedures, development and integration tools for user applications in the GIS, and others (Tsvetkov, 1997).

The GIS possesses the term basic characteristic properties: the presence of spatial databases, coordinate reference of object modeling and analysis, and spatial analysis tools. Apparently, one should proceed from this, taking into account the target orientation of the information system and the depth of use of digital models in spatial analysis.

Examples of the transition to a single GIS platform

Based on the research conducted above, the experience of the transition of the armies of foreign countries to a single GIS platform is interesting.

For example, the US Geospatial Intelligence Agency purchased the Commercial Joint Mapping Toolkit, which provides access to scalable GIS using standard interfaces. Northrop Grumman, the developer of the GIS, acts as a system integrator, ESRI became ArcGIS core, Leica Geosystems supplied image processing modules, and Analytical Graphics offered tools for analyzing satellite data. Vector maps in the system are maintained on the Oracle 10g DBMS, and raster maps are supported by the ESRI File Based Geodatabase engine. ArcGIS Explorer, which supports web architecture, is used as a typical client software.

At the first stage of the introduction of unified GIS technology within the framework of the C31 program (operational command, control and communication information systems), the Swedish army acquired several thousand licenses of MapObjects and ArcView. Products are used at all levels of command, as well as by lower-level personnel for everyday tasks. As the circle deepened and expanded, which can be solved using GIS tasks, the Swedish Armed Forces realized the need to create a GIS battlefield with specialized functions for creating tactical situational maps, planning convoys, analyzing targets, monitoring war games, and solving other operational and tactical tasks. The new software product, called GeoPres, is based on the ArcView GIS and MapObjects standards adopted by the Swedish Armed Forces, expanded in accordance with the requirements of the army.

Standardization was based on ArcView GIS and MapObjects from ESRI. As a result, the Swedish Armed Forces have developed many extensions to both software products to adapt them in the military field. A GIS built into the C3I system provides a solution to a number of typical problems associated with the use of this technology in everyday activities in peacetime, during exercises and in a combat situation on the battlefield. It is quickly mastered by end users and allows a quick response to a constantly changing situation on the ground.

According to the results of a closed competition in January 2013 for the best GIS development, in order to create a single GIS platform for all power structures in Russia, the GIS Operator was unanimously determined by order of the Minister of Defense of the Russian Federation

No. 588 of 08/15/13. The Operator geographic information system is accepted for supply to the Armed Forces of the Russian Federation.

In order to select a single GIS platform for the Armed Forces of the Republic of Kazakhstan, it is proposed: to develop our own software products with similar functions that exist in the best examples of foreign GIS, which will form the basis of a single information platform for the power structures of the Republic of Kazakhstan; to intensify interaction with the Ministry of Transport and Communication, as the responsible body for the implementation of "electronic government" and JSC "National Information Technologies", as the project integrator of the infrastructure of "electronic government". When choosing a GIS platform for the Armed Forces of the Republic of Kazakhstan, use the results of the development of technical documentation for the creation of a national GIS; organize trial operation of the GIS CJSC KB Panorama software and hardware on the basis of Kazakhstan GIS Center JSC and, based on its results, determine the feasibility of determining it as a GIS platform.

Formation of the special geoinformation platform structure

The structure and content of a special geographic information platform

The research team has formed the structure of a unified geographic information platform. The goals and objectives, the place of the GIP in the Digital Army are defined, the architecture is developed taking into account the vertical of subordination and the movement of the created geospatial engineering products, and a typical GIS solution is found. The sources of geospatial information were identified and a list of software necessary for the development of software products was compiled.

The work of the research group was organized on the basis of Kazakhstan GIS Center JSC, according to the contract for the lease of premises and equipment of equipment from 03/06/2018. No. 9/18/1.

Technical specification for the acquisition of software and development tools

In 2018, agreement No. 9/18/2 of March 6 2018 was signed for the purchase of software and development tools for the creation of special programs that form the basis of the GIP platform.

The following software and processing tools are acquired under the contract, including: a complex for maintaining a geoportal; software for

creating and updating digital terrain models; specialized software for displaying and editing the military situation; GIS application development tools; development tools for geographic information WEB applications; environment program for fast program development with the ability to create client-server solutions, multilevel databases, and web applications.

Technical specification for the development of a special SGIP program

Based on the established structure of the GIP, the study of domestic and international experience in creating various GIS systems, the research group developed the Technical specification for the creation of its own special software products that form the basis of the GIS platform (Koshkarev & Tikunov, 1993).

The technical specification formulates and describes the structure and functioning of the SGIP, and describes the functionality of each software module.

Development of special geoinformation platform programs

Development of a program for generating atlases of electronic terrain maps

As part of the research work, a program for the formation of atlases of electronic maps of the area was developed (DeMers, 2008).

The program maps the raster maps of BMP, JPEG, TIFF, GeoTIFF, TGA (Targa), BIL (SPOT), and SID formats with the geographical information contained in them with the possibility of transforming the raster.

It allows building mosaic raster atlases of the formats BMP, JPEG, TIFF, GeoTIFF, TGA (Targa), and BIL (SPOT) based on the use of adjacent and overlapping raster data of large volumes of the formats BMP, JPEG, TIFF, GeoTIFF, TGA (Targa), BIL (SPOT), and SID by transforming them over a set of control points.

It is possible to combine the attached raster with a previously created electronic map and to interactively create atlases of electronic topographic maps, geographic and special maps, which are nomenclature sheets of electronic materials sewn into a single block, belonging to one or different blocks, belts, zones, which allows selecting the zone number and recalculation of coordinates in the coordinate

system of this zone, as well as automatic stitching of double and quadruple nomenclature sheets.

There are also opportunities for interactive selection with the mouse of nomenclature sheets for creating atlases on the layouts (prefabricated tables - blank maps) of the corresponding subsystems and blocks displayed on the screen and drawing lines of a dynamic coordinate grid on a map of the area at the operator's command.

The program localizes the list of errors when stitching atlases with the name of the error.

It is also possible to create an atlas from materials in different projections, coordinate systems, with different units of measurement and automatically determine the working area of the atlas by the spatial position of the data and their coordinate system.

Development of a converter for converting digital terrain models into a single platform format

Geospatial data materials are in various vector formats and, when they are converted by standard means, there arises a problem of ambiguous conversion of digital map data into the selected single format - a combination of the ways of graphical representation of objects, a set and attribute values (KB Panorama, 2020). In particular, it requires establishing a correspondence between the attributes of objects on the source map and objects on the map in a single format, processing incorrect input of attribute values, etc.

A system is proposed for converting cartographic information presented in the MID / MIF (MapInfo) exchange format into a single SIP format.

The developed converter for re-designing the DTM allows a change of the existing geospatial data from the original format to the unified format of the SIP.

The converter allows users to accurately and reliably reformat existing cards into a single format. The developed converter allows forming the source digital data in the SGIP system, including both metrics and semantics. The converter also provides an unambiguous conversion of these materials to the SIPIP card format.

With the converter, the map data in the MID / MIF format is converted to the SIPM map format. The converter parses a MID / MIF file, forming both a graphic and semantic representation of objects.

Thus, the development of the SGIP will help achieve the goals of creating a modern combat-ready army, the effective use of geo-

information technologies in the implementation of combat control of troops and weapons.

During the reporting period, the scientific group carried out the following work:

- the analysis of the views of domestic and foreign experts on the development of geographic information platforms;
- the structure of a special geographic information platform has been formed;
- developed technical specifications for the SGIP;
- prepared technical specification for the acquisition of software and development tools:
- a program for the formation of atlases of electronic terrain maps has been developed;
- a converter has been developed for redesigning digital terrain models (DTMs) into a single platform format.

The formation of the SGIP structure, the development of technical specifications, the acquisition of the necessary software equipment and the development of special programs will allow to:

- promptly display and use in work any popular area from a large volume of source bases geospatial information (satellite images, cartographic materials);
- along with electronic maps, create geographic information products that are visualized in the form of layers of maps and tabular information;
- ensure the uniformity of requirements for protocols for the exchange of geospatial information between users of the GIS;
- ensure the formation of electronic documents (orders, directives, orders) and the issuance of commands when changing environmental conditions;
- and, on the whole, create a single information space based on the integration of generally applicable data and their descriptions by types of functional activity at all levels (links) of the Armed Forces command.

Conclusion

The development of the State Information System will provide managers of all levels of government agencies and organizations whose joint activities are aimed at solving the problems of ensuring the military security of the Republic of Kazakhstan with objective and operational geospatial information, as well as increase the efficiency of decisions by reducing the time to collect information about the area, to evaluate current geospatial data and to communicate it to the troops. This will help

achieve the goals of creating a modern combat-ready army, the effective use of geo-information technologies in the implementation of combat control of troops and weapons.

The development of special programs allows you to:

- promptly display and use in work any requested area of the terrain from a large volume of source geospatial information databases (satellite images, cartographic materials);
- along with electronic maps, create geographic information products that are visualized in the form of map layers and tabular information.

In general, it will contribute to the creation of a single information space based on the integration of generally applicable data and their descriptions of the types of functional activities at all levels (links) of command of both the Armed Forces and other troops and military units of the Republic of Kazakhstan.

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ПРИМЕНЕНИЕ ГЕОИНФОРМАЦИОННЫХ СИСТЕМ В ВООРУЖЕННЫХ СИЛАХ, ДРУГИХ ВОЙСКАХ И ВОИНСКИХ ФОРМИРОВАНИЯХ В РЕСПУБЛИКЕ КАЗАХСТАН

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РУБРИКА ГРНТИ: 36.00.00 ГЕОДЕЗИЯ. КАРТОГРАФИЯ;
36.29.00 Топография. Фототопография
36.29.33 Топографические и специализированные карты и планы. Цифровые модели местности.
ВИД СТАТЬИ: профессиональная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Введение/цель: Данная статья написана с целью ознакомления читателей со значимостью геоинформационной системы (ГИС) в процессе топогеодезического обеспечения всех сегментов командного управления и необходимостью развития концепции платформы ГИС, основанной на геоинформационных данных и функциях поддержки при принятии решений.

Методы: Применяя аналитический подход в изучении имеющихся причин, а также на основании опыта развития системы ГИС за рубежом, в данной статье приведены содержание и архитектура, установленной программы «Разработка специальной геоинформационной платформы в интересах обороны и безопасности Республики Казахстан»

Результаты: В статье приведен краткий обзор достигнутого уровня развития и структуры единой специальной геоинформационной платформы (СГИП), которая будет способствовать осуществлению государственных задач в создании современной армии и эффективном использовании геоинформационных технологий в поддержке вооруженным силам Республики Казахстан.

Выводы: В статье рассматривается важность создания единого государственного географического информационного пространства, основанного на интеграции геопространственных данных на всех уровнях управления, а также важность устранения дублирования бюджетных расходов при сборе и отображении геопространственной информации. Соответствующее применение геоинформационных технологий будет также способствовать повышению эффективности в управлении и контроле воинскими формированиями и вооружением, а также в создании современной армии, подготовленной к военным конфликтам.

Ключевые слова: геотопографическое и картографическое обеспечение, геоинформационные данные, геоинформационная система, визуализация, географический обзор, аэронавигационные карты, план города, электронный фотоплан, матрица свойств местности, автоматизированная система, дистанционное зондирование.

ПРИМЕНА ГЕОИНФОРМАЦИОНИХ СИСТЕМА У ОРУЖАНИМ СНАГАМА, ДРУГИМ ВОЈСКАМА И ВОЈНИМ ФОРМАЦИЈАМА У РЕПУБЛИЦИ КАЗАХСТАН

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ОБЛАСТ: геоинформационе технологије
ВРСТА ЧЛАНКА: стручни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Увод/циљ: Циљ рада је предочавање значаја геоинформационог система (ГИС) у процесу геотопографског обезбеђења свих сегмената командовања и неопходност развоја концепта ГИС платформе засноване на геоинформационим подацима у функцији подршке доношењу одлуке.

Методе: Користећи аналитички приступ на бази узрока и страних искустава развоја ГИС система приказује се садржај и архитектура усвојеног програма „Развој посебне ГИС платформе за одбрану и безбедност Републике Казахстан".

Резултати: Приказан је достигнут степен развоја и структура јединствене географске информационе платформе (СГИП) која треба да послужи остварењу државних циљева – стварању модерне војске и ефикасном коришћењу геоинформационих технологија у подршци оружаним снагама Казахстана.

Закључак: Сагледан је значај стварања јединственог државног географског информационог простора, заснованог на интеграцији геопросторних података на свим нивоима органа управљања, као и важност елиминисања дуплирања буџетских издатака при изради геопросторних информација. Такође, ефикасно коришћење геоинформационих технологија допринеће спровођењу борбене контроле трупа и наоружања и стварању модерне војске спремне за борбу.

Zakiev, E. et al, Application of geoinformation systems in the armed forces and other military formations in the Republic of Kazakhstan, pp.356-382

Кључне речи: геотопографска и картографска подршка, геоинформациони подаци, геоинформациони систем, визуализација, географски преглед, аеронаутичке карте, урбанистички план, електронски фотографски план, матрице карактеристика терена, аутоматизовани систем, даљинска детекција.

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Пољска тенковска флота[1,2]

Пољска тенковска флота једна је од најбројнијих у Европи захваљујући великом војном буџету (по европским мерилима), као и тенковима наслеђеним од пољске народне армије. Састоји се од руских тенкова *T-72M1,* домаћих варијанти *T-72* и различитих модела немачких тенкова *Leopard 2*. Пољска би представљала прву линију одбране у евентуалном копненом сукобу између Русије и Запада. Колико је пољска тенковска флота заиста способна? Колико су ефикасне разне модернизације и какви су планови за будућност?

T-72M1s

Највећи број тенкова у пољској војсци чине T-72M1 са 350 возила и 200 у оперативној употреби. Ради се углавном о стандардним тенковима T-72A из 1979. године, опремљеним првим генерацијама топа 125 мм 2A46, активним ноћним нишаном и ласерским даљиномером који снабдева подацима систем за управљање ватром *1A40*. Оклоп је израђен на бази

[1] The national interest November 15, 2019
[2] Jane's Defence Monthly, December 2019

совјетске композитне технологије: сендвич-текстолита и челика. Купола има оклоп „*Dolly Parton*". Ови тенкови обезбеђују основни ниво борбених способности, али су врло застарели у поређењу са савременим руским тенковима. Наиме, сва модерна противтенковска муниција, чак и лаки ручни бацачи, пробијају оклоп ових тенкова.

Следећи по бројности су тенкови *PT-91 Twardy.* У оперативној употреби су 232 тенка овог типа. Неки су нови, произведени у фабрикама, док други представљају модернизовану верзију руског тенка *T-72M1* . Овај тенк има већу могућност преживљавања, поседује пољски упозоравач ласерског озрачења типа *SSC-1 Obra*, систем за сузбијање пожара *DEUGRA*, оклопне пакете типа *ERAWA-1* и *2* и бацаче димних граната типа *WGD-1 Erb* и *WPD-1 Tellur.* Опремљени су материјалом за упијање радијације и пакетима типа *ERAWA* ради умањења радарског одраза. Наоружање се састоји од топа типа *2A46* упареног са новим пољским дигиталним системом за управљање ватром типа *DRAWA-1T*. Извршене су и одређене промене на аутоматском пуњачу ради побољшања брзине пуњења. Нишани су унапређени на ниво пасивног ноћног осматрања, док је нишанџија опремљен првом генерацијом термалног нишана израелске производње. Неке од термалних нишанских справа којима је истекао рок трајања замењене су домаћим термалним нишанским справама треће генерације типа *Asteria-1.* Тенк је опремљен јачим мотором пољске производње под називом *Wola S-12U* који обезбеђује 850 КС у односу на 780 КС оригиналног мотора руског тенка *T-72M1.*

Захваљујући оклопном пакету *ERAWA*, тенк *PT-91* има много већу моћ преживљавања у односу на *T-72M1.* Како се оцењује, оклопни пакет *ERAWA-1 ERA* је на нивоу ефикасности совјетског пакета *Kontakt-1* из осамдесетих година. *ERAWA-2*, као прилично ефикасан оклопни пакет, састоји се од два слоја експлозива у једном паковању. Овакав дизајн омогућује сузбијање тандемкумулативних бојевих глава, као оних који се налазе на ручном ракетном бацачу *PG-7VR*, противтенковских вођених ракета и топовских зрна. Испоставило се да пакет *ERAWA-2* може неутралисати руске противтенковске вођене ракете до нивоа убојитости ракете *Konkurs*. Овај пакет је неутралисао и пројектиле топа *125 мм 3BM15* и *3BK14M* типа *APFSDS* и *HEAT,* иако не у свакој ситуацији. Ипак, ради се о релативно старим топовским пројектилима, док пакет *ERAWA-2* и није првенствено намењен за неутралисање кинетичких пројектила. Модерни руски тенковски пројектили типа *APFSDS* и *HEAT* врло вероватно пробијају овај оклопни пакет.

Упркос томе, оклопни пакет *ERAWA-2,* постављен на предњој страни тенка, неутралише дејство тандембојеве главе типа *HEAT* ручног бацача *Panzerfaust 3-IT,* која, како се тврди, пробија 900 мм хомогеног челика. Ови подаци потврђују да би тај оклоп могао да одоли већини ручних ракетних бацача руске пешадије, као и лаким и средњим противтенковским ракетама, али се не би могао одбранити од кинетичких пројектила са модерних руских тенковских топова. На основу тога могло би се закључити

да је оклопни пакет *ERAWA-2* инфериоран у односу на касније совјетске оклопне пакете *Kontakt-5* и модерне руске оклопне пакете типа *Relikt,* имајући у виду да они обезбеђују заштиту од кинетичких пенетратора и тандемкумулативних бојевих глава.

Постоје и други начини повећања степена преживљавања тенка, као што је додатак слоја за упијање радарских таласа с обзиром на то да руска војска користи земаљске радаре у великој мери. Систем за упозоравање радарског озрачивања омогућује боље осматрање терена, па се чак користи и у основној верзији система за активну заштиту. Могуће је упарити овај систем са бацачем димних бомби након откривања континуираног ласерског снопа који се користи за навођење противтенковске ракете. С обзиром на широку заступљеност оваквог начина навођења противтенковских ракета у руској војсци овакав развој система није занемарљив. Ипак, може се закључити да је овакав систем инфериоран у односу на руски систем *Shtora* који се налази на руским тенковима *T-90, T-90A* и *T80UK*. Потпуно опремљен систем *Shtora* обезбеђује могућност ометања ласерског навођења уз употребу емитујућих „очију" са обе стране топа.

Оба тенка, *PT-91* и пољски *T-72M1,* користе исту муницију за топ 125 мм. Поред совјетске муниције типа *3OF19 HE-Frag, 3BK14M HEAT* и *3BM15 APFSDS* које производи Пољска, постоји и домаћа поткалибарна граната са пенетратором типа *APFSDS.* Ради се о пројектилу *Pronit* који користи прилагођени израелски пенетратор са гранате *M711 Mk 2,* топа од 120 мм. Шипке пенетратора обезбедио је Израел, али су многи имали недостатке, што је изазвало и мањи скандал у пољској влади. Тврди се да ови пенетратори имају пробојност до 540 мм хомогеног челика на даљинама до два километра, али је наводно реч о мањим количинама. Развијена је и граната под називом *Pionki* домаће производње, која наводно пробија до 520 мм хомогеног челика на даљинама до два километра. Извесно је да пољски тенкови типа *PT-91* или *T-72M1* не могу пробити ниједан руски тенк прве линије (*T-72B3, T-80UM, T-90A*) са фронталне стране, јер њихови оклопни пакети штите од пробијања кинетичких пројектила пробојности и до 700 мм хомогеног челика.

Пољска је недавно приказала и нови модел тенка *PT-91M2* на којем је примећено неколико новина у односу на ранији модел *PT-91*. Ради се о новој дигиталној архитектури која омогућује интегрисање различитих система, као што је систем за управљање борбом. Нови системи омогућују командиру и нишанџији да се виртуелно замењују на дисплејима и контролама без физичког померања.

Сви чланови посаде сада имају унапређене осматрачке системе. Возач и механичар добили су дневну и термалну осматрачку камеру која им омогућује поглед спреда и отпозади. Ноћна нишанска справа нишанџије сада је замењена уређајем *SAVAN-15* компаније *Safran* и омогућује двоструко и десетоструко повећање у функцији дневног осматрања. Овај уређај је могуће опционо заменити и дневном камером типа CCD.

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Термална нишанска справа ради у краткоталасном или дуготаласном инфрацрвеном спектру, а додат је и ласерски даљиномер домета до 10 км.

Тенк PT-91M2

Осматрачки уређај нишанџије је независно стабилизован и ради независно од топа, што је решило проблем који је постојао на старијим тенковима *T-72* којима се уређај подизао заједно са топом приликом пуњења и на тај начин губио слику циља.

Командир сада користи независан осматрачки уређај *PASEO* компаније *Safran,* што омогућава посади да спроводи мисије типа ловац-убица у којима командир лоцира мете и предаје их нишанџији, а затим тражи нове мете. Уређај је независно стабилисан и укључује ТВ камеру високе резолуције у боји, као и термални канал у којем се могу бирати различити спектрални канали.

Тенк може бити опремљен словачким топом *2A46MS L48* и украјинским *KBA-3 L48* који су иначе слични руском топу *2A46M-5.*

Тенк је опремљен системом за управљање ватром *SAVAN 15*. Аутоматски пуњач је измењен, тако да пројектили улазе у пуњач под углом ради коришћења дужих поткалибарних граната које имају могућност пробијања до 740 мм челика, што је отприлике једнако руском пројектилу *Svinets*.

Тенк је опремљен мотором *Renk ESM350M* који развија до 1000 КС, а постоје и друге опције, као што су *ESM350S* компаније *Scania* и мотори *PP-1000* и *PP-1200* компаније *Yugoimport*. На задњој страни тенка постављен је

и помоћни мотор којим се напајају интерни и екстерни системи тенка без укључивања главног мотора.

Заштитни оклоп састављен од плоча експлозивно-реактивног оклопа обезбеђује заштиту од јединачних и тандемкумулативних бојевих глава са ручних ракетних бацача. Ипак, за време тестова је утврђенода уколико пројектили ударе у плочу под одређеним већим углом не долази до активације плоча експлозивно-реактивног оклопа већ до пробијања основне оклопне плоче.

Ради заштите од ручних ракетних бацача, задња половина тенка је покривена решеткастим оклопом .

Посада има на располагању GPS навигациони систем, навигациони систем *TALIN 3000 INS* и нови дигитални радио-комуникациони систем отпоран на ометање.

Поред домаћих тенкова *PT-91* и *T-72M1*, Пољска поседује и знатан број немачких тенкова типа *Leopard 2*: 142 тенка *Leopard 2A4* и 105 тенкова *Leopard 2A5*. Ради се о стандардним тенковима *Leopard 2* без модернизације који су опремљени оригиналним немачким оклопом, термалним справама, стабилизаторима и системима за управљање ватром. Пољска жели да купи још ових тенкова, али се смањује број држава које желе да их продају. За сада ни Швајцарска, Шпанија, Грчка и Финска не одговарају на понуду Пољске .

Муниција за топове немачких тенкова 120 мм типа *L/44* није много боља од пољске муниције за топове 125 мм. Већина пројектила састоји се од муниције *DM33A1 APFSDS* која је купљена са тенковима и која гарантује пробојност челичног хомогеног оклопа до 560 мм на даљинама до два километра. Постоји и домаћа граната типа *PZ-531 APFSDS,* али она пробија само 500 до 520 мм хомогеног челика. Неки извори наводе да се, у ствари, ради о пројектилу типа *Pionki* који је упакован у кућиште од 120 мм. Постоји и пољска распрскавајућа граната 120 мм *PZ-511*. Помињу се и анегдоте о пољским гранатама 120 мм које при испаљивању производе толико дима да им није потребан бацач димних кутија, а говорило се и о инциденту у којем је погинуо пољски члан посаде тенка приликом испаљивања тенковске гранате. На основу тога би се могло закључити да Пољска ипак још није достигла немачки квалитет производње тенковских граната.

Ради побољшања оклопних пакета немачких тенкова 2A4 (који се баш нису доказали током турских операција у Сирији), пољска армија планира модернизацију својих тенкова Leopard 2A4 на ниво Leopard 2PL (или 2A4PL). Након такве модернизације очекује се да би тенкови били у оперативној употреби следећих 30 година. Ниво модернизације је обиман и састојао би се од новог оклопног пакета за куполу који би укључивао оклоп сличан оном на тенку Leopard 2A5. Очекују се одређене измене на топу, иако би у суштини остао исти кратки L/44, само што би могао испаљивати нове гранате типа DM11 и DM63 које захтевају комору са већим притиском, али и нове гранате са програмирајућим распрскавањем. Промене би се

односиле и на замену хидрауличних механизама окретања куполе са електричним, што би урадиле пољске компаније. Термалне камере на независној нишанској справи командира и нишанџије биле би замењене домаћим уређајем KLW Asteria 1.

Leopard 2PL

Након овакве модернизације Leopard 2PL више не би спадао у стандардне тенкове Leopard 2, нити би могао добијати резервне делове из такозваног клуба LeoBen club, међународне заједнице корисника тенкова Leopard 2. У том случају резервни делови би стизали из других логистичких праваца. Модернизација је, чини се, фокусирана на механизоване одбрамбене операције. Недостатак ефикасног оклопа на бочним странама или на самој шасији приморава Leopard 2PL на борбу из припремљених укопаних позиција и чини га прилично рањивим у офанзивним операцијама. То се прилично разликује од смера којим је кренула америчка војска са својим тенком M1A2 TUSK који има врло ефикасан бочни оклоп и оклопљена места око нишанџије ради што већег степена преживљавања у градским борбама. Тренутно се не планирају никаква унапређења пољске флоте тенкова 2A5, осим набавке модерније муниције.

Размишља се и о различитим начинима модернизације флоте тенкова PT-91 које укључују замену тенковских топова са украјинским топовима 120 мм L/50 KMB-2 или словачким топовима 125 мм 2A46MS, додатним оклопним пакетима, јачим моторима, помоћним агрегатима и бољим оптичким уређајима. За сада још ништа није одлучено, јер се ради о

модернизацији која је врло скупа, а не би знатно допринела већој ватреној моћи.

Тренутно само један пољски тенк може да се супротстави новим руским тенковима, а то је Leopard 2A5. Мада, питање је да ли би и он могао са постојећом муницијом да пробије савремене руске тенкове. Можда би PT-91 представљао ефикасно решење, али у другој одбрамбеној линији. Његови застарели системи за управљање ватром и слабији оклопни пакети онемогућили би га у маневарској борби. Модернизовани Leopard 2PL би ипак мало променио однос снага, али до модернизације још није дошло, а појавио се и „нови играч" на пољском тржишту. Јужнокорејска компанија Hyundai Rorem конкурисала је за добијање огромног уговора у вредности од чак 9 милијарди долара за испоруку својих основних борбених тенкова типа K2 Black Panther. Извори наводе да би Јужна Кореја могла добити уговор за испоруку чак до 800 тенкова овог типа. Ради се о тенку који је један од постојећа три тенка четврте генерације, поред јапанског тенка Type 10 и руског T-14. Турска већ производи K2 на основу лиценце, под називом Atlay, а планира производњу до 1000 комада. Такође, планирана је и његова испорука Оману.

K2 Black Panther

Тенк K2 могао би се много ефикасније супротставити руским тенковима T-90M и T-80BVM, јер у односу на њих има многе предности. Black Panther је опремљен напредним композитним оклопом, експлозивно-

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реактивним оклопом и неексплозивним реактивним оклопом и напредним системом за управљање ватром повезаним са радаром високих фреквенција који се налази на предњој страни куполе. Термографска камера има могућност „закључавања на циљу" и омогућава тенку да прати мете на даљинама до 9,8 км. Радар са милиметарским снопом може да открива надолазеће ракете на основу чега компјутер тенка триангулацијом одређује правац ракете и лансира инфрацрвене димне облаке. Такође, К2 може деловати и као артиљеријско оруђе гађајући мете на врло великим удаљеностима. Захваљујући стабилизаторима тенк може испаљивати топовске гранате док се креће брзином до 70 км на сат. Иако се ради о скупом тенку, он је и даље јефтинији од француског тенка Leclerc и британског Challenger 2.

Поред интереса за овај тенк, Пољска је заинтересована и за корејску самоходну хаубицу К99, а ту је и потенцијална наруџбина веће количине америчких ловаца F-35. Остаје да се види да ли Пољска може да поднесе толике трошкове.

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Јапански невидљиви ловац[3]

У Јапану се размишља о производњи домаћег ловца, али се јавила дилема да ли је то исплативо.

У априлу 2016. године бели млазњак са црвеним и плавим детаљима изрулао је са аеродрома Nagoya у Јапану и полетео. Јапан је постала четврта држава која је развила свој невидљиви авион *Mitsubishi X-2 Shinshin*.

Две године касније, након тридесет и четвртог пробног лета, од планираних педесет, изгледи нису добри за будућност ловца *Shinshin.* Јапанске самоодбрамбене снаге приморане су да одлуче да ли ће Јапан производити нову генерацију невидљивог ловца или ће га поручити од земаља произвођача. Најновији извештаји указују да Токио ипак нагиње другој опцији.

Излази Raptor, улази Shinshin

Јапан има самоодбрамбене снаге уместо класичне војске, што значи да су оружане снаге потпуно оријентисане на одбрану своје острвске државе од ваздушних и поморских напада. Овај задатак постаје све комплекснији захваљујући великој кинеској ваздушној флоти, моћним арсеналом балистичких ракета средњег домета и све јачој кинеској поморској флоти. Сваке године јапански ловци имају неколико стотина ваздушних

[3] The National Interest November 8, 2019

пресретања кинеских и руских војних летелица. Јапан се суочава са новом петом генерацијом кинеских ловаца *J-20* којима се за сада супротстављају домаћи ловци *F-15* и *F-2* (домаћа верзија *F-16).*

Mitsubishi X-2 Shinshin

Токио је крајем двадесетог века покушао да набави америчке невидљиве ловце *F-22 Raptor* који су тада сматрани за најбоље у очувању ваздушне премоћи. Међутим, амерички Конгрес је забранио извоз ловца, а престала је и његова производња. Уместо тога, јапанске самоодбрамбене снаге су наручиле и примиле у оперативну употребу 42 ловца *F-35A,* иако они нису на нивоу *F-22*.

Јапански институт за техничко истраживање и развој је, независно од набавке авиона, проучавао технологију невидљивости. Како су им САД забраниле тестирања 2005. године, Институт је послао макету невидљивог ловца у Француску ради тестирања радарског одраза. Једанаест година касније, јапанска компанија *Mitsubishi* приказала је напредни технички демонстратор – *Advanced Technical-Demonstrator (ATD)* под називом *X-2.* Програм развоја невидљивог авиона је до сада коштао Јапан преко 360 милиона долара и укључио је 220 подизвођача, тако да је 90 процената делова летелице *AT-D* домаћег порекла.

Демонстратор *X-2* је малих димензија, само четрнаест метара дужине, има распон крила до девет метара и масу до 10,5 тона, јер није предвиђено да носи било какво наоружање.

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Уместо употребе оплате од радарских упијајућих материјала, демонстратор *Shinshin* израђен је од нерефлектујућег силиконског карбида и керамике, па је и купола пилотске кабине направљена од специјалне танке легуре. Поред тога, површину летелице чине оштре ивице и неједнаке кривине ради умањења радарске рефлексије.

Јапански званичник министарства одбране тврди да одраз *Shinshin*-а није већи од велике бубашвабе на даљинама од десет километара. То се подудара са изјавама из америчке војске да F-35 има радарски одраз лоптице за голф, а *Raptor* радарски одраз бубашвабе. С друге стране, неки војни аналитичари ипак сматрају да радарски одраз *X-2* више одговара одразу кинеског *J-20,* нарочито због конфигурације векторских млазница.

Два јапанска мотора *XF5-1* представљају прве јапанске млазне моторе опремљене форсажем. Израђени су од керамичких композитних материјала са деловима легуре титанијума отпорних на високе температуре. Издувни део сваког мотора има три дела којима се постиже тродимензионални потисак (вертикално и хоризонтално) којима се омогућава врло висока маневарска способност. Касније ће летелице у серијског производњи имати покретне издувне млазнице ради даљег умањења радарског одраза.

Иако мотори авиона *X-2* имају потисак од по 2494 кг, захваљујући малој тежини летелице омогућавају постизање брзине од преко два маха или константну суперсоничну брзину без употребе форсажа.

Shinshin је, такође, интегрисао и друге јапанске технологије. Модерни ловци користе контролне системе типа *fly-by-wire* уместо хидрауличних, док је компанија *Mitsubishi* отишла и корак даље употребљавајући фибер-оптичка влакна која брже преносе податке и отпорнија су на електромагнетне нападе. Авион *X-2* опремљен је и „самопоправљајућим" контролним системом који открива штету на контролним површинама авиона и аутоматски прилагођава употребу других контролних површина ради компензације лета.

Од демонстратора до ловца: Mitsubishi F-3?

Shinshin није прототип на основу којег ће се развијати производни модел већ технолошки демонстратор. Наиме, много је једноставније развијати ненаоружани млазњак него војну летелицу која носи хиљаде килограма оружних средстава, компјутере и електронске системе.

Такав невидљиви ловац, под називом *Mitsubishi F-3,* тренутно се налази у раној концептној фази. Јапански министар одбране изјавио је да очекује велики, двомоторни невидљиви ловац који би могао да носи до шест ракета ваздух-ваздух и који би могао ући у серијску производњу од 2027. године. Јапанске самоодбрамбене снаге имају потребу за око стотинак оваквих летелица које би замениле старије јапанске пресретаче типа *F-15J* и *F-4EJ Phantom*.

Године 2019. Јапан је почео са тестирањем нових млазних мотора *XF-9-1* који би генерисали 11 до 12 тона сувог потиска или 15 до 16 „влажног"

потиска (пумпањем горива у форсажу) и који би издржавали температуре до 1800 степени Целзијуса. Док мотори ловца *F-22,* два *F119*, производе снагу до 13 тона сувог потиска и 17,5 тона „влажног" потиска, мотори типа *XF-9* су до 0,5 м краћи и 30 см ужи од америчких, што би омогућило више простора за унутрашње спремиште.

Сваки мотор *XF-9* може генерисати невероватних 180 kW струје, што би могло бити употребљено за напајање директних енергетских оружја као што су ласери и радарска микроталасна оружја намењена пржењу компјутерских кола у балистичким пројектилима који би се кретали према јапанским острвима.

Инструменти у кокпиту били би концентрисани на дисплеју на пилотској кациги спрегнутој са великим дисплејом од течног кристала, као што је решено у ловцу *F-35*. Развијен је интерфејс човек-машина на основу вештачке интелигенције ради оптимизације протока података и мањег оптерећења пилота.

Јапан је, такође, истраживао даталинкове великих брзина којима би били умрежени сензори и којима би се размењивали подаци са савезничким снагама. Овакви даталинкови били би неопходни за супротстављање бројнијим непријатељским авионима као што су кинески невидљиви ловац *J-20* или предстојећи невидљиви бомбардер *H-20.*

Постоје два јавности доступна модела – један који личи на *F-22,* док дизајн другог подсећа на шесту генерацију ловаца без вертикалног репа, сличан концепту *Boeing F-A-XX*. Авион би био опремљен напредним мултифункционалним радаром који не само што би откривао надолазеће авионе већ би служио и као електромагнетни сензор, па чак и као микроталасно оружје за онеспособљавање непријатељских електричних система.

Међутим, током априла 2018. године, агенција Ројтерс је известила да су јапанске одбрамбене снаге одлучиле да зауставе развој домаћег невидљивог ловца док се не нађе иностран партнер. Уколико се не донесе одлука о финансирању, будући ловац *F-3* неће се наћи у следећем петогодишњем плану одбране.

Јапан очекује да би развој домаћег невидљивог ловца коштао чак 40 милијарди долара иницијалних трошкова. Поређења ради, 2018. године укупни годишњи буџет ове земље био је 46 милијарди долара и спада у највеће до сада.

Као што је закључено у САД док су развијали нове технологије за *F-35,* многе ствари могу поћи наопако, узрокујући временска кашњења и увећање трошкова. Стога је можда боље инвестирати у постојеће технологије, оне које су већ развијене, него прихватити ризик.

F-35 против F-3

Многи аналитичари су предвидели да ће бити напуштен програм F-3 након што је Токио објавио намеру да набави 105 додатних ловаца F-35A и F-35B Lightning, поред 42 која су већ наручена. Токио би могао чак

набавити више оваквих ловаца и то брже и јефтиније него што би били произведени у јапанским фабрикама.

Ипак, *F-35* је намењен, пре свега, за операције ваздух-ваздух, док је *F-22 Raptor* намењен за постизање ваздушне надмоћи.

Одбрамбене ваздушне патроле представљају примарну мисију јапанских самоодбрамбених снага. Кинеско војно ваздухопловство има шест пута више авиона, а најновији ловци, као што су *J-11D* и *J-20,* врло брзо могу престићи јапанску технолошку премоћ.

Неопходно је да војни ловци имају велики домет за дуге патроле, велику брзину којом би били пресретнути непријатељски авиони пре него што би употребили своје противваздушно оружје. По тим карактеристикама, стари јапански ловци *F-15J Eagle* превазилазе авионе *F-35*.

Ипак, мали радарски одраз ловца *F-35* и моћни умрежени сензори чине га много жилавијим и опаснијим од ловца *F-15* који се може детектовати на много већим даљинама. Данас Јапан тражи ловца који би био невидљив и посвећен борбама ваздух-ваздух.

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ПОЗИВ И УПУТСТВО АУТОРИМА
ПРИГЛАШЕНИЕ И ИНСТРУКЦИЯ ДЛЯ АВТОРОВ РАБОТ
CALL FOR PAPERS AND INSTRUCTIONS FOR AUTHORS

ПОЗИВ И УПУТСТВО АУТОРИМА О НАЧИНУ ПРИПРЕМЕ ЧЛАНКА

Упутство ауторима о начину припреме чланка за објављивање у *Војнотехничком гласнику* урађено је на основу Акта о уређивању научних часописа, Министарства за науку и технолошки развој Републике Србије, евиденциони број 110-00-17/2009-01, од 09. 07. 2009. године. Примена овог Акта првенствено служи унапређењу квалитета домаћих часописа и њиховог потпунијег укључивања у међународни систем размене научних информација. Засновано је на међународним стандардима ISO 4, ISO 8, ISO 18, ISO 215, ISO 214, ISO 18, ISO 690, ISO 690-2, ISO 999 и ISO 5122, односно одговарајућим домаћим стандардима.

Војнотехнички гласник / Vojnotehnički glasnik / Military Technical Courier (втг.мо.упр.срб, www.vtg.mod.gov.rs, ISSN 0042-8469 – штампано издање, e-ISSN 2217-4753 – online, UDC 623+355/359, DOI: 10.5937/VojnotehnickiGlasnik; https://doi.org/10.5937/VojnotehnickiGlasnik), јесте мултидисциплинарни научни часопис Министарства одбране и Војске Србије. Часопис објављује научне и стручне чланке из области основних истраживања (математике, рачунарских наука и механике) и технолошког развоја (електронике, телекомуникација, информационих технологија, машинства, материјала и хемијских технологија), као и техничке информације о савременим системима наоружања и савременим војним технологијама. Часопис прати јединствену интервидовску техничку подршку Војске на принципу логистичке системске подршке, области основних, примењених и развојних истраживања, као и производњу и употребу средстава наоружања и војне опреме, те остала теоријска и практична достигнућа која доприносе усавршавању свих припадника српске, регионалне и међународне академске заједнице, а посебно припадника Министарства одбране и Војске Србије.

Уређивачка политика Војнотехничког гласника заснива се на препорукама Одбора за етичност у издаваштву (COPE Core Practices), као и на најбољим прихваћеним праксама у научном издаваштву. Војнотехнички гласник је члан COPE (Committee on Publication Ethics) од 2. маја 2018. године.

Министарство просвете, науке и технолошког развоја Републике Србије, сагласно одлуци из члана 27. став 1. тачка 4), а по прибављеном мишљењу из члана 25. став 1. тачка 5) Закона о научноистраживачкој делатности („Службени гласник РС”, бр. 110/05, 50/06-испр. и 18/10), утврдило је категоризацију Војнотехничког гласника, за 2019. годину:

за област технолошки развој:

– на листи часописа за електронику, телекомуникације и информационе технологије:

категорија водећи научни часопис националног значаја **(М51)**,

– на листи часописа за материјале и хемијске технологије:

категорија научни часопис националног значаја **(М52)**,

– на листи часописа за машинство:

категорија научни часопис националног значаја **(М52)**,

за област основна истраживања:

– на листи часописа за математику, рачунарске науке и механику:

категорија научни часопис **(М53)**.

Усвојене листе домаћих часописа за 2019. годину могу се видети на сајту Војнотехничког гласника, страница *Категоризација часописа* (Министарство просвете, науке и технолошког развоја Републике Србије још увек није објавило званичну категоризацију научних часописа за 2020. годину).

Детаљније информације могу се пронаћи и на сајту Министарства просвете, науке и технолошког развоја Републике Србије.

Подаци о категоризацији могу се пратити и на сајту КОБСОН-а (Конзорцијум библиотека Србије за обједињену набавку).

Категоризација часописа извршена је према Правилнику о поступку и начину вредновања и квантитативном исказивању научноистраживачких резултата истраживача, који је прописао Национални савет за научни и технолошки развој (Службени гласник РС, број 38/2008).

У складу са овим правилником и табелом о врсти и квантификацији индивидуалних научноистраживачких резултата (у саставу Правилника), објављени рад у Војнотехничком гласнику вреднује се са 2 бода (категорија М51), 1,5 бод (категорија М52) и 1 бод (категорија М53).

Часопис се прати у контексту Српског цитатног индекса – СЦИндекс (база података домаћих научних часописа) и Руског индекса научног цитирања (РИНЦ). Подвргнут је сталном вредновању (мониторингу) у зависности од утицајности (импакта) у самим базама и, посредно, у међународним (Clarivate Analytics) цитатним индексима. Детаљи о индексирању могу се видети на сајту Војнотехничког гласника, страница *Индексирање часописа*.

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Радови се предају путем онлајн система за електронско уређивање АСИСТЕНТ, који је развио Центар за евалуацију у образовању и науци (ЦЕОН).

Приступ и регистрација за сервис врше се на сајту www.vtg.mod.gov.rs, преко странице *АСИСТЕНТ* или *СЦИНДЕКС*, односно директно на линку aseestant.ceon.rs/index.php/vtg.

Детаљно упутство о регистрацији и пријави за сервис налази се на сајту www.vtg.mod.gov.rs, страница *Упутство за АСИСТЕНТ*.

Потребно је да се сви аутори који подносе рукопис за објављивање у Војнотехничком гласнику региструју у регистар ORCID (Open Researcher and Contributor ID), према упутству на страници сајта *Регистрација за добијање ORCID идентификационе шифре*.

Војнотехнички гласник објављује чланке на српском, руском и енглеском језику (arial, српска ћирилица или српска латиница, величина слова 11 pt, проред Single).

Поступак припреме, писања и уређивања чланка треба да буде у сагласности са *Изјавом о етичком поступању* (http://www.vtg.mod.gov.rs/izjava-o-etickom-postupanju.html).

Чланак треба да садржи сажетак са кључним речима, увод, разраду, закључак, литературу и резимеа са кључним речима на енглеском и руском језику (без нумерације наслова и поднаслова). Обим чланка треба да буде око једног ауторског табака (16 страница формата А4 са проредом Single), а највише 24 странице.

Чланак треба да буде написан на обрасцу за писање чланка, који се у електронској форми може преузети са сајта на страници *Образац за писање чланка*.

Наслов

Наслов треба да одражава тему чланка. У интересу је часописа и аутора да се користе речи прикладне за индексирање и претраживање. Ако таквих речи нема у наслову, пожељно је да се придода и поднаслов. Наслов треба да буде преведен и на енглески и руски језик.

Ови наслови исписују се испред сажетка на одговарајућем језику.

Текући наслов

Текући наслов се исписује са стране сваке странице чланка ради лакше идентификације, посебно копија чланака у електронском облику. Садржи презиме и иницијал имена аутора (ако аутора има више, преостали се означавају са „et al.“ или „и др.“), наслове рада и часописа и колацију (година, волумен, свеска, почетна и завршна страница). Наслови часописа и чланка могу се дати у скраћеном облику.

Име аутора

Наводи се пуно име и презиме (свих) аутора. Веома је пожељно да се наведу и средња слова аутора. Имена и презимена домаћих аутора увек се исписују у оригиналном облику (са српским дијакритичким знаковима), независно од језика на којем је написан рад.

Назив установе аутора (афилијација)

Наводи се пун (званични) назив и седиште установе у којој је аутор запослен, а евентуално и назив установе у којој је аутор обавио истраживање. У сложеним организацијама наводи се укупна хијерархија (нпр. Универзитет одбране у Београду, Војна академија, Катедра природно-математичких наука). Бар једна организација у хијерархији мора бити правно лице. Ако аутора има више, а неки потичу из исте установе, мора се, посебним ознакама или на други начин, назначити из које од наведених установа потиче сваки од наведених аутора. Афилијација се исписује непосредно након имена аутора. Функција и звање аутора се не наводе.

Контакт подаци

Адреса или е-адреса свих аутора даје се поред имена и презимена аутора.

Категорија (тип) чланка

Категоризација чланака обавеза је уредништва и од посебне је важности. Категорију чланка могу предлагати рецензенти и чланови уредништва, односно уредници рубрика, али одговорност за категоризацију сноси искључиво главни уредник.

Чланци у *Војнотехничком гласнику* класификују се на научне и стручне чланке.

Научни чланак је:

– оригиналан научни рад (рад у којем се износе претходно необјављени резултати сопствених истраживања научним методом);

– прегледни рад (рад који садржи оригиналан, детаљан и критички приказ истраживачког проблема или подручја у којем је аутор остварио одређени допринос, видљив на основу аутоцитата);

– кратко или претходно саопштење (оригинални научни рад пуног формата, али мањег обима или прелиминарног карактера);

– научна критика, односно полемика (расправа на одређену научну тему, заснована искључиво на научној аргументацији) и осврти.

Изузетно, у неким областима, научни рад у часопису може имати облик монографске студије, као и критичког издања научне грађе (историјско-архивске, лексикографске, библиографске, прегледа података и сл.), дотад непознате или недовољно приступачне за научна истраживања.

Радови класификовани као научни морају имати бар две позитивне рецензије.

Ако се у часопису објављују и прилози ваннаучног карактера, научни чланци треба да буду груписани и јасно издвојени у првом делу свеске.

Стручни чланак је:

– стручни рад (прилог у којем се нуде искуства корисна за унапређење професионалне праксе, али која нису нужно заснована на научном методу);

– информативни прилог (уводник, коментар и сл.);

– приказ (књиге, рачунарског програма, случаја, научног догађаја, и сл.).

Језик рада

Језик рада може бити српски, руски или енглески.

Текст мора бити језички и стилски дотеран, систематизован, без скраћеница (осим стандардних). Све физичке величине морају бити изражене у Међународном систему мерних јединица – SI. Редослед образаца (формула) означава се редним бројевима, са десне стране у округлим заградама.

Сажетак (апстракт) и резиме

Сажетак (апстракт) јесте кратак информативан приказ садржаја чланка који читаоцу омогућава да брзо и тачно оцени његову релевантност. У интересу је уредништава и аутора да сажетак садржи термине који се често користе за индексирање и претрагу чланака. Саставни делови сажетка су циљ истраживања, методи, резултати и закључак. Сажетак треба да има од 100 до 250 речи и треба да се налази између заглавља (наслов, имена аутора и др.) и кључних речи, након којих следи текст чланка. Ако је рад написан на српском или руском језику, пожељно је да се, поред сажетка на српском и руском, даје и сажетак у проширеном облику на енглеском језику – као тзв. резиме (summary). Овакав резиме треба да буде на крају чланка, након одељка Литература. Важно је да резиме буде у структурираном облику, а његова дужина може бити до 1/10 дужине чланка (опширнији је од сажетка са почетка чланка). Почетак овог резимеа може бити преведени сажетак (са почетка чланка), а затим треба да следе преведени главни наслови, поднаслови и основе закључка чланка (литература се не преводи). Потребно је да се у структурираном резимеу преведе и део текста испод наслова и поднаслова, водећи рачуна да он буде пропорционалан њиховој величини, а да одражава суштину. Након резимеа на енглеском језику (проширеног сажетка) додаје се његов превод на српском, да би редакција извршила проверу и лектуру.

Кључне речи

Кључне речи су термини или фразе које адекватно представљају садржај чланка за потребе индексирања и претраживања. Треба их додељивати ослањајући се на неки међународни извор (попис, речник или тезаурус) који је најшире прихваћен или унутар дате научне области. За нпр. науку уопште, то је листа кључних речи Web of Science. Број кључних речи не може бити већи од 10, а у интересу је уредништва и аутора да учесталост њихове употребе буде што већа. Кључне речи дају се на језику на којем је написан чланак (сажетак) и на енглеском језику. У чланку се пишу непосредно након сажетка, односно након резимеа.

Систем АСИСТЕНТ у ту сврху користи специјалну алатку KWASS: аутоматско екстраховање кључних речи из дисциплинарних тезауруса/речника по избору и рутине за њихов одабир, тј. прихватање односно одбацивање од стране аутора и/или уредника.

Датум прихватања чланка

Датум када је уредништво примило чланак, датум када је уредништво коначно прихватило чланак за објављивање, као и датуми када су у међувремену достављене евентуалне исправке рукописа наводе се хронолошким редоследом, на сталном месту, по правилу на крају чланка.

Захвалница

Назив и број пројекта, односно назив програма у оквиру којег је чланак настао, као и назив институције која је финансирала пројекат или програм, наводи се у посебној напомени на сталном месту, по правилу при дну прве стране чланка.

Претходне верзије рада

Ако је чланак у претходној верзији био изложен на скупу у виду усменог саопштења (под истим или сличним насловом), податак о томе треба да буде наведен у посебној напомени, по правилу при дну прве стране чланка. Рад који је већ објављен у неком часопису не може се објавити у Војнотехничком гласнику (прештампати), ни под сличним насловом и измењеном облику.

Табеларни и графички прикази

Пожељно је да наслови свих приказа, а по могућству и текстуални садржај, буду дати двојезично, на језику рада и на енглеском језику.

Табеле се пишу на исти начин као и текст, а означавају се редним бројевима са горње стране. Фотографије и цртежи треба да буду јасни, прегледни и погодни за репродукцију. Цртеже треба радити у програму word или corel. Фотографије и цртеже треба поставити на жељено место у тексту.

За слике и графиконе не сме се користити снимак са екрана рачунара програма за прикупљање података. У самом тексту чланка препоручује се употреба слика и графикона непосредно из програма за анализу података (као што су Excel, Matlab, Origin, SigmaPlot и други).

Навођење (цитирање) у тексту

Начин позивања на изворе у оквиру чланка мора бити једнообразан.

Војнотехнички гласник за референцирање (цитирање и навођење литературе) примењује Харвардски систем референци, односно Харвардски приручник за стил (Harvard Referencing System, Harvard Style Manual). У самом тексту, у обичним заградама, на месту на којем се врши позивање, односно цитирање литературе набројане на крају чланка, обавезно у обичној загради написати презиме цитираног аутора, годину издања публикације из које цитирате и, евентуално, број страница. Нпр. (Petrović, 2012, pp.10–12).

Детаљно упутство о начину цитирања, са примерима, дато је на страници сајта *Упутство за Харвардски приручник за стил*. Потребно је да се позивање на литературу у тексту уради у складу са поменутим упутством.

Систем АСИСТЕНТ у сврху контроле навођења (цитирања) у тексту користи специјалну алатку CiteMatcher: откривање изостављених цитата у тексту рада и у попису референци.

Напомене (фусноте)

Напомене се дају при дну стране на којој се налази текст на који се односе. Могу садржати мање важне детаље, допунска објашњења, назнаке о коришћеним изворима (на пример, научној грађи, приручницима), али не могу бити замена за цитирану литературу.

Листа референци (литература)

Цитирана литература обухвата, по правилу, библиографске изворе (чланке, монографије и сл.) и даје се искључиво у засебном одељку чланка, у виду листе референци. Референце се не преводе на језик рада и набрајају се у посебном одељку на крају чланка.

Војнотехнички гласник, као начин исписа литературе, примењује Харвардски систем референци, односно Харвардски приручник за стил (Harvard Referencing System, Harvard Style Manual).

Литература се обавезно пише на латиничном писму и набраја по абецедном редоследу, наводећи најпре презимена аутора, без нумерације.

Детаљно упутство о начину пописа референци, са примерима, дато је на страници сајта *Упутство за Харвардски приручник за стил*. Потребно је да се попис литературе на крају чланка уради у складу са поменутим упутством.

Нестандардно, непотпуно или недоследно навођење литературе у системима вредновања часописа сматра се довољним разлогом за оспоравање научног статуса часописа.

Систем АСИСТЕНТ у сврху контроле правилног исписа листе референци користи специјалну алатку RefFormatter: контрола обликовања референци у складу са Харвардским приручником за стил.

Пропратно писмо (само за ауторе из Републике Србије и по посебном захтеву уредника)

Поред чланка доставља се пропратно писмо у којем треба истаћи о којој врсти чланка се ради, који су графички прилози (фотографије и цртежи) оригинални, а који позајмљени.

У пропратном писму наводе се и подаци аутора: име, средње слово, презиме, чин, звање, е-маил, адреса послодавца (ВП), кућна адреса, телефон на радном месту и кућни (мобилни) телефон, рачун и назив банке, СО места становања, број личне карте и ЈМБ грађана.

Сви радови подлежу стручној рецензији.

Списак рецензената Војнотехничког гласника може се видети на страници сајта *Списак рецензената*. Процес рецензирања објашњен је на страници сајта *Рецензентски поступак*.

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ПРИГЛАШЕНИЕ И ИНСТРУКЦИЯ ДЛЯ АВТОРОВ О ПОРЯДКЕ ПОДГОТОВКИ СТАТЬИ

Инструкция для авторов о порядке подготовки статьи к опубликованию в журнале «Военно-технический вестник» разработана в соответствии с Актом о редактировании научных журналов Министерства науки и технологического развития Республики Сербия, № 110-00-17/2009-01 от 09.07.2009 г. Применение этого Акта способствует повышению качества отечественных журналов и их более полному вовлечению в международную систему обмена научной информацией. Инструкция соответствует международным стандартам ISO 4, ISO 8, ISO 18, ISO 215, ISO 214, ISO 18, ISO 690, ISO 690-2, ISO 999, ISO 5122 и соответствующим стандартам Республики Сербия.

Военно-технический вестник (**Vojnotehnički glasnik / Military Technical Courier**), втг.мо.упр.срб, www.vtg.mod.gov.rs/index-ru.html, ISSN 0042-8469 – печатное издание, e-ISSN 2217-4753 – online, UDK 623+355/359, DOI: 10.5937/VojnotehnickiGlasnik; https://doi.org/10.5937/VojnotehnickiGlasnik, является мультидисциплинарным научным журналом Министерства обороны и Вооруженных сил Республики Сербия.. В журнале публикуются научные и профессиональные статьи, исследующие такие области как: математика, компьютерные науки и механика, а также области технологического развития: электроника, телекоммуникации, информационные технологии, машиностроение, материалы и химические технологии, в журнале также публикуется: техническая информация о современных системах вооружения и современных военных технологиях. Журнал следит за единой межвидовой технической поддержкой вооруженных сил, основанной на принципах системной логистики, за прикладными и инновационными научными исследованиями, в том числе, в области производства вооружения и военной техники, и за прочими теоретическими и практическими достижениями, которые способствуют профессиональному росту представителей сербского, регионального и международного академического сообщества, и особенно военнослужащих Министерства Обороны и Вооружённых сил Республики Сербия.

Редакционная политика журнала «Военно-технический вестник» основана на рекомендациях Комитета по этике научных публикаций (COPE Core Practices), а также на лучшей практике в научно-издательской деятельности. «Военно-технический вестник» является членом COPE со 2 мая 2018 года.

Министерство образования, науки и технологического развития Республики Сербия, согласно решению принятому в соотвествии со ст. 27 абзац 1, пункт 4 и на основании толкования ст. 25 абзац 1 пункт 5 Закона о научно-исследовательской деятельности («Службени гласник РС», № 110/05, утвердило категоризацию «Военно-технического вестника» за 2019 год:

Категории в области технологического развития:

– Область электроники, телекоммуникаций и информационных технологий:

ведущий научный журнал национального значения **(M51)**,

– Область материалов и химической технологии:

научный журнал национального значения **(M52)**,

– Область механики:

научный журнал национального значения **(M52)**.

Категории в области основных исследований:

– Область математика, компьютерные науки, технические науки:

научный журнал **(M53)**.

С информацией относительно категоризации за 2019 год можно ознакомиться на странице сайта «Военно-технического вестника» *Категоризация Вестника* (Министерством просвещения, науки и технологического развития Республики Сербия пока не произведено официального ранжирования научных журналов за 2020 год).

Более подробную информацию можно найти на сайте Министерства образования, науки и технологического развития Республики Сербия.

С информацией о категоризации можно ознакомиться и на сайте КОБСОН (Консорциум библиотек Республики Сербия по вопросам объединения закупок).

Категоризация Вестника проведена согласно Положению о порядке и способе категоризации научно-исследовательских результатов, утверждённого Национальным комитетом по науке и технологиям (Службени гласник РС, № 38/2008).

В соответствии с вышеуказанным Положением и таблицей с показателями классификации и категоризации индивидуальных научно-исследовательских результатов, являющейся неотъемлемой частью Положения, научная статья, опубликованная в «Военно-техническом вестнике», оценивается следующим способом: 2 балла (категория М51), 1,5 балла (категория М52) и 1,5 балл (категория М53).

Журнал соответствует стандартам Сербского индекса научного цитирования (СЦИндекс/SCIndeks) – наукометрической базы данных научных журналов Республики Сербия, а также Российского индекса научного цитирования (РИНЦ). Журнал постоянно подвергается мониторингу и оценивается количественными наукометрическими показателями, отражающими его научную ценность, в т.ч. опосредованно в международных индексах цитирования (Clarivate Analytics).

С информацией об индексировании можно ознакомиться на странице сайта журнала *Индексирование Вестника*.

«Военно-технический вестник» обеспечивает читателям возможность открытого доступа, в соответствии с положениями об авторских правах, утверждёнными Creative Commons (CC BY). С инструкцией об авторских правах можно ознакомиться на странице *Авторские права и политика самоархивирования*, перейдя по ссылке http://www.vtg.mod.gov.rs/index-ru.html.

Рукописи статей направляются в редакцию журнала с использованием online системы ASSISTANT, запущенной Центром поддержи развития образования и науки (ЦПРОН).

Регистрация в системе и оформление прав доступа выполняется по адресу http://www.vtg.mod.gov.rs/index-ru.html, через страницу *ASSISTANT* или *СЦИНДЕКС* (aseestant.ceon.rs/index.php/vtg).

С инструкцией по регистрации и правам доступа можно ознакомиться по адресу http://www.vtg.mod.gov.rs/index-ru.html, на странице *Инструкция по ASSISTANT*.

Все авторы, предоставляющие свои рукописи для публикации в редакцию журнала «Военно-технический вестник» должны пройти предварительную регистрацию в реестре ORCID (Open Researcher and Contributor ID). Эта процедура осуществляется в соответствии с инструкцией, размещенной на странице сайта *Регистрация в реестре ORCID для присвоения идентификационного кода*.

«Военно-технический вестник» публикует статьи на сербском, русском или английском языках (Arial, шрифт 11 pt, пробел Single).

Процесс подготовки, написания и редактирования статьи должен осуществляться в соответствии с принципами *Этического кодекса* (http://www.vtg.mod.gov.rs/etichyeskiy-kodyeks.html).

Статья должна содержать аннотацию с ключевыми словами, введение, основную часть, выводы, список использованной литературы и резюме с ключевыми словами на английском языке (без нумерации заголовков и подзаголовков). Объём статьи не должен превышать один авторский лист (16 страниц формата А4 с пробелом Single).

Статья должна быть набрана на компьютере с использованием специально подготовленного редакцией макета, который можно скачать на странице сайта *Правила и образец составления статьи*.

Заголовок

Заголовок должен отражать тему статьи. В интересах журнала и автора необходимо использовать слова и словосочетания, удобные для индексации и поиска. Если такие слова не содержатся в заголовке, то желательно их добавить в подзаголовок. Заголовок должен быть переведён на английский язык. Название заголовка (подзаголовка) пишется перед аннотацией на соответствующем языке.

Текущий заголовок

Текущий заголовок пишется в титуле каждой страницы статьи с целью упрощения процесса идентификации, в первую очередь копий статьей в электронном виде. Заголовок содержит в себе фамилию и инициал имени автора (в случае если авторов несколько, остальные обозначаются с «et al.» или «и др.»), название работы и журнала (год, том, выпуск, начальная и заключительная страница). Заголовок статьи и название журнала могут быть приведены в сокращенном виде.

ФИО автора

Приводятся полная фамилия и полное имя (всех) авторов. Желательно, чтобы были указаны инициалы отчеств авторов. Фамилия и имя авторов из Республики Сербия всегда пишутся в оригинальном виде (с сербскими диакритическими знаками), независимо от языка, на котором написана работа.

Наименование учреждения автора (аффилиация)

Приводится полное (официальное) наименование и местонахождение учреждения, в котором работает автор, а также наименование учреждения, в котором автор провёл исследование. В случае организаций со сложной структурой приводится их иерархическая соподчинённость (напр. Военная академия, кафедра военных электронных систем, г. Белград). По крайней мере, одна из организаций в иерархии должна иметь статус юридического лица. В случае если указано несколько авторов, и если некоторые из них работают в одном учреждении, нужно отдельными обозначениями или каким-либо другим способом указать в каком из приведённых учреждений работает каждый из авторов. Аффилиация пишется непосредственно после ФИО автора. Должность и специальность по диплому не указываются.

Контактные данные

Электронный адрес автора указываются рядом с его именем на первой страницы статьи.

Категория (тип) статьи

Категоризация статьей является обязанностью редакции и имеет особое значение. Категорию статьи могут предлагать рецензенты и члены редакции, т.е.

редакторы рубрик, но ответственность за категоризацию несет исключительно главный редактор. Статьи в журнале распределяются по следующим категориям:

Научные статьи:

– оригинальная научная статья (работа, в которой приводятся ранее неопубликованные результаты собственных исследований, полученных научным методом);

– обзорная статья (работа, содержащая оригинальный, детальный и критический обзор исследуемой проблемы или области, в который автор внёс определённый вклад, видимый на основе автоцитат);

– краткое сообщение (оригинальная научная работа полного формата, но меньшего объёма или имеющая предварительный характер);

– научная критическая статья (дискуссия-полемика на определённую научную тему, основанная исключительно на научной аргументации) и научный комментарий.

Однако, в некоторых областях знаний научная работа в журнале может иметь форму монографического исследования, а также критического обсуждения научного материала (историко-архивного, лексикографического, библиографического, обзора данных и т.п.) – до сих пор неизвестного или недостаточно доступного для научных исследований. Работы, классифицированные в качестве научных, должны иметь, по меньшей мере, две положительные рецензии.

В случае если в журнале объявляются и приложения, не имеющие научный характер, научные статьи должны быть сгруппированы и четко выделены в первой части номера.

Профессиональные статьи:

– профессиональная работа (приложения, в которых предлагаются опыты, полезные для совершенствования профессиональной практики, но которые не должны в обязательном порядке быть обоснованы на научном методе);

– информативное приложение (передовая статья, комментарий и т.п.);

– обзор (книги, компьютерной программы, случая, научного события и т.п.).

Язык работы

Работа может быть написана на сербском, русском или английском языке.

Текст должен быть в лингвистическом и стилистическом смысле упорядочен, систематизирован, без сокращений (за исключением стандартных). Все физические величины должны соответствовать Международной системе единиц измерения – СИ. Очередность формул обозначается порядковыми номерами, проставляемыми с правой стороны в круглых скобках.

Аннотация (абстракт) и резюме

Аннотация (абстракт) является кратким информативным обзором содержания статьи, обеспечивающим читателю быстроту и точность оценки её релевантности. В интересах редакции и авторов, чтобы аннотация содержала термины, часто используемые для индексирования и поиска статьей. Составными частями аннотации являются цель исследования, методы и заключение. В аннотации должно быть от 100 до 250 слов, и она должна находится между титулами (заголовок, ФИО авторов и др.) и ключевыми словами, за которыми следует текст статьи. Если работа написана на сербском или русском языке, желательно, чтобы кроме аннотации на сербском и русском, была бы предоставлена и аннотация в расширенном виде на английском языке – в качестве т.н. резюме (summary). Такое

резюме должно находиться в конце статьи, после раздела Литература. Важно, чтобы резюме было в структурированном виде, и его длина может составлять до 1/10 длины статьи (оно более обширно, чем аннотация из начала статьи). Началом данного резюме может быть переведенная аннотация (из начала статьи), а затем должны следовать переведенные главные заголовки, подзаголовки и основы заключения статьи (литература не переводится). В структурированном резюме нужно перевести часть текста под заголовком и заголовком, принимая во внимание, чтобы оно было пропорционально их размеру и в то же время отражала суть.

Ключевые слова

Ключевыми словами являются термины или фразы, адекватно представляющие содержание статьи, необходимые для индексирования и поиска. Ключевые слова необходимо выбирать, опираясь при этом на какой-либо международный источник (регистр, словарь, тезаурус), наиболее используемый внутри данной научной области. Число ключевых слов не может превышать 10. В интересах редакции и авторов, чтобы частота их встречи в статье была как можно большей. Ключевые слова даются на языке, на котором написана статья (аннотация), и на английском языке. В статье они пишутся непосредственно после аннотации (в начале) и после резюме (в конце).

Программа ASSISTANT предоставляет возможность использования сервиса KWASS, автоматически фиксирующего ключевые слова из источников/словарей по выбору автора/редактора.

Дата получения статьи

Дата, когда редакция получила статью; дата, когда редакция окончательно приняла статью к публикации; а также дата, когда были предоставлены необходимые исправления рукописи, приводятся в хронологическом порядке, как правило, в конце статьи.

Выражение благодарности

Наименование и номер проекта, т.е. название программы благодаря которой статья возникла, совместно с наименованием учреждения, которое финансировало проект или программу, приводятся в отдельном примечании, как правило, внизу первой страницы статьи.

Предыдущие версии работы

В случае если статья в предыдущей версии была изложена устно (под одинаковым или похожим названием, например, в виде доклада на научной конференции), сведения об этом должны быть указаны в отдельном примечании, как правило, внизу первой страницы статьи. Работа, которая уже была опубликована в каком-либо из журналов, не может быть напечатана в «Военно-техническом вестнике» ни под похожим названием, ни в изменённом виде.

Нумерация и название таблиц и графиков

Желательно, чтобы нумерация и название таблиц и графиков были исполнены на двух языках (на языке оригинала и на английском). Таблицы подписываются таким же способом как и текст и обозначаются порядковым номером с верхней стороны. Фотографии и рисунки должны быть понятны, наглядны и удобны для репродукции. Рисунки необходимо делать в программах Word или Corel. Фотографии и рисунки надо поставить на желаемое место в тексте. Для создания изображений и графиков использование функции снимка с экрана (скриншота) не допускается. В самом тексте статьи рекомендуется применение изображений и графиков, обработанных такими компьютерными программами, как: Excel, Matlab, Origin, SigmaPlot и др.

Ссылки (цитирование) в тексте

Оформление ссылок на источники в рамках статьи должно быть однообразным. «Военно-технический вестник» для оформления ссылок, цитат и списка использованной литературы применяет Гарвардскую систему (Harvard Referencing System, Harvard Style Manual). В тексте в скобках приводится фамилия цитируемого автора (или фамилия первого автора, если авторов несколько), год издания и по необходимости номер страницы. Например: (Petrović, 2010, pp.10-20). Рекомендации о способе цитирования размещены на странице сайта *Инструкция по использованию Гарвардского стиля*. При оформлении ссылок, цитат и списка использованной литературы необходимо придерживаться установленных норм. Программа ASSISTANT предоставляет при цитировании возможность использования сервиса CiteMatcher, фиксирующего пропущенные цитаты в работе и в списке литературы.

Примечания (сноски)

Примечания (сноски) к тексту указываются внизу страницы, к которой они относятся. Примечания могут содержать менее важные детали, дополнительные объяснения, указания об использованных источниках (напр. научном материале, справочниках), но не могут быть заменой процедуры цитирования литературы.

Литература (референции)

Цитированной литературой охватываются, как правило, такие библиографические источники как статьи, монографии и т.п. Вся используемая литература в виде референций размещается в отдельном разделе статьи.

Названия литературных источников не переводятся на язык работы.

«Военно-технический вестник» для оформления списка использованной литературы применяет Гарвардскую систему (Harvard Style Manual). В списке литературы источники указываются в алфавитном порядке фамилий авторов или редакторов. Рекомендации о способе цитирования размещены на странице сайта *Инструкция по использованию Гарвардского стиля*. При оформлении списка использованной литературы необходимо придерживаться установленных норм.

При оформлении списка литературы программа ASSISTANT предоставляет возможность использования сервиса RefFormatter, осуществляющего контроль оформления списка литературы в соответствии со стандартами Гарвардского стиля.

Нестандартное, неполное и непоследовательное приведение литературы в системах оценки журнала считается достаточной причиной для оспаривания научного статуса журнала.

Все рукописи статей подлежат профессиональному рецензированию.

Список рецензентов журнала «Военно-технический вестник» размещён на странице сайта *Список рецензентов*. Процесс рецензирования описан в разделе *Правила рецензирования*.

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CALL FOR PAPERS AND ARTICLE FORMATTING INSTRUCTIONS

The instructions to authors about the article preparation for publication in the *Military Technical Courier* are based on the Act on scientific journal editing of the Ministry of Science and Technological Development of the Republic of Serbia, No 110-00-17/2009-01 of 9th July 2009. This Act aims at improving the quality of national journals and raising the level of their compliance with the international system of scientific information exchange. It is based on international standards ISO 4, ISO 8, ISO 18, ISO 215, ISO 214, ISO 18, ISO 690, ISO 690-2, ISO 999 and ISO 5122 and their national equivalents.

The Military Technical Courier / Vojnotehnički glasnik (www.vtg.mod.gov.rs/index-e.html, втг.мо.упр.срб, ISSN 0042-8469 – print issue, e-ISSN 2217-4753 – online, UDC 623+355/359, DOI: 10.5937/VojnotehnickiGlasnik; https://doi.org/10.5937/VojnotehnickiGlasnik) is a multidisciplinary scientific journal of the Ministry of Defence and the Serbian Armed Forces. The journal publishes scientific and professional papers covering fundamental research (mathematics, computer science and mechanics) and technological development (electronics, telecommunications, information technologies, mechanical engineering, material science and chemical technologies) as well as technical data on modern weapon systems and military technologies. The journal covers inter-service technical support to the Army on the principle of logistic system support; fundamental, applied and development research; production and use of weapons and military equipment as well as other theoretical and practical achievements leading to professional development of all members of Serbian, regional and international academic communities, members of the Ministry of Defence and the Army of Serbia in particular.

The editorial policy of the Military Technical Courier is based on the COPE Core Practices and the journal articles are consistent with accepted best practices in their subject areas. As of 2 May 2018, the Military Technical Courier is a member of COPE (Committee on Publication Ethics).

Pursuant to the decision given in Article 27, paragraph 1, point 4, and in accordance with the acquired opinion given in Article 25, paragraph 1, point 5 of the Act on Scientific and Research Activities (Official Gazette of the Republic of Serbia, No 110/05, 50/06-cor and 18/10), the Ministry of Education, Science and Technological Development of the Republic of Serbia classified the Military Technical Courier for the year 2019

in the field technological development:
– on the list of periodicals for electronics, telecommunications and IT,
category: leading scientific periodical of national interest **(M51)**,
– on the list of periodicals for materials and chemical technology,
category: scientific periodical of national interest **(M52)**,
– on the list of periodicals for mechanical engineering,
category: scientific periodical of national interest **(M52)**,
in the field fundamental research:
– on the list of periodicals for mathematics, computer sciences and mechanics,
category: scientific periodical **(M53)**.

The approved lists of national periodicals for the year 2019 can be viewed on the website of the Military Technical Courier, page *Journal categorization* (The Ministry of Education, Science and Technological Development of the Republic of Serbia has not yet published the official evaluation of scientific journals for 2020).

More detailed information can be found on the website of the Ministry of Education, Science and Technological Development of the Republic of Serbia.

The information on the categorization can be also found on the website of KOBSON (Consortium of Libraries of Serbia for Unified Acquisition).

The periodical is categorized in compliance with the Regulations on the procedure and method of evaluation and quantitative formulation of scientific and research results of researchers, stipulated by the National Council for Scientific and Technological Development (*Official Gazette of RS*, No 38/2008). More detailed information can be found on the website of the Ministry of Education, Science and Technological Development.

In accordance with the Regulations and the table about types and quantification of individual scientific and research results (as a part of the Regulations), a paper published in the *Military Technical Courier* scores 2 (two) points (category M51), 1,5 (one and a half) point (category M52) and 1 (one) point (category M53).

The journal is in the Serbian Citation Index – SCIndex (data base of national scientific journals), in the Russian Index of Science Citation/Российский индекс научного цитирования (RINC/РИНЦ) and is constantly monitored depending on the impact within the bases themselves and indirectly in the international (e.g. Clarivate Analytics) citation indexes. More detailed information can be viewed on the website of the Military Technical Courier, page *Journal indexing*.

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The procedures of article preparation, writing and editing should be in accordance with the *Publication ethics statement* (http://www.vtg.mod.gov.rs/publication-ethics-statement.html).

The article should contain the abstract with keywords, introduction, body, conclusion, references and the summary in English language (without heading and subheading enumeration). The article length should not exceed 24 pages of A4 paper format.

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The title should be informative. It is in both Journal's and author's best interest to use terms suitable for indexing and word search. If there are no such terms in the title, the author is strongly advised to add a subtitle. The title should be given in English as well.

The titles precede the abstract and the summary in an appropriate language.

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Abstract and summary

An abstract is a concise informative presentation of the article content for fast and accurate evaluation of its relevance. It is both in the Editorial Office's and the author's best interest for an abstract to contain terms often used for indexing and article search. The abstract describes the purpose of the study and the methods, outlines the findings and state the conclusions. A 100- to 250- word abstract should be placed between the title and the keywords with the body text to follow. Besides an abstract in Serbian and Russian, articles in Serbian and Russian are advised to have a summary in English, at the end of the article, after the Reference list. The summary should be structured and long up to 1/10 of the article length (it is more extensive than the abstract). It can start with the translated Serbian or Russian abstract from the beginning of the article with translated main headings, subheadings and major conclusions to follow (Reference list is not translated). The structured summary should also contain the proportional informative parts of the text below the headings and subheadings.

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Article acceptance date

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Acknowledgements

The name and the number of the project or programme within which the article was realised is given in a separate note at the bottom of the first page together with the name of the institution which financially supported the project or programme.

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If an article preliminary version has appeared previously at a meeting in a form of an oral presentation (under the same or similar title), this should be stated in a separate note at the bottom of the first page. An article published previously cannot be published in the *Military Technical Courier* even under a similar title or in a changed form.

Tables and illustrations

All the captions should be in the original language as well as in English, together with the texts in illustrations if possible. Tables are typed in the same style as the text and are denoted by Arabic numerals at the top. Photographs and drawings, placed

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For figures and graphs, proper data plot is recommended i.e. using a data analysis program such as Excel, Matlab, Origin, SigmaPlot, etc. It is not recommended to use a screen capture of a data acquisition program as a figure or a graph.

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Citation in the text must be uniform. The Military Technical Courier applies the Harvard Referencing System given in the Harvard Style Manual. When citing sources within your paper, i.e. for in-text references of the works listed at the end of the paper, place the year of publication of the work in parentheses and optionally the number of the page(s) after the author's name, e.g. (Petrovic, 2012, pp.10-12). A detailed guide on citing, with examples, can be found on Military Technical Courier website on the page *Instructions for Harvard Style Manual*. In-text citations should follow its guidelines.

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In journal evaluation systems, non-standard, insufficient or inconsequent citation is considered to be a sufficient cause for denying the scientific status to a journal.

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