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NETWORK SECURITY SOLUTIONS AND INFORMATION SECURITY AT VIETNAM UNIVERSITIES IN THE DIGITAL AGE

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Abstract: *With the development of information technology in universities in Vietnam today, information network at the campus are more and more important, and gradually become an essential infrastructure for teaching, scientific research, personnel management, finance and international cooperation at the University. However, using the network on campus still has potential risks of cyber attacks. Therefore, ensuring network security and database information security has become the most important issue in the construction and development of the university. In this article, the author presents existing problems in information security and confidentiality at Vietnamese universities and propose measures for cybersecurity and information in the current Digital age.*

Keywords: *Cybersecurity, precautions, information security, university of Vietnam.*

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1. INTRODUCTION

In the current information era, the Internet penetrates into all aspects of human life and production. With the continuous development of the internet, crimes using high technology have arisen, existed and developed rapidly, which seriously threatens network information security. Currently, Universities in Vietnam have applied information technology more often and serves an important role in increasing the management of teaching, scientific research, personnel management, finance and international cooperation. However, universities are also faced with major security risks, such as data leaks, hacker attacks and other problems, Which impact negatively on teaching activities and development of the school. Faced with these issues, the Ministry of Education and Training has issued Decision No.5809/QD-BGDĐT on "Promulgating the Regulation on ensuring information security in information technology application activities of units under the Ministry of Education and Training". Thereby, higher education institutions need to comprehensively understand the current security situation of the network of current members, build a team of experts on information

security and privacy, create a reasonable and confidential security system, improve applications on the network environment, increase security education and awareness about online databases, ensure network and information security among staff, lecturers and students in the university. In this article, the author presents the problems that exist in security and information security at the University of Vietnam and propose measures to the problem of network security and information in the Digital era.

2. BODY

2.1. Threats to Cybersecurity and Information Security in Universities in Vietnam

The issue of safety and security become the main concern of the current university. The rapid rise of technology deployment, security, network security has become a necessity in an effort to adjust the protective measures, either directly or indirectly, to prevent the system from attacks on the network environment. However, even if the network has installed anti-virus and firewall, it is difficult to prevent hackers stealing, forgery, destruction and other attacks on the data or information of the server. Additionally, staff, faculty and college students inadvertently access sites that are not secure or inadvertently downloaded software can't be determined hackers uploaded with embedded viruses on them, making the whole the campus network at risk.

- There are two main reasons why hackers like to attack university networks:

• First, the information and data resources in the University are very large, and the value is relatively high. For this reason, some hackers do not break the media networks, and try to use all sorts of loopholes in the university's network to steal illegal and destructive;

• Second, the protective measures of network security universities relatively slow, along with the campus network. Network architecture and user mode is adopted basically the same, this makes cybercriminals can infiltrate the different users of the campus network in a similar way.

- In addition, there are many software supports Internet hackers, such as remote access tools, web attack tools, port scanners, overflow tools, network snooping tools, and port redirection tools. Some of these tools are easy to use and highly destructive. As long as people with a little knowledge of the Internet can basically use them. This also makes some students, out of curiosity or self-disclosure, use these hacker software to attack the school's network and application system. In fact, in 2021, the incident of a hacker selling 300,000 personal information of university students in Vietnam was recorded. In addition to student information such as age, name, address and phone number, the data file also contains a variety of information such as bank account, parent ID card, lost link address... Therefore, it can be seen that the campus network of universities is in fact at risk of being attacked by hackers at any time.

2.2. Measures to strengthen network security and information security at universities in Vietnam nowaday

To ensure network security and information security at universities in Vietnam

nowaday, the author proposes a number of measures as follows:

2.2.1. Develop a comprehensive information security policy

Many university managers believe that ensuring information security belongs to the technical team. In fact, this has to be a combination of the technical team and the managers. Schools need to develop plans and security solutions network system to respond when an emergency incident occurs. When there is a plan when an emergency occurs with the school's network system, it will proactively prevent and minimize the damage to its system. A network security solutions comprehensive, appropriate to each type of organization is the optimal choice for both operating costs and ensure maximum security.

2.2.2. Improve the technical level of network safety and security of network administrators

With the upgrading of network security issues, is difficult to avoid the existence of security gaps. University network management technology is generally low, hackers can penetrate and attack university networks quite easily.

Along with the strengthening of upgrading of network and information security options in universities, it is necessary to fundamentally improve the technical level of network administrators in universities through technical exchange between the university and security agencies, organizations and enterprises specializing in security systems, security, network security, and professional technology.

2.2.3. Raise awareness of information security for officials, lecturers and students in educational institutions

The implementation of the technical means and set the standards system is the most basic measures to ensure the safety of internal information of the university. How to implement effective security systems in the security system and continuously enhance the safety awareness of all staff, faculty and students is key. Therefore, the importance of university network management is the management of people. On the one hand, it is necessary to strengthen the training of professional skills of the establishment.

On the other hand, network administrator staff needed to increase the security awareness on campus network application of network users. In particular, we need to help develop good online habits and increase cybersecurity awareness, such as changing passwords frequently, setting passwords that are not too simple (like 123456, 123456@oke,...), do not visit malicious websites and unsafe websites at will, patch the system in time, do not download large-scale P2P,do not download and install unknown software at will, do not disclose personal privacy information, etc. In addition, they should be especially reminded to data and important information in your computer or network equipment, data backup must be done well, otherwise, once encountered network status suddenly lost the data will lead to unimaginable consequences are.

2.2.4. Developing measures to enhance network security and information security database

Through the previous introduction, the author realized that it is necessary to build network and information security measures to strengthen network security and database information security in universities. However, the development of preventive measures should be combined with network security technologies available today. At present, general network security technology means mainly including network infrastructure virtualization technology, access control technology, intrusion detection technology, artificial intelligence technology, firewall technology.

• **The network infrastructure virtualization**: Virtualization technology infrastructure is to simulate complete physical network infrastructure based on software. Virtualized network infrastructures provide the same features and guarantees as physical networks, they provide the operational and hardware-independent benefits of virtualization - rapid resource allocation, rapid resources, continuous deployment, automated maintenance, and support for both existing and new applications. Virtualization technology introduces network infrastructure equipment and network infrastructure services logic - ports, switches, routers, firewalls, load balancers, VPN and more to connect the blocks work. Virtualization technology introduces network infrastructure equipment and network infrastructure services logic - ports, switches, routers, firewalls, load balancers, VPN and more to connect the blocks work. Applications running on virtualized network infrastructure are similar to running on physical network infrastructure. Users can create highly scalable network infrastructures, bring the level operation more efficient, more flexible, allocate resources more quickly, troubleshooting and cloning, the process of monitoring, QoS (Quality of Service) and security, all supported by part network infrastructure virtualization software.

• **Access control technology**: The main purpose of access control technology is to prevent unauthorized access to any resources and to ensure that the operation and use of external computer systems is within the legal scope. Access control technology through the network authorization mechanism, through different authorizations for different campus network users, to restrict or prohibit unauthorized users from accessing.

• **Intrusion detection technology**: Intrusion Detection technology analyzes actions, security logs, data audits, or other information available on the network to try to understand the hacker's intent and purpose of intrusion. Intrusion detection technology is a type of technology designed and configured to ensure the security of the system computer that can detect and report unauthorized or unusual phenomena in the system in a timely manner. It is a technology used to detect violations of security policy in the computer network. Through this technology, it can discover the intention of the attacker attack and timely attack mode, and the corresponding measures to prevent attacks.

• **Artificial intelligence technology**: As the number and complexity of cyberattacks continues to increase, artificial intelligence (AI) has begun to help under-resourced security operations analysts learn about threats early on. threat and quick response. It can do everything faster and more accurately with large amounts of data which is time consuming for humans. AI can automatically use the tool complex pattern recognition to identify the

signs of a malicious program.Although it is not omnipotent and can't identify all the threats, but it's an essential tool to help reduce the amount of time that IT professionals need to investigate warnings.

• **Firewall technology**: A firewall is a type of technical measures to protect the security of computer networks. It can be used as a barrier between the internal network of the campus and external network security, to prevent the intrusion of the outside world. It can manage the user access to the network of the campus, on the other hand, it can scan the data packets entering the network on campus, so it can effectively prevent the attack and the virus entry.

3. CONCLUSION

In the information age, cybersecurity and information security Security has been entering every corner of social life and has gradually become an important part of each organization and individual. In the process of network management on campus, to build a secure system and network security systems on campus stability. It is necessary to conduct real-time monitoring and analysis of network activities on the network environment, promptly detect abnormal network activities, and continuously update and develop new network security solutions on the strategy. management technology and management technology, to gradually improve the school's network security system.

Develop a plan to plan and promote the technical level of network management staff, increase the security awareness of network users in universities, and prevent and mitigate any illegal access , operate and use through network technical means and management methods as much as possible, minimizing unsafe factors to a minimum to help build and develop technological information at university in Vietnam.

REFERENCES

1. Narayana, I.N.C.S., Gopinath, G., Mogan, K.P.C. et al. (2014), "A multilevel thrust filtration defending mechanism against DDoS attacks in cloud computing environment", *International Journal of Grid and Utility Computing*, Vol. 5, No. 4, pp.236–248.
2. Naser, S., Kamil, S. and Thomas, N. (2015), "A case study in inspecting the cost of security in cloud computing", *Electronic Notes in Theoretical Computer Science*, Vol. 318, No. 11, pp.179–196.
3. Stuttard D, PintoM (2012), *The web application hacker's handbook*, 2nd Ed, ISBN-13: 978-1118026472, ISBN-10: 1118026470.
4. Thomson, G. (2012), "BYOD: Enabling the chaos", *Network Security*, 2012(2), pp.5–8, DOI:10.1016/S1353- 4858(12)70013-2.
5. Vance, A., Siponen, M., & Pahnila, S. (2012), "Motivating IS security compliance: Insights from habit and protection motivation theory", *Information & Management*, 49(3-4), 190–198, DOI:10.1016/j.im.2012.04.002.

GIẢI PHÁP AN NINH MẠNG VÀ BẢO MẬT THÔNG TIN TẠI CÁC TRƯỜNG ĐẠI HỌC VIỆT NAM TRONG KỶ NGUYÊN THÔNG TIN

Tóm tắt. *Với sự phát triển của công nghệ thông tin trong các trường đại học tại Việt Nam hiện nay, mạng lưới thông tin tại khuôn viên trường ngày càng có vai trò quan trọng hơn, và dần trở thành cơ sở hạ tầng quan trọng cho việc giảng dạy, nghiên cứu khoa học, quản lý nhân sự, tài chính và hợp tác quốc tế tại các trường Đại học. Tuy nhiên, còn tiềm ẩn những nguy cơ rủi ro bị tấn công không gian mạng. Vì vậy việc đảm bảo an ninh mạng và bảo mật thông tin cơ sở dữ liệu đã trở thành vấn đề quan trọng nhất trong việc xây dựng và phát triển đại học. Trong bài viết này, tác giả trình bày các vấn đề tồn tại trong vấn đề an ninh và bảo mật thông tin tại các trường Đại học Việt Nam và đề xuất các các biện pháp cho vấn đề an ninh mạng và thông tin trong kỷ nguyên thông tin hiện nay.*

Từ khoá: *An ninh mạng, biện pháp phòng ngừa, Bảo mật thông tin, Đại học Việt Nam.*

INVESTIGATION OF LATTICE CONSTANTS AND ELASTIC MODULI OF YTTRIA-DOPED CERIA CRYSTAL BY STATISTICAL MOMENT METHOD

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Abstract: *In the present study, we developed a formalism based on the statistical moment method to investigate lattice constant and elastic moduli of yttria-doped ceria crystal including the anharmonicity effects of thermal lattice vibrations. The lattice constant and elastic moduli are calculated as functions of the dopant concentration, temperature, and pressure. We calculate the elastic moduli under temperature up to 1800K and pressure up to 60GPa using Buckingham potential. Our calculations are compared with theoretical and experimental results.*

Keywords: *Lattice constant, elastic moduli, yttria-doped ceria crystal.*

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1. INTRODUCTION

Pure ceria (CeO_2) electrolyte is not a good oxygen ion conductor. There are very few oxygen vacancies in ceria due to the high vacancy formation energy. Because of Y^{3+} ion of lower charge than the host cation, the substitution of Ce^{4+} by Y^{3+} ions creates many oxygen vacancies to maintain overall charge neutrality in the crystal lattice [3, 14, 10, 25]. Yttria-doped ceria (YDC) crystal is a well-known oxygen ion conductor and a very relevant material as an electrolyte in solid oxide fuel cells (SOFCs). With the fluorite structure, the presence of the oxygen vacancies allows the oxygen ions to be extracted (or inserted into) the lattice sites of YDC crystal in a low-oxygen (or oxygen-rich) environment, respectively [4].

A large number of experimental and theoretical studies have been carried out on catalytic [19], lattice vibrational [13], structural [26] and mechanical properties [21] of cerium dioxides. Theoretical study on the structure, stability and, morphology of stoichiometric ceria crystallines has been done using the simulation method [20]. The change

in cubic lattice constant of YDC crystal as a function dopant concentration obtained from the molecular dynamics (MD) simulation and previous X-ray diffraction (XRD) experiment at 300K and zero external pressure [2]. However, the dependence of lattice constant on the pressure has not been evaluated in detail. In a recent study, E. Wachtel and I. Lubomirsky [21] measured the elastic modulus of pure and doped ceria to understand the mechanical behavior under doping level and oxygen vacancy concentration. They found that the presence of oxygen vacancies makes the chemical bonds "softer" and the measured value depends strongly on the measurement technique and the thermal history of the sample. It is noted that elastic properties play an important role in controlling crystallization of amorphous phases, and the stiffness of the chemical bonds can be reflected by the elastic modulus [17]. Notwithstanding, the anharmonicity of lattice vibrations has been neglected in most of the previous theoretical studies related to the lattice constant and elastic moduli of YDC crystal.

The present work attempts to provide an overview of the lattice constant and elastic moduli of YDC crystal. The lattice constant, Young's, bulk, and shear moduli are calculated in detail at various dopant concentrations, temperature, and pressure using the statistical moment method (SMM). The analytic expressions of lattice constant and elastic moduli are derived taking into account the anharmonicity effects of the lattice vibrations. The present calculations are compared with the previous theoretical calculations as well as with the available experimental results.

2. BODY

2.1. Theory

YDC crystal has the fluorite structure where O^{2-} ions occupy the fcc sites and Ce^{4+} and Y^{3+} ions occupy the tetrahedral interstitial sites. Due to Y^{3+} ions of lower charge than the host cations, an oxygen vacancy is generated for every two Y^{3+} ions [16]. Let us consider YDC crystal with N_{Ce} Ce^{4+} ions, N_Y Y^{3+} ions, N_O O^{2-} ions and N_{va} oxygen vacancies. The number of cations and yttrium concentration in YDC crystal are denoted by N and x, respectively, then $N_{Ce} = N(1-x)$, $N_Y = Nx$, $N_O = N(2-x/2)$ and $N_{va} = Nx/2$. Hence, the formulation of YDC crystal is written as $Ce_{1-x}Y_xO_{2-x/2}$.

Using the Boltzmann relation, the Helmholtz free energy of $Ce_{1-x}Y_xO_{2-x/2}$ system can be written by taking into account the configuration entropy of system, S_c^*, [8, 9]

$$\Psi = \Psi_{CeO_{2-x/2}} + \Psi_Y - N_Y u_0^{Ce} - TS_c^*, \quad (1)$$

with u_0^{Ce} is the average interaction potential of a Ce^{4+} ion in $CeO_{2-x/2}$ system, $\Psi_{CeO_{2-x/2}}$ is the Helmholtz free energy of $CeO_{2-x/2}$ system, Ψ_Y is the Helmholtz free energy of Y^{3+} ions,

$$\Psi_{CeO_{2-x/2}} = C_{Ce}\Psi_{Ce} + C_O\Psi_O - TS_c, \quad (2)$$

$$\Psi_Y = U_0^Y + \Psi_0^Y + 3N_Y\left\{\frac{\theta^2}{k_Y^2}\left[\gamma_Y^2 X_Y^2 - \frac{2\gamma_Y^1}{3}a_1^Y\right] + \right.$$

$$\left. + \frac{2\theta^3 a_1^Y}{k_Y^4}\left[\frac{4}{3}\left(\gamma_2^Y\right)^2 X_Y - 2\left(\left(\gamma_1^Y\right)^2 + 2\gamma_1^Y\gamma_2^Y\right)\left(2a_1^Y - 1\right)\right]\right\}, \quad (3)$$

here, C_{Ce}, C_O are the concentrations of Ce^{4+} and O^{2-} ions in $CeO_{2-x/2}$ system, respectively, $C_{Ce} = x/3$, $C_O = (2-x/2)/3$, and Ψ_{Ce}, Ψ_O are the Helmholtz free energies of Ce^{4+}, O^{2-} ions in $CeO_{2-x/2}$ system, respectively,

$$\Psi_{Ce} = U_0^{Ce} + \Psi_0^{Ce} + 3N_{Ce}\left\{\frac{\theta^2}{k_{Ce}^2}\left[\gamma_{Ce}^2 X_{Ce}^2 - \frac{2\gamma_{Ce}^1}{3}a_1^{Ce}\right]\right.$$

$$\left. + \frac{2\theta^3 a_1^{Ce}}{k_{Ce}^4}\left[\frac{4}{3}\left(\gamma_2^{Ce}\right)^2 X_{Ce} - 2\left(\left(\gamma_1^{Ce}\right)^2 + 2\gamma_1^{Ce}\gamma_2^{Ce}\right)\left(2a_1^{Ce} - 1\right)\right]\right\}, \quad (4)$$

$$\Psi_O = U_0^O + \Psi_0^O + 3N_O\left\{\frac{\theta^2}{k_O^2}\left[\gamma_O^2 X_O^2 - \frac{2\gamma_O^1}{3}a_1^O\right]\right.$$

$$\left. + \frac{2\theta^3 a_1^O}{k_O^4}\left[\frac{4}{3}\left(\gamma_2^O\right)^2 X_O - 2\left(\left(\gamma_1^O\right)^2 + 2\gamma_1^O\gamma_2^O\right)\left(2a_1^O - 1\right)\right]\right\}$$

$$+ 3N_O\left\{\frac{\theta\beta}{6K\gamma_O}\left(\frac{k_O}{K} - 1\right) + \frac{\theta^2\beta}{K}\left[\left(\left(\frac{2\gamma_O a_1^O}{3K^3}\right)^{\frac{1}{2}} - \frac{\beta a_1^O}{9K^2} + \frac{\beta k_O a_1^O}{9K^3} + \frac{\beta}{6Kk_O}\left(X_O - 1\right)\right)\right]\right\}. \quad (5)$$

In Eqs. (3), (4), (5), the parameters $k_{Ce,O,Y}$, $x_{Ce,O,Y}$, x_Y, $a_1^{Ce,O,Y}$, β, K, $\gamma_1^{Ce,O,Y}$, $\gamma_2^{Ce,O,Y}$, $\gamma_{Ce,O,Y}$ are defined as Refs. [8, 9], and Ψ_0^{Ce}, Ψ_0^O, Ψ_0^Y, denote the harmonic contributions of Ce^{4+}, O^{2-}, Y^{3+} ions to the free energies with the general formula as $\Psi_0 = 3N\theta\left[x + \ln\left(1 - e^{-2x}\right)\right]$, and U_0^{Ce}, U_0^O represent the sums of effective pair interaction energies of Ce^{4+}, O^{2-} ions, respectively, in $CeO_{2-x/2}$ system, and U_0^Y represents the sum of effective pair interaction potentials of Y^{3+} ions in $Ce_{1-x}Y_xO_{2-x/2}$ system. It is noted that the presence of oxygen vacancies impacts strongly on the interaction potentials of Ce^{4+}, O^{2-}, Y^{3+} ions. Based on probability theory, the total interaction potentials of Ce^{4+}, O^{2-} and Y^{3+} ions in $CeO_{2-x/2}$ and $Ce_{1-x}Y_xO_{2-x/2}$ systems, respectively, taking into account the role of oxygen vacancies can be determined as

$$U_0^{Ce} = \frac{N_{Ce}}{2}\left(\sum_i b_i^{Ce-Ce}\varphi_{i0}^{*Ce-Ce} + \left(1 - \frac{N_{va}}{2N}\right)\sum_i b_i^{Ce-O}\varphi_{i0}^{*Ce-O}\right), \quad (6)$$

$$U_0^O = \frac{N_O}{2}\left(\sum_i b_i^{O-Ce}\varphi_{i0}^{*O-Ce} + \left(1-\frac{N_{va}}{2N-1}\right)\sum_i b_i^{O-O}\varphi_{i0}^{*O-O}\right), \quad (7)$$

$$U_0^Y = \frac{N_Y}{2}\left(\frac{N_{Ce}}{N-1}\sum_i b_i^{Y-Ce}\varphi_{i0}^{*Y-Y} + \frac{N_Y-1}{N-1}\sum_i b_i^{Y-Y}\varphi_{i0}^{*Y-Y} + \left(1-\frac{N_{va}}{2N}\right)\sum_i b_i^{Y-O}\varphi_{i0}^{*Y-O}\right), \quad (8)$$

with b_i^{X-Ce} (or b_i^{X-O}, or b_i^{X-Y}) is the number of the i-*th* nearest-neighbor sites relative to X ion (X = Ce^{4+}, O^{2-}, Y^{3+}) that Ce^{4+} (or O^{2-}, or Y^{3+}) ions can occupy, and φ_{i0}^{*X-Ce} (or φ_{i0}^{*X-O}, or φ_{i0}^{*X-Y}) is the interaction potential between the 0-*th* X ion and a Ce^{4+} (or O^{2-}, or Y^{3+}) ion at the i-*th* nearest-neighbor sites relative to this X ion, respectively. In $CeO_{2-x/2}$ and $Ce_{1-x}Y_xO_{2-x/2}$ systems with fluorite structure, the interaction potential between the i-*th* and the j-*th* ions includes the electrostatic Coulomb potential and Buckingham potential including the short-range interactions

$$\varphi_{ij}(r) = \frac{q_i q_j}{r} + A_{ij}\exp\left(-\frac{r}{B_{ij}}\right) - \frac{C_{ij}}{r^6}, \quad (9)$$

where q_i and q_j are the charges of the *i*-th and the *j*-th ions, *r* is the distance between them and the parameters A_{ij}, B_{ij} and *c* are empirically determined (listed in Table 1).

Table 1. The parameters of the Buckingham potential in $Ce_{1-x}Y_xO_{2-x/2}$ system [11].

Interaction	A_{ij}/eV	B_{ij} /Å	C_{ij}/eV (Å^6)
O^{2-}– O^{2-}	9547.96	0.2192	32.00
Ce^{4+}– O^{2-}	1809.68	0.3547	20.40
Y^{3+}– O^{2-}	1766.4	0.3385	19.43

Since pressure *P* is determined by

$$P = -\left(\frac{\partial\Psi}{\partial V}\right)_T = -\frac{a}{3V}\left(\frac{\partial\Psi}{\partial a}\right)_T, \quad (10)$$

from Eq.(1), it is easy to take out an equation of state of $Ce_{1-x}Y_xO_{2-x/2}$ system at temperature T = 0K and pressure *P*

$$Pv = -a\left\{C_{Ce}\left[\frac{1}{6}\frac{\partial u_0^{Ce}}{\partial a} + \frac{\hbar\omega_{Ce}}{4k_{Ce}}\frac{\partial k_{Ce}}{\partial a}\right] + \frac{x}{3}\left[\frac{1}{6}\frac{\partial u_0^{Y}}{\partial a} + \frac{\hbar\omega_{Y}}{4k_{Y}}\frac{\partial k_{Y}}{\partial a}\right] + \right.$$

$$\left. + C_O\left[\frac{1}{6}\frac{\partial u_0^{O}}{\partial a} + \frac{\hbar\omega_{O}}{4k_{O}}\frac{\partial k_{O}}{\partial a}\right] - \frac{x}{18}\frac{\partial u_0^{Zr}}{\partial a}\right\}. \quad (11)$$

with *v* là the atomic volume.

The average nearest-neighbor distance of $Ce_{1-x}Y_xO_{2-x/2}$ system at temperature T = 0K and pressure P, $r_1(P,0)$ can be derived by numerically solving the equation of state Eq.(11). Then the average nearest-neighbor distance at temperature T and pressure P can be written as

$$r_1(P,T) = r_1(P,0) + C_{Ce}y_0^{Ce} + C_Y y_0^Y + C_O y_0^O, \tag{12}$$

with y_0^{Ce}, y_0^Y and y_0^O are the displacements of Ce^{4+}, Y^{3+} and O^{2-} ions from the equilibrium position in the crystal lattice

$$y_0^{Ce} \approx \sqrt{\frac{2\gamma_{Ce}\theta^2}{3k_{Ce}^3}A_{Ce}}, \quad y_0^Y \approx \sqrt{\frac{2\gamma_Y\theta^2}{3k_Y^3}A_Y}, \tag{13}$$

$$y_0^O = \sqrt{\frac{2\gamma_O\theta^2}{3K_O^3}A_O} - \frac{\beta_O}{3\gamma_O} + \frac{1}{K_O}\left(1+\frac{6\gamma_O^2\theta^2}{K_O^4}\right)\left[\frac{2\gamma_O\theta}{3k_O^2}\left(x\coth x - 1\right) - \frac{2\beta_O^2}{27\gamma_O k_O} + \frac{1}{3}\right], \tag{14}$$

where parameters A_{Ce}, A_Y, A_O are determined as Ref.[14]. The lattice constant of $Ce_{1-x}Y_xO_{2-x/2}$ system is then can be defined in relation to the average nearest-neighbor distance as $a(P,T) = 4/\sqrt{3}\,r_1(P,T)$.

Young's modulus is a mechanical parameter to measure the stiffness of solid materials. In previous study, the Young's modulus E of CeO_2 crystal was given by V.V Hung *et al.* [6]

$$E = \frac{\partial\sigma}{\partial\varepsilon} = \frac{1}{v}\frac{\partial^2\Psi}{\partial\varepsilon^2}, \tag{15}$$

with ε is the train, σ denotes the stress.

From Eqs.(1) and (15), it is easy to derive the explicit expression of Young's modulus in the harmonic approximation as

$$E = E_{CeO_{2-x/2}} + \frac{v}{3v}\left(-\frac{\partial^2 u_0^{Ce}}{\partial\varepsilon^2} + \frac{\partial^2\Psi_Y}{\partial\varepsilon^2}\right), \tag{16}$$

where

$$E_{CeO_{2-x/2}} = \frac{1}{v}\frac{\partial^2\Psi_{CeO_{2-x/2}}}{\partial\varepsilon^2}, \tag{17}$$

$$\frac{\partial^2 u_0^{Ce}}{\partial\varepsilon^2} = 4a_0^2\frac{\partial^2 u_0^{Ce}}{\partial a^2} + 2a_0\frac{\partial u_0^{Ce}}{\partial a}, \tag{18}$$

$$\frac{\partial^2\Psi_Y}{\partial\varepsilon^2} = 4a_0\left\{\frac{\partial^2 u_0^Y}{\partial a^2} + \frac{3\hbar\omega_Y}{4k_Y}\left[\frac{\partial^2 k_Y}{\partial a^2} - \frac{1}{2k_Y}\left(\frac{\partial k_Y}{\partial a}\right)^2\right]\right\} + 2a_0\left\{\frac{\partial u_0^Y}{\partial a} + \frac{3}{4k_Y}\hbar\omega_Y\coth x_Y\frac{\partial k_Y}{\partial a}\right\}. \tag{19}$$

The isothermal bulk modulus K and shear modulus G can be derived using the following relations

$$K = \frac{E}{3(1-2\upsilon)}, \tag{20}$$

$$G = \frac{E}{2(1+\upsilon)}, \tag{21}$$

where υ is Poisson's ratio related to the stability of crystal under shear deformation. In this study, the value of Poisson's ratio is assumed to be 0.33 in accordance with experiment [1].

2.2. Results and discussion

The lattice constant of YDC crystal at the different dopant concentrations is presented in Fig. 1. One can see that the lattice constant decreases with the increasing dopant concentration. This dependence arises mainly from the creation of the oxygen vacancies that leads to a lattice contraction. Using empirical equations, N. Kim *et al.* [7] showed a linear relationship between the lattice constant and the dopant concentration in fluorite-structure oxide solid solutions. Fig.1 shows that SMM results at the room temperature are in good agreement with the results obtained from other theories [2, 27] and experiments [7, 27].

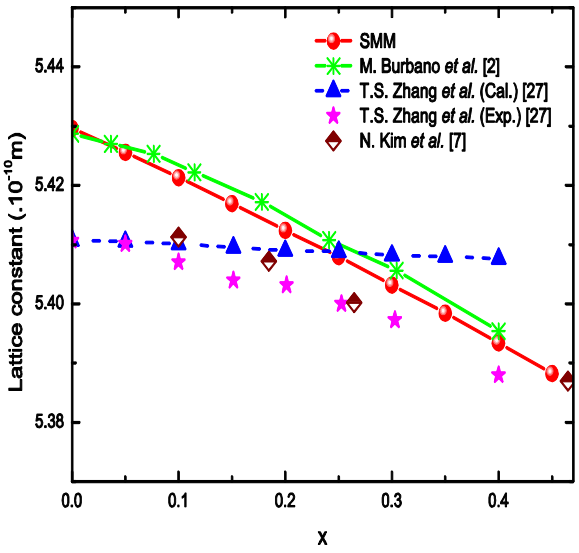

Figure 1. *The dopant concentration dependence of lattice constant at T = 300K. The other theoretical [2, 27] and experimental [7, 27] results are presented for comparison.*

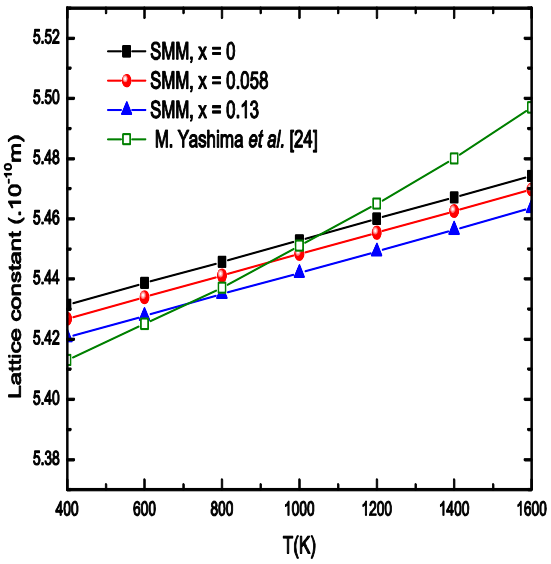

Figure 2. *The temperature dependence of lattice constant at various dopant concentrations, x = 0, x = 0.06, x = 0.13. The experimental results [24] are presented for comparison*

In Fig. 2, we compare the lattice constant at pressure P = 0 using the SMM with the experimental results (in the case of pure CeO_2) [24] for temperature range T = 400K – 1600K. The calculated lattice constants by the present theory are slightly larger than the experimental values for temperature range T = 400K – 800K, and slightly smaller than the experimental values for temperature range T = 800K – 1600K, but overall features are in good agreement

with the experimental results [24]. The predicted zero-pressure lattice constant a(0,400K) = 5.4314 Å agrees within 0.4% with the corresponding experimental value 5.413 Å.

In Fig. 3, we compare the SMM results of lattice constant at the room temperature and various pressures with the experimental results (in the case x = 0). Fig. 3 also shows the experimental lattice constants of pure CeO_2 [5, 22] as functions of the pressure. The pressure dependence of the lattice constant at the different dopant concentrations is similar for a wide pressure range. Our SMM theory predicts that the lattice constant of YDC crystal decreases rapidly with the pressure. The obtained results are in agreement with those measured by experiments for pure CeO_2 [5, 22]. The predicted zero-pressure lattice constant a(0,300K) = 5.4291Å agrees within 0.3 % with the corresponding experimental value 5.411Å.

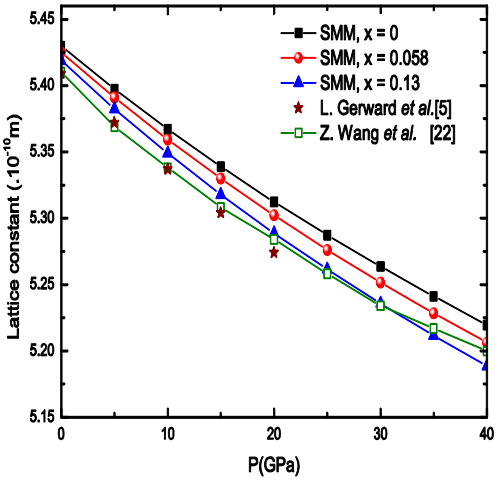

Figure 3. *The pressure dependence of lattice constant at various dopant concentrations, x = 0, x = 0.06, x = 0.13. The experimental results [5, 22] are presented for comparison.*

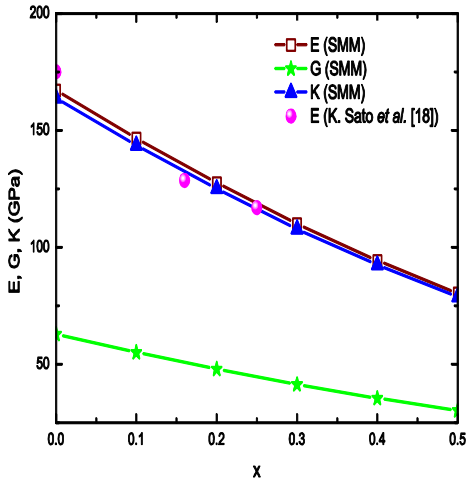

Figure 4. *The dopant concentration dependence of Young's, bulk, shear moduli at the room temperature. The experimental results [18] are presented for comparison.*

Fig. 4 shows how the dopant concentration dependence of the Young's E, bulk K, and shear moduli G. One can see that all YDC with different dopant concentrations has lower Young's E, bulk K, and shear moduli values than those of pure ceria (x = 0). The presence of oxygen vacancies related to the replacement of Ce^{4+} by Y^{3+} ions decreases the binding energy between cations and anions near the oxygen vacancies. Consequently, the elastic moduli decrease as the dopant concentration increases. The SMM results of bulk modulus K are in good agreement with the experimental results using scanning electron microscopy and small specimen technique [18]. The temperature dependence of Young's, bulk, shear moduli is given in Fig. 5. The SMM results of the Young's, bulk and shear moduli with x = 0.2 decrease gradually with the increasing temperature. Accordingly, YDC crystal becomes easier to elongate at high temperatures. The rapid reduction in the elastic moduli indicates the stronger anharmonicity contributions of the thermal lattice vibrations at high temperatures.

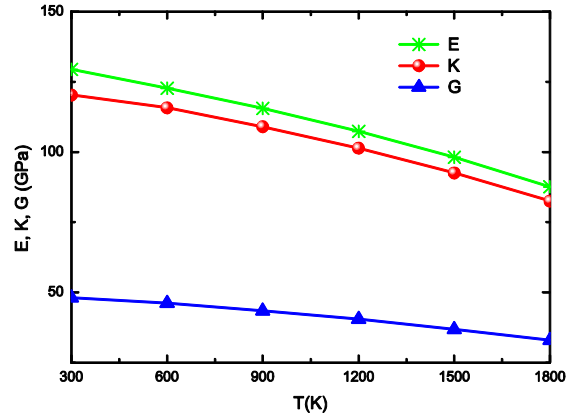

Figure 5. *The temperature dependence of Young's, bulk, shear moduli of YDC crystal.*

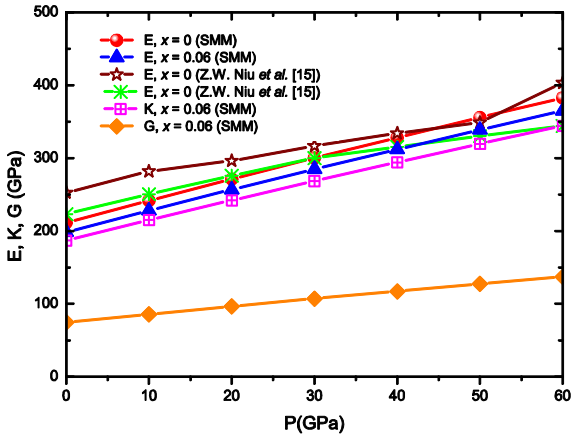

Figure 6. *The pressure dependence of Young's, bulk, shear moduli at various dopant concentrations, x = 0, x = 0.06. The results using LDA and LDA+U methods [15] are presented for comparison.*

In Fig. 6, the calculated Young's, bulk and shear moduli with $x = 0.06$ are plotted as functions of pressure P. It is clearly seen that the Young's, bulk and shear moduli depend sensitively on the pressure. The lattice constant decreases due to an increase of pressure, therefore the elastic moduli become larger. The obtained results of Young's modulus using the local-density approximation (LDA) and LDA+U methods [15] are also shown for comparison with the SMM result for CeO_2 crystal. N. Wei *et al.* [23] explained that the material with larger Young's modulus responds to the more covalent feature of the material. The Young's modulus increases linearly with the increase of the pressure, which means that CeO_2 and YDC crystals become more stiff under the pressure.

3. CONCLUSION

The lattice constant and elastic moduli of YDC crystal are investigated using the SMM including the anharmonicity effects of thermal lattice vibrations. The SMM calculations are also performed using the Buckingham potential for YDC crystal with fluorite structure. The lattice constant and elastic moduli are calculated as functions of the dopant concentration,

temperature, and pressure. The influences of dopant concentration, temperature, and pressure on the lattice constant and elastic moduli have been studied in detail. Our results are in good agreement with previous experiments and several theoretical calculations.

REFERENCES

1. A. Atkinson and A. Selcuk (2000), "Mechanical behaviour of ceramic oxygen ion-conducting membranes", *Solid State Ionic*. **134**, pp.59.
2. A. Tschope, W. Liu, M. Flytzanistephanopoulos, and J. Y. Ying (1995), "Redox activity of nonstoichometric cerium oxide based nanocrystalline catalysts", *Journal of Catalysis*. **157**, pp.42.
3. D. Marrocchelli, S.R. Bishop, H.L. Tuller and B. Yildiz (2012), "Understanding Chemical Expansion in Non-Stoichiometric Oxides: Ceria and Zirconia Case Studies", *Adv. Funct. Mater.* **22**, pp.1958-1965.
4. E. Wachtel and I. Lubomirsky (2011), "The elastic modulus of pure and doped ceria", *Scripta Materialia*. **65**, pp.112.
5. F. Zhang, S.-W. Chan, J.E. Spanier, E. Apak, Q. Jin, R.D. Robinson and I.R. Herman (2002), "Cerium oxide nanoparticles: Size-selective formation and structure analysis", *Appl. Phys. Lett.* **80**, pp.127.
6. J.L.M. Rupp, C. Solenthaler, P. Gasser, U.P. Muecke and L.J. Gauckler (2007), "Crystallization of amorphous ceria solid solutions", *Acta Mater*. **55**, pp.3505.
7. J.R. McBride, K.C. Hass, B.D. Poindexter and W.H. Weber (1994), "Raman and x-ray studies of $Ce_{1-x}RE_xO_{2-y}$, where RE = La, Pr, Nd, Eu, Gd, and Tb", *J. Appl. Phys.* **76**, pp.2435.
8. K. Muthukkumaran, R. Bokalawela, T. Mathews and S. Selladurai (2007), "Determination of dopant of ceria system by density functional theory", *J. Mater. Sci*. **42**, pp.7461.
9. K. Sato, H. Yugami and T. Hashida (2004), "Effect of rare-earth oxides on fracture properties of ceria ceramics", *Journal of Materials Sciences*. **39**, pp.5765.
10. L. Gerward, J. Staun Olsen, L. Petit, G. Vaitheeswaran, V. Kanchana and A. Svane (2005), "Bulk modulus of CeO_2 and PrO_2 - An experimental and theoretical study", *Journal of Alloys and Compounds*. **400**, pp.56.
11. L.T. Lam, V.V. Hung, B.D. Tinh (2019), "Investigation of electrical properties of Yttria- doped Ceria and Yttria-Stabilized Zirconia by statistical moment method", *Journal of the Korean Physical Society*. **75** (4), pp.293.
12. L.T. Lam, V.V. Hung, N.T. Hai (2019), "Effect of temperature on electrical properties of Yttria-doped Ceria and Yttria-stabilized Zirconia", *HNUE Journal of Science*. **64** (6), pp.68.
13. M. Burbano, S.T. Norberg, S. Hull, S.G. Eriksson, D. Marrocchelli, P.A. Madden and G.W. Watson (2012), "Oxygen Vacancy Ordering and the Conductivity Maximum in Y_2O_3-Doped CeO_2", *Chem. Mater.* **24**, pp.222.
14. M. Yashima, D. Ishimura, Y. Yamaguchi, K. Ohoyama and K. Kawachi (2003), "High-temperature neutron powder diffraction study of cerium dioxide CeO_2 up to 1770K", *Chemical Physics Letters*. **372**, pp.784.
15. M.-Y. Cheng, D.-H. Hwang, H.-S. Sheu and B.-J. Hwang (2008), "Formation of $Ce_{0.8}Sm_{0.2}O_{1.9}$ nanoparticles by urea-based low-temperature hydrothermal process", *Journal of Power Sources*. **175**, pp.137.
16. N. Kim and J.F. Stebbins (2007), "Vacancy and Cation Distribution in Yttria-Doped Ceria: An

^{89}Y and ^{17}O MASNMR Study", *Chem. Mater*. 19, pp.5742.
17. N. Wei, X. Zhang, C. Zhang, S. Hou and Z. Zeng (2015), "First-principles investigations on the elastic and thermodynamic properties of cubic ZrO_2 under high pressure", *International Journal of Modern Physics*. C26, pp.1550056.
18. P. Li, I-W. Chen, J.E. Penner-Hahn and T.-Y. Tien (1991), "X-ray Absorption Studies of Ceria with Trivalent Dopants", *J. Am. Ceram. Soc.* **7**4, pp.958
19. P.-L. Chen and I.W. Chen (1994), "Role of Defect Interaction in Boundary Mobility and Cation Diffusivity of CeO_2", *J. Am. Cream. Soc*. **77**, pp.2289.
20. R. Pornprasertsuk, P. Ramanarayanan, C. B. Musgrave, and F. B. Prinz (2005), "Predicting ionic conductivity of solid oxide fuel cell electrolyte from first principles", *Journal of Applied Physics*. **98**, pp.103513.
21. S. Vyas, R.W. Grimes, D.H. Gay and A.L. Rohl, J. Chem. Soc. (1998), "Structure, Stability and Morphology of Stoichiometric Ceria Crystallites", *Faraday Trans.* **94** (3), pp.427.
22. T.S. Zhang, J. Ma, H.T. Huang, P. Hing, Z.T. Xia, S.H. Chan and J.A. Kilner (2003), "Effects of dopant concentration and aging on the electrical properties of Y-doped ceria electrolytes", *Solid State Sciences*. **5**, pp.1505.
23. V.G. Zavodinsky (2004), "The mechanism of ionic conductivity in stabilized cubic zirconia", *Physics of the Solid State*. **46**, pp.453.
24. V.V. Hung, L.T.M. Thanh, "Study of elastic properties of CeO_2 by statistical moment method", *Physica B*. **406** (2011), pp.4014.
25. Z. Wang, Y. Zhao, D. Schiferl, C.S. Zha and R.T. Downs (2004), "Pressure induced increase of particle size and resulting weakening of elastic stiffness of nanocrystals", *J. Appl. Phys.* 85, pp.124.
26. Z.-P. Li, T. Mori, F. Ye, D. Ou, G. J. Auchterlonie, J. Zou, and J. Drennan (2012), "Cerium-Reduction-Induced Defects Clustering, Ordering, and Associated Microstructure Evolution in Yttrium-Doped Ceria", *J. Phys. Chem. C*. 116, pp.5435.
27. Z.W. Niu, B. Zhu, Y. Cheng, R.N. Song and G.F. Ji (2014), "Elastic and electronic properties of cubic cerium oxide under pressure via first principles", *International Journal of Modern Physics*. *B***28**, pp.1450070.

NGHIÊN CỨU HẰNG SỐ MẠNG VÀ MÔ ĐUN ĐÀN HỒI CỦA TINH THỂ CERIA PHA TẠP YTTRIA BẰNG PHƯƠNG PHÁP THỐNG KÊ MÔMEN

Tóm tắt: *Trong nghiên cứu này, chúng tôi đã phát triển hình thức luận dựa vào phương pháp thống kê momen đển nghiên cứu hằng số mạng và môđun đàn hồi của tinh thể Ceria pha tạp Yttria có tính đến các ảnh hưởng phi điều hoà của các dao động mạng tinh thể. Hằng số mạng, môđun đàn hồi được tính toán là các hàm của nồng độ tạp chất, nhiệt độ và áp suất. Sử dụng thế Buckingham, chúng tôi tính toán môđun đàn hồi với nhiệt độ lên tới 1800K và áp suất lên tới 60 GPa. Các tính toán của chúng tôi được so sánh với các kết quả lí thuyết và thực nghiệm.*

Từ khóa: *Hằng số mạng, môđun đàn hồi, tinh thể ceria pha tạp yttria.*

THE SPACE OF LINEARLY CORRELATED FUZZY NUMBER $\mathbb{R}_{\mathcal{F}(A)}$

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Abstract: *This article introduces the space of linearly correlated fuzzy number $\mathbb{R}_{\mathcal{F}(A)}$. It is a subspace of the space of fuzzy numbers. we first review the algebraic operations on $\mathbb{R}_{\mathcal{F}(A)}$ defined mean of linear isomorphism between $\mathbb{R}^2$ and $\mathbb{R}_{\mathcal{F}(A)}$ provided that A is a non-symmetric fuzzy number. Second, we present a quotient set $\mathbb{R}^2/_{\equiv_A}$ by defining an appropriate equivalence relation on $\mathbb{R}^2$ when A is a symmetric fuzzy number. After that, we will introduce some types of Fréchet derivative defined on the class of linear correlated fuzzy-valued functions namely Fréchet derivative and LC derivative . That allows us to introduce three types of Fréchet fractional derivatives, which are Fréchet Caputo derivative, Fréchet Riemann-Liouville derivative and Fréchet Caputo-Fabrizio derivative.*

Keywords: *Linearly correlated fuzzy number, Fréchet derivative, LC derivative, Fréchet Caputo derivative, Fréchet Riemann-Liouville derivative and Fréchet Caputo-Fabrizio derivative.*

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1. INTRODUCTION

In [5], the H-difference of two fuzzy numbers has been introduced. It is well-known that the usual Hukuhara difference between two fuzzy numbers exists only under very restrictive conditions [11, 12, 16]. The gH-difference of two fuzzy numbers exists under much less restrictive conditions, however it does not always exist [31, 32]. The g-difference proposed in [38] overcomes these shortcomings of the above discussed concepts and the g-difference of two fuzzy numbers always exists. The same remark is valid if we regard differentiability concepts in fuzzy settings. Based on these types of differences, different types of derivatives on the space of fuzzy functions are also studied in turn.

In 2009 [30], generalized Hukuhara difference (gH difference) of two interval numbers

which was more general than H-difference was introduced, based on which the generalized Hukuhara derivative (gH-derivative) was defined for interval-valued functions. Based on the g-difference, a very general fuzzy differentiability concept is defined and studied, the so-called g-derivative [5, 30]. Based on the gr-difference, Granular derivative (gr-derivative) is introduced [22]. In [13], Esmi et al has introduced the concept of difference of two fuzzy numbers in the linear correlated fuzzy-valued $\mathbb{R}_{\mathcal{F}(A)}$ space. In fact, the structure of the space of linearly correlated fuzzy numbers depends on the symmetry of the basic fuzzy number. Specifically, this space is a linear one if the basic fuzzy number is a non-symmetric fuzzy number, whereas if the basic fuzzy number is symmetric, then the space is not a linear space. Therefore, the calculus they established are mainly for the case where the basic fuzzy number is non-symmetric . In some special cases, subtraction in space $\mathbb{R}_{\mathcal{F}(A)}$ is always possible. Furthermore we will also have $B \ominus_A B = \hat{0}$ for all $B \in \mathbb{R}_{\mathcal{F}(A)}$. This is because the space $\mathbb{R}_{\mathcal{F}(A)}$ has some special analytical properties. The $\mathbb{R}_{\mathcal{F}(A)}$ space is a special space because it can be embedded into $\mathbb{R}_{\mathcal{F}}$ via ψ_A function as a complete linear subspace if is A a non-symmetric fuzzy number. Consequently, $(\mathbb{R}_{\mathcal{F}(A)}, \oplus_A, \odot_A)$ becomes a Banach space $\mathbb{R}_{\mathcal{F}}$. However, when the basic fuzzy number is symmetric, it is impossible to directly propose a suitable difference through the addition and the scalar multiplication mentioned above, because the operator is no longer a linear isomorphism and the space of linearly correlated fuzzy number spaces is also not linear. To deal with this problem, the author [26] introduced the LC-difference in the space of linearly correlated fuzzy numbers. Coincidentally, the LC-difference and the gH difference introduced in [26]are equal for interval numbers. It is worth mentioning that LC-difference is adaptable regardless of whether the basic fuzzy number is symmetric or non-symmetric, and this difference always exists in the space of linearly correlated fuzzy numbers.

Recently, the derivative concepts built in the space $\mathbb{R}_{\mathcal{F}(A)}$ are being studied. In [23], authors develop a theory of calculus for linearly correlated fuzzy processes via the Frechet derivative and the Riemann integral. The author [26] reconsidered the calculus of linearly correlated fuzzy number-valued functions with the help of their representation functions. In details, the differentiability of a linearly correlated fuzzy number-valued function can be characterized by its representation functions. If the basic fuzzy num-ber is non-symmetric, the differentiability is equivalent to the Fréchet differentiability proposed by Esmi et al. [13], and it is also equivalent to the differentiability of its representation functions. In addition, if the basic fuzzy number is symmetric, then the differentiability can be described by the representation functions of the canonical form of a linearly correlated fuzzy number-valued function. Along with the study of derivatives in the space $\mathbb{R}_{\mathcal{F}(A)}$, fractional derivatives are also gradually receiving much attention. In [29], we introduce the definition of Frechet Caputo fractional derivative, Frechet Riemann-Liouville fractional derivative and Frechet

Caputo-Fabrizio fractional derivative and the relationship between them. In this paper, we present recent studies on space $\mathbb{R}_{\mathcal{F}(A)}$, specifically, types of derivatives as well as some dynamical systems.

2. PRELIMINARY

Firstly, we recall from [5] some fundamental arithmetic operations on the fuzzy number space $\mathbb{R}_{\mathcal{F}}$

(i) The addition between two fuzzy numbers u and v is defined via the Minkowski sum of their α - level sets

$$[u \oplus v]^{\alpha} = [u]^{\alpha} + [v]^{\alpha} = \{a + b : a \in [u]^{\alpha}, b \in [v]^{\alpha}\}, \alpha \in [0,1].$$

(ii) The scalar multiplication of a fuzzy number u with a scalar λ is given by

$$[\lambda u]^{\alpha} = \lambda [u]^{\alpha} = \{\lambda a : a \in [u]^{\alpha}\}, \alpha \in [0,1].$$

(i) The H-difference of u and v is known as an element $w \in \mathbb{R}_{\mathcal{F}}$ such that $u = v \oplus w$ and is denoted by $u \ominus v$. Note that the H-difference $u \ominus v$ (if exists) is unique and its $\alpha-$ level sets are

$$[u \ominus v]^{\alpha} = [u_{\alpha}^{-} - v_{\alpha}^{-}, u_{\alpha}^{+} - v_{\alpha}^{+}] \quad \text{for all } \alpha \in [0,1].$$

(ii) The gH-difference of u and v, denoted by $u \ominus_{gH} v$, is known as an element $w \in \mathbb{R}_{\mathcal{F}}$ such that $u = v \oplus w$ or $v = u \oplus (-1)w$.

Here, it should be noted that if $u \ominus v$ exists then $u \ominus_{gH} v = u \ominus v$.

Definition 2.1. [13] A fuzzy number $A \in \mathbb{R}_{\mathcal{F}}$ is symmetric with respect to $x \in \mathbb{R}$ if $A(x - y) = A(x + y)$ for all $y \in \mathbb{R}$.. We say that A is non-symmetric if there exists no x such that A is symmetric.

Example 2.1. Consider a fuzzy number u whose membership function is given by

$$u(x) = \begin{cases} 0 & \text{if } x < 0 \\ x & \text{if } 0 \le x < 1 \\ 1 & \text{if } 1 < x \le 2 \\ 3 - x & \text{if } 2 < x \le 3 \\ 0 & \text{if } x > 3 \end{cases}$$

We can see that u is a symmetric fuzzy number with respect to x=3/2 , see Figure 1 for illustration.

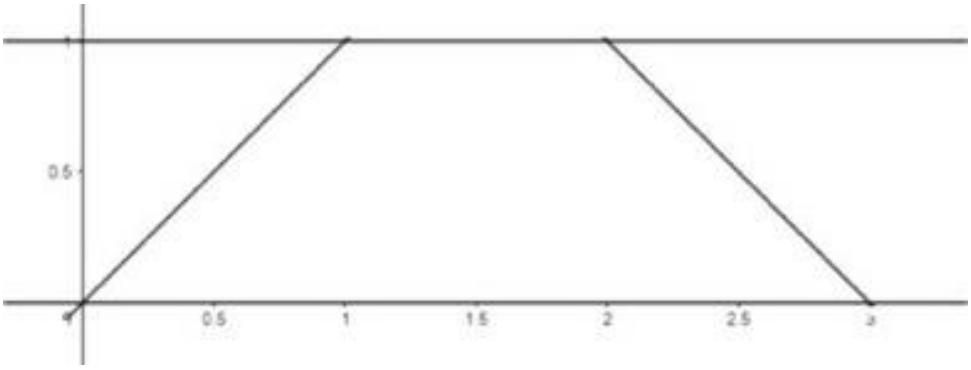

Figure 1. The symmetric fuzzy number u

Example 2.2. The fuzzy set $v:\mathbb{R}\to[0,1]$, given by is a symmetric fuzzy number with respect to x=5/4, see Figure. 2.

$$v(x)=\begin{cases}0 & \text{if } x<0\\ x^3 & \text{if } 0\le x<1\\ 1 & \text{if } 1\le x<1,5\\ (2,5-x)^3 & \text{if } 1,5<x\le 2,5\\ 0 & \text{if } x>2,5,\end{cases}$$

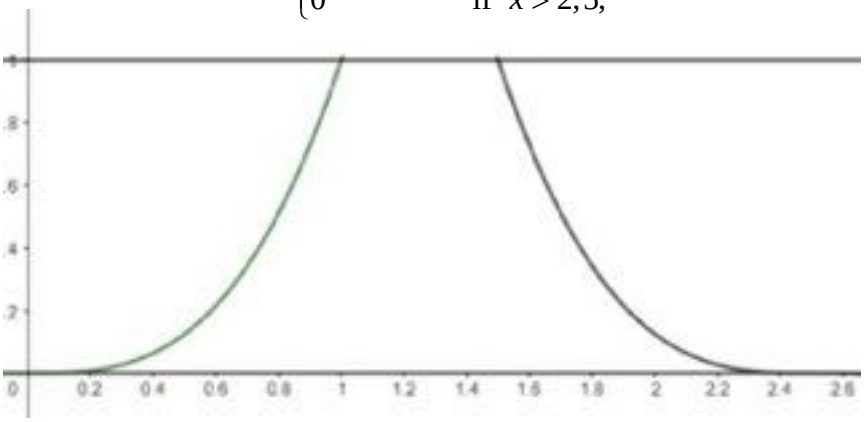

Figure 2. The symmetric fuzzy number v

Example 2.3. The fuzzy set $w:\mathbb{R}\to[0,1]$

$$w(x)=\begin{cases}0 & \text{if } x<-1\\ \dfrac{x+1}{4} & \text{if } -1\le x<3\\ \dfrac{5-x}{2} & \text{if } 3\le x\le 5\\ 0 & \text{if } x>5,\end{cases}$$

is a non-symmetric fuzzy number since there is no $x\in\mathbb{R}$ such that the equality

$w(x+y)=w(x-y)$ is satisfied for all $y\in\mathbb{R}$.

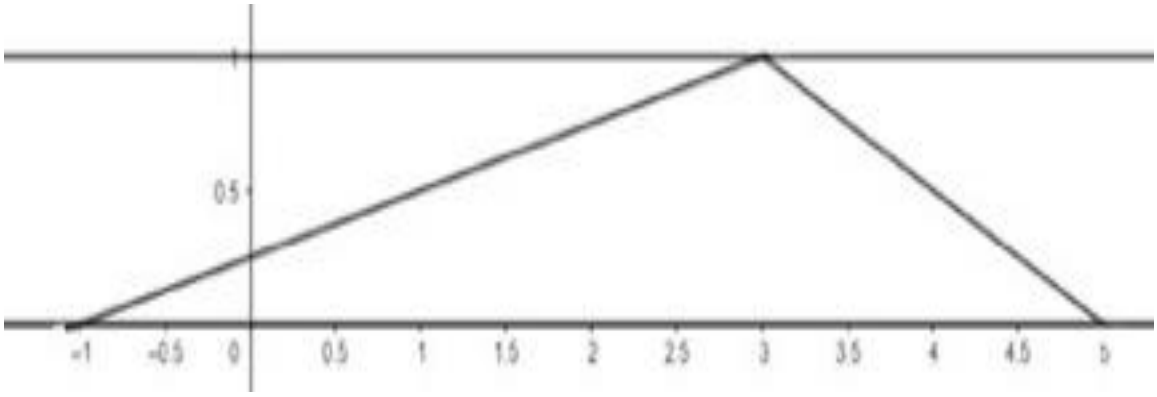

Figure 3. The symmetric fuzzy number w

2.1. The sapce of linearly correlated fuzzy number $\mathbb{R}_{\mathcal{F}(A)}$.

a. A ***is non-symmetric***

According to [13], for each non-symmetric fuzzy number $A\in\mathbb{R}_{\mathcal{F}}$, there is a linear isomorphism

$$\psi_A:\mathbb{R}\times\mathbb{R}\to\mathbb{R}_{\mathcal{F}}$$
$$(q,r)\mapsto\psi_A(q,r)$$

where $\psi_A(q,r)$ is a fuzzy number whose $\alpha-$level sets are given by

$$[\psi_A(q,r)]^{\alpha}=\{qa+r:a\in[A]^{\alpha}\},\ \forall\alpha\in[0,1],\ q,r\in\mathbb{R}.$$

Additionally, we denote the fuzzy number $\psi_A(q,r)$ by $q\odot_A A+r$ and the range of the isomorphism ψ_A by $\mathbb{R}_{\mathcal{F}(A)}$. An important fact that is worth emphasizing is that $\mathbb{R}$ can be embedded in $\mathbb{R}_{\mathcal{F}(A)}$ since every real number r can be identified with the fuzzy number $\psi_A(0,r)\in\mathbb{R}_{\mathcal{F}(A)}$ that is $\mathbb{R}\subseteq\mathbb{R}_{\mathcal{F}(A)}$.

From the results in [13], if $A\in\mathbb{R}_{\mathcal{F}}$ is a non-symmetric fuzzy number then the arithmetic operations on the space $\mathbb{R}_{\mathcal{F}(A)}$. such as addition, subtraction and scalar product are well-defined as follows:

(i) $u\oplus_A v=\psi_A\left(\psi_A^{-1}(u)+\psi_A^{-1}(v)\right)$

(ii) $\lambda\odot_A u=\psi_A\left(\lambda\psi_A^{-1}(u)\right)$;

(iii) $u-_A v=u+_A(-1)v=\psi_A\left(\psi_A^{-1}(u)+(-1)\psi_A^{-1}(v)\right)$,

where $u,v\in\mathbb{R}_{\mathcal{F}(A)}$ and $\lambda\in\mathbb{R}$.

The metric on the space $\mathbb{R}_{\mathcal{F}(A)}$ is defined by

$$d_A(u,v) = |q_u - q_v| + |r_u - r_v| \quad \text{for all } u,v \in \mathbb{R}_{\mathcal{F}(A)}.$$

Moreover, the space $\mathbb{R}_{\mathcal{F}(A)}$ endowed with metric d_A is a complete metric space.

In addition, if the fuzzy number A is non-symmetry then the space $\mathbb{R}_{\mathcal{F}(A)}$ is isometric to the Banach space $\mathbb{R}^2$ and hence, it implies that the space $(\mathbb{R}_{\mathcal{F}(A)}, +_A, \cdot_A, \|\cdot\|_{\psi_A})$ is a Banach space with the induced norm $\|u\|_{\psi_A} = \|\psi_A^{-1}(u)\|_{\mathbb{R}^2} = |q_u| + |r_u| = d_A(u,\hat{0})$ where $u = \psi_A(q_u, r_u) \in \mathbb{R}_{\mathcal{F}(A)}$ and $\hat{0} = \psi_A(0,0)$ is the neutral element of the space $\mathbb{R}_{\mathcal{F}(A)}$.

b. A ***is non-symmetric***

When A is a symmetric fuzzy number, a linearly correlated fuzzy number-valued function fmay have many infinitely representation functions. Considering the structure of the space $\mathbb{R}_{\mathcal{F}(A)}$, from [26], author introduce the canonical form of a linearly correlated fuzzy number-valued function $f(t) = q(t)A + r(t)$ provided that A is a symmetric fuzzy number *namely* an equivalence realtion $\equiv_A$ is defined in $\mathbb{R}^2$ by $(q,r) \equiv_A (p,s)$ if and only if $(q,r) = (p,s)$ or $(q,r) = (-p, 2px^* + s)$ for $(q,r),(p,s) \in \mathbb{R}^2$. Define the equivalence class

$$[q,r]_{\equiv_A} \overset{\text{def}}{=} \{(q,r),(-q, 2qx^* + r)\}.$$

Using the equivalence relation $\equiv_A$, the quotient set of $\mathbb{R}^2$ is defined by

$$\mathbb{R}^2 /_{\equiv_A} \overset{\text{def}}{=} \{[q,r]_{\equiv_A} \mid (q,r) \in \mathbb{R}^2\}.$$

Note that we choose (q,r) with $q \geq 0$ as the representative element. The function $\hat{\psi} : \mathbb{R}^2 / \equiv_A \to \mathbb{R}_{\mathcal{F}(A)}$ is defined by

$$\hat{\psi}_A([q,r]_{\equiv_A}) = q \odot_A A + r$$

where $[q,r]_{\equiv_A} \in \mathbb{R}^2 / \equiv_A$. Clearly, $\hat{\psi}_A$ is a bijection.

For $u = \hat{\psi}_A([q_u, r_u]_{\equiv_A}), v = \hat{\psi}_A([q_v, r_v]_{\equiv_A})$, with $\lambda \in \mathbb{R}, q_u, q_v \geq 0$. The addition $\hat{\oplus}_A$ and the

$$(i) \quad u \hat{\oplus}_A v = \hat{\psi}_A([q_u + q_v, r_u + r_v]_{\equiv_A}),$$

$$(ii) \quad \lambda \hat{\odot} u = \begin{cases} \hat{\psi}_A([\lambda q_u, \lambda r_v]_{\equiv_A}), & \lambda \geq 0, \\ \hat{\psi}_A([-\lambda q_u, 2\lambda q_u x^* + \lambda r_u]_{\equiv_A}), & \lambda < 0, \end{cases}$$

scalar multiplication $\hat{\odot}_A$ in $\mathbb{R}^2/\equiv A$ are defined

Definition 3.2. [26] For $u=\psi_A(q_u,r_u), v=\psi_A(q_v,r_v)$ are non symmetric fuzzy number. The LC-difference of u and v is defined by

Example 3.4. Let $A=(1;3;4)$ be a non-symmetric fuzzy number, $u=\psi_A(t^2,2t)$ and $v=\psi_A(t,t^2)$ for all $t\in[0,\infty)$. Then we have

$u \boxminus_A v=\psi_A(t^2-t,2t-t^2)=(t^2-t)\odot_A A+(2t-t^2).$

If $t\geq 1$ then $t^2-t\geq 0$, we have $u\boxminus_A v=(t;2t^2-t;3t^2-2t)$.

If $t\in(0,1)$ then $t^2-t<0$,we have $u\boxminus_A v=(3t^2-2t;2t^2-t;t)$.

Definition 3.3. [26] For $u=\hat{\psi}_A([q_u,r_u]_{\equiv_A}), v=\hat{\psi}_A([q_v,r_v]_{\equiv_A})$ are symmetric fuzzy numbers with symmetric point x^*. The LC-difference of u and v is defined by

$$u\hat{\boxminus} v=\begin{cases}\hat{\psi}_A([(q_u-q_v),r_u-r_v]_{\equiv_A}), & q_u\geq q_v,\\ \hat{\psi}_A([(q_v-q_u),2(q_u-q_v)x^*+r_u-r_v]_{\equiv_A}), & q_u<q_v.\end{cases}$$

In [27], it is proved that the LC-difference and the gH-difference are equivalent for interval numbers, since each interval number can be regarded as a symmetric fuzzy number. Therefore, the LC-difference can be seen as a gener-alization of the gH-difference of interval numbers in the space of linearly correlated fuzzy numbers $\mathbb{R}_{\mathcal{F}(A)}$.

Example 3.5. Let $A=(1;3;5)$ is a symmetric fuzzy number with the symmetry point $x^*=2$, $u=\psi_A(t^2,2t)$ and $v=\psi_A(t,t^2)$ for all $t\in[0,\infty)$. Then we have

- if $t\geq 1$ then $t^2\geq t$, we get

$B\hat{\boxminus} C=\hat{\psi}_A([t^2-t,2t-t^2]_{\equiv_A}),$

- if $t\in(0,1)$ then $t^2-t<0$, we get

$B\hat{\boxminus} C=\hat{\psi}_A([t-t^2,2(t^2-t)2+2t-t^2]_{\equiv_A})=\hat{\psi}_A([t-t^2,3t^2-2t]_{\equiv_A})$.

From [26], $u=\psi_A(q_u,r_u)$ is non-symmetric fuzzy number, the norm $\|.\|_A$ in $\mathbb{R}_{\mathcal{F}(A)}$ is introduced as follows

$\|u\|_A=\max\{|q_u|,|r_u|\}.$

Based on the LC-difference [26], for $u=\psi_A(q_u,r_u), v=\psi_A(q_v,r_v)$ are non-symmetric fuzzy

number with the symmetric point x^*. The metric d_{ψ_A} is given by

$d_{\psi_A}(u,v) = \| u \boxminus_A v \|_A = \max\{|q_u - q_v|, |r_u - r_v|\}$.

If $B = \hat{\psi}_A([q_u, r_u]_{\equiv_A})$ is a symmetric fuzzy number with the symmetric point x^* then the norm $\|.\|_{\hat{A}}$ in $\mathbb{R}_{\mathcal{F}(A)}$

$\| u \|_{\hat{A}} = \max\{|q_u|, |r_u|, |2q_u x^* + r_u|\}$,

and for $u = \hat{\psi}_A([q_u, r_u]_{\equiv_A}), v = \hat{\psi}_A([q_v, r_v]_{\equiv_A}) \in \mathbb{R}_{\mathcal{F}(A)}$ the metric $d_{\hat{\psi}_A}$ is given by

$$d_{\hat{\psi}_A}(u,v) = \| u \hat{\boxminus}_A v \|_{\hat{A}} = \max\{|q_u - q_v|, |2(q_u - q_v)x^* + r_u - r_v|, |r_u - r_v|\}$$

2.2. Derivative of linear correlated fuzzy-valued function

Remark 4.1. [13] Let $g: J \to \mathbb{R}_{\mathcal{F}(A)}$ and the functions $q, r: J \to \mathbb{R}$ such $g(t) = \psi_A(q(t), r(t))$, $t \in J$. We have

1. when A is a non-symmetric fuzzy number, then g is Fréchet differentiable at $t \in J$ if and only if $q'(t), r'(t) \in \mathbb{R}$ exist. Additionally, $g'_{\mathcal{F}}(t) = \psi_A(q'(t), r'(t))$, $t \in J$;

2. when A is a symmetric fuzzy number then we define $g'_{\mathcal{F}}(t) = \psi_A(q'(t), r'(t)), t \in J$; provided there exist $q'(t), r'(t) \in \mathbb{R}, t \in J$.

Definition 4.1. [26] Let A is a symmetric fuzzy number with the symmetry point x^* and Let $f: J \to \mathbb{R}_{\mathcal{F}(A)}$ is a linearly correlated fuzzy number value function with $f(t) = q(t)A + r(t)$. Then the canonical form of f is defined by

$f(t) = \hat{\psi}_A([q(t), \tilde{r}(t)]_{\equiv_A}) = q(t) \hat{\odot}_A A + \tilde{r}(t)$,

Wherre

$$q(t) = \begin{cases} q(t), & q(t) \geq 0 \\ -q(t), & q(t) < 0 \end{cases} \qquad \tilde{r}(t) = \begin{cases} r(t), & q(t) \geq 0, \\ 2q(t)x^* + r(t), & q(t) < 0. \end{cases}$$

Example 4.1.

- Let $A = (-2; 0; 2)$ be a symmetric triangular fuzzy number with the symmetry point $x^* = 0$. Assume that $f(t) = (3-t) \hat{\odot} A + 2t + 1$ for all $t \in [0, \infty)$. Then the canonical form of $f(t)$ is $f(t) = |3-t| \hat{\odot}_A A + 2t + 1$.
- Let $A = (1; 2; 3)$ be a symmetric triangular fuzzy number with the symmetry point $x^* = 1$. Assume that $f(t) = -t^2 \hat{\odot}_A A + t^2$ for all $t \in [0; +\infty)$. We can see that $-t^2 \leq 0$ for all $t \geq 0$. Then the canonical form of $f(t)$ is $f(t) = \hat{\psi}_A(t^2, -2t^2.1 + t^2) = \hat{\psi}_A(t^2, -t^2)$.

Definition 4.2. [26] Let A is a non-symmetric fuzzy number and let : $f: J \to \mathbb{R}_{\mathcal{F}(A)}$ be a linearly correlated fuzzy number-valued function with $f(t) = q(t)A + r(t)$. For $t_0 \in int(J)$, we say that

- (i) f is left LC-differentiable at t_0 provided that the following limit

$$\lim_{t \to t_0^-} \frac{1}{t - t_0} \odot_A (f(t) \boxminus_A f(t_0))$$

exists in the sense of the metric d_{ψ_A}.

- (i) f is right LC-differentiable at t_0 provided that the following limit

$$\lim_{t \to t_0^+} \frac{1}{t - t_0} \odot_A (f(t) \boxminus_A f(t_0))$$

exists in the sense of the metric d_{ψ_A}.

Meantime, the left LC-derivative and the right LC-derivative of f at t_0 are denote by $f'_-(t_0)$ and $f'_+(t_0)$, respectively.

Definition 4.3. [26] Let A is a non-symmetric fuzzy number and let $f: (a,b) \to \mathbb{R}_{\mathcal{F}(A)}$ be a linearly correlated fuzzy number-valued function with with $f(t) = q(t)A + r(t)$. For $t_0 \in (a,b)$, we say that f is LC-differentiable at t_0 provided that f is both left and right LC-differentiable and $f'_-(t_0) = f'_+(t_0)$. Furthermore, the LC-derivative is denoted by $f'(t_0)$.

Definition 4.4. [26] Let A is a symmetric fuzzy number with the symmetry point x^* and let $f: J \to \mathbb{R}_{\mathcal{F}(A)}$ be a linearly correlated fuzzy-valued function with the canonical form $f(t) = q(t)A + \tilde{r}(t)$. For $t_0 \in int(J)$, we say that

- (i) f is left LC-differentiable at t_0 provided that the following limit

$$\lim_{t \to t_0^-} \frac{1}{t - t_0} \hat{\odot}_A (f(t) \hat{\boxminus}_A f(t_0))$$

exists in the sense of the metric $d_{\hat{\psi}_A}$,

- (i) f is right LC-differentiable at t_0 provided that the following limit

$$\lim_{t \to t_0^+} \frac{1}{t - t_0} \hat{\odot}_A (f(t) \hat{\boxminus}_A f(t_0))$$

exists in the sense of the metric $d_{\hat{\psi}_A}$.

Remark 4.2. [27] We define

$$q_1(t_0) = \begin{cases} q'(t_0), & q'_-(t_0) \geq 0 \\ -q'(t_0), & q'_-(t_0) < 0 \end{cases} \quad and \quad r_1(t_0) = \begin{cases} \tilde{r}'(t_0), & q'_-(t_0) \geq 0 \\ -q'(t_0), & q'_-(t_0) < 0 \end{cases}$$

Then we can obtain $f^{'}(t_0) = q_1 A + r_1(t_0)$. More generally, for any $t \in (a;b)$ the derivative function of *f* can be represented by

$f^{'}(t) = \hat{\psi}_A[q_1(t), r_1(t)]_{\equiv_A}$.

Example 4.2. Let $A = (1;2;3)$ be a symmetric triangular fuzzy number with the symmetry point $x^* = 1$ and let $f(t) = (t^2+1)\hat{\odot}_A A + t^2, t \in (-1;1)$. We can get $q(t) = t^2 + 1$, $r(t) = t^2$. For each $t \in (-1;1)$, we can obtain $q_{-}^{'}(t) = q_{+}^{'}(t) = 2t, \tilde{r}_{-}^{'}(t) = \tilde{r}_{+}^{'}(t) = 2t,$. Furthermore, we have

$$q_1(t) = \begin{cases} 2t & t \geq 0 \\ -2t & t < 0 \end{cases} \quad \text{and} \quad r_1(t) = \begin{cases} 2t & t \geq 0 \\ -2t & t < 0. \end{cases}$$

Hence, we conclude that $f(t)$ is differentiable in $(-1;1)$ and $f'(t) = q_1 \hat{\odot}_A A + r_1(t)$ for each $t \in (-1;1)$.

Corollary 4.2 [27] Let $A \in \mathbb{R}_{\mathcal{F}} \setminus \mathbb{R}$ be a symmetric fuzzy number with the symmetric point x^* and let be the linearly correlated fuzzy number function in $(a;b)$. Suppose that $q(t), r(t)$ are differentiable with $q(t)$ has the same sign and $q'(t) \geq 0$ in $(a;b)$. Then $f(t)$ is differentiable in $(a;b)$ and $f'(t) = q'(t)\hat{\odot}_A + r'(t)$.

Corollary 4.3. [27] Let $A \in \mathbb{R}_{\mathcal{F}} \setminus \mathbb{R}$ be a symmetric fuzzy number with the symmetric point x^* and let $f(t) = q(t) \odot_A + r(t)$ be the linearly correlated fuzzy number function in $(a;b)$. Suppose that $q(t), r(t)$ are differentiable with $q(t)$ has the same sign and $q'(t) < 0$ in $(a;b)$. Then f (t) is differentiable in $(a;b)$ and $f'(t) = -q'(t)\hat{\odot}_A + 2q'(t)x^* + r'(t)$.

Example 4.3. Let $A \in \mathbb{R}_{\mathcal{F}} \setminus \mathbb{R}$ be a symmetric fuzzy number with the symmetric point x^* and let $f(t) = t^3 \hat{\odot}_A + 1$ for all $t \in \mathbb{R}$. By Corollary 3.1, we know that $f(t)$ is differentiable in $\mathbb{R}$ and $f'(t) = t^2 \hat{\odot}_A$.

Example 4.4. Let $A \in \mathbb{R}_{\mathcal{F}} \setminus \mathbb{R}$ be a symmetric fuzzy number with the symmetric point x^* and let $f(t) = -t^3 \hat{\odot}_A + 1$ for all $t \in \mathbb{R}$. By Corollary 3.2, we know that *f (t)* is differentiable in R and and $f'(t) = t^2 \hat{\odot}_A - 2t^2 x^*$.

2.3. Fractional derivatives of linear correlated fuzzy-valued function

Definition 5.1. [29] Let $A \in \mathbb{R}_{\mathcal{F}}$ be non-symmetric fuzzy number, $f \in \mathcal{L}(J, \mathbb{R}_{\mathcal{F}(A)})$ and $f(t) = q(t) \odot_A A + r(t)$ with $q, r \in L^1(J, \mathbb{R}) \cap C(J, \mathbb{R})$. Then, the Riemann-Liouville

fractional integral of order $p \in (0;1]$ of the function f is defined

$${}^{RL}_{\mathcal{F}}\mathcal{I}^{p}_{0^+} f(t) = \psi_A\left(I^{p}_{0^+} q(t), I^{p}_{0^+} r(t)\right), t \in J$$

Example 5.1. Let $A = (0;1;4)$ be non-symmetric fuzzy number and $f(t) = (t^2 - t) \odot_A + t$ for all $t \in [0,\infty)$. We have $q(t) = t^2 - t, r(t) = t$. Then

$$I^{1/2}_{0^+} q(t) = \frac{16}{3\sqrt{\pi}}\sqrt{t^5} - \frac{8}{3\sqrt{\pi}}\sqrt{t^3},\ I^{1/2}_{0^+} r(t) = \frac{8}{3\sqrt{\pi}}\sqrt{t^3}$$

This implies $${}^{RL}_{\mathcal{F}}\mathcal{I}^{1/2}_{0^+} f(t) = \psi_A\left(\frac{16}{3\sqrt{\pi}}\sqrt{t^5} - \frac{8}{3\sqrt{\pi}}\sqrt{t^3}, \frac{8}{3\sqrt{\pi}}\sqrt{t^3}\right).$$

If A is a symmetric fuzzy number then the operator ψ_A is not injective, we introduce the follows concept of Riemann-Liouville fractional integral of order $p \in (0,1]$ when A is symmetric as

Definition 5.2. [29] Let $A \in \mathbb{R}_{\mathcal{F}}$ be a symmetric fuzzy number and $f : J \subset \mathbb{R} \to \mathbb{R}_{\mathcal{F}(A)}$ be a linear correlated fuzzy-valued function which is given by $f(t) = \psi_A(q(t), r(t))$. If there exist $q(t), r(t) \in L^1(J, \mathbb{R}) \cap C(J, \mathbb{R})$ and $q(t)$ does not change the sign in J then the Riemann-Liouville (RL) fractional integral of order $p \in (0,1]$ of the function $f(t)$ is defined by

$${}^{RL}_{\mathcal{F}}\mathcal{I}^{p}_{0^+} f(t) = \psi_A\left(I^{p}_{0^+} q(t), I^{p}_{0^+} r(t)\right), t \in J.$$

Example 5.2. Let $A = (0;1;2)$ be a symmetric fuzzy number with the symmetry point $x^* = 1$

and $f(t) = t^2 \odot_A + t$ for all $t \in [0,\infty)$. We have $q(t) = t^2, r(t) = t$. This implies

$$I^{1/2}_{0^+} q(t) = \frac{16}{r\sqrt{\pi}}\sqrt{t^5} \qquad I^{1/2}_{0^+} r(t) = \frac{8}{3\sqrt{\pi}}\sqrt{t^3}$$

Therefore

$${}^{RL}_{\mathcal{F}}\mathcal{I}^{1/2}_{0^+} f(t) = \psi_A\left(\frac{16}{3\sqrt{\pi}}\sqrt{t^5}, \frac{8}{3\sqrt{\pi}}\sqrt{t^3}\right).$$

Definition 5.3. Let A be a non-symmetric fuzzy number and $f : J \subset \mathbb{R} \to \mathbb{R}_{\mathcal{F}(A)}$, $f(t) = q(t)A \oplus r(t)$ is Frechet differentiable for each $t \in J$. The Frechet Caputo-Fabrizio (FCF) fractional derivative of order $p \in (0;1]$ of fuzzy-valued function f is defined by

$$
\begin{aligned}
{}^{CF}_{\mathcal{F}}D^{p}_{0^+}f(t) &= \frac{1}{1-p}\int_0^t e^{\frac{-p(t-s)}{1-p}} f'_{\mathcal{F}'}(s)ds \\
&= \psi_A\left({}^{CF}D^{p}_{0^+}q(t), {}^{CF}D^{p}_{0^+}r(t)\right).
\end{aligned} \tag{2}
$$

In the case A is a symmetric fuzzy number, assume that $f(t) = q(t)A \oplus r(t)$ is Frechet differentiable for each $t \in J$ and $q'(\cdot), r'(\cdot)$ do not change the sign in J, we define the FCF fractional derivative of order $p \in [0,1)$ of f f by formula (2).

3. CONCLUSION

In this paper, we present knowledge around the space of linearly correlated fuzzy numbers $\mathbb{R}_{\mathcal{F}(A)}$. The construction of the two-element difference in space, especially the LC difference has opened a new way for approaching integral definitions on space $\mathbb{R}_{\mathcal{F}(A)}$. This leads to dynamical systems on $\mathbb{R}_{\mathcal{F}(A)}$ that can be converted to systems on the set of real numbers. This makes it easier to understand the solution posture as well as show the existence of solutions.

REFERENCES

1. A.A.Kilbas, H.M. Srivastava, J.J. Trujillo (2006), "Theory and Applications of Fractional Differential Equations", *North-Holland Mathematics Studies*, Vol. 204.
2. B. Bede, L. Stefanini (2013), "Generalized differentiability of fuzzy-valued functions", *Fuzzy Sets and Systems*, Vol. 230, pp. 119-141.
3. B. Bede, S. G. Gal (2005), "Generalizations of the differentiability of fuzzynumber-valued functions with applications to fuzzy differential equations", *Fuzzy Sets and Systems*, Vol.151, No.3, pp. 581-599.
4. Caibin Zeng, Yang Quan Chen (2015), "Global Pade' approximation of the generalized Mittag-Leffler function and its inverse", *Fractional Calculus and Applied Analysis*, Vol.18, Issue 6, pp. 1492-1506.
5. Debbouche, J.J. Nieto (2014), "Sobolev type fractional abstract evolution equations with nonlocal conditions and optimal multi-controls", *Appl. Math. Comput*. 245, pp.74-85.
6. Don-Lin Mon (1995), "Evaluating weapon system using fuzzy analytic hierarchy process based on entropy weight", *IEEE International Conference on Fuzzy Systems* , Vol. 5.
7. E. Esmi, F.S. Pedro, L.C. Barros (2018), "Fréchet derivative for linearly correclated fuzzy-valued function", *Information Sciences*, 435 (2018), 150-160.
8. E. Hernández, D. O'Regan (2009), "Controllability of Volterra-Fredholm type systems in Banach spaces", *J. Franklin Inst.* 346 (2009), pp. 95-101.
9. E.H Mamdani (1974), "Application of fuzzy algorithms for simple dynamic plant", *Proceedinqs of the lEE*, Part D, 121(1974), pp.1585-1588.

10. E.H Mamdani, S. Asilian (1975), "An experiment in linguistic synthesis with afuzzy logic controller. 1111", *Journal of Man-Machine Studies*, 7, pp.1-13.
11. F.S. Pedroa, E.Esmi, L.Barros (2020), "Calculus for linearly correlated fuzzy function using Frechet derivative and Riemann integral", *Information Sciences*, Vol. 512, pp.219-237.
12. G. Arthi, J. Park (2014), "On controllability of second-order impulsive neutral integro-differential systems with infinite delay", *IMA J. Math. Control Inf*., pp. 1-19.
13. Kaleva (1987), "Fuzzy di§erential equations", *Fuzzy Sets and Systems*, 24(1987).
14. L. A. Zadeh (1965), "Fuzzy sets", *Informat. Control*, Vol. 8, pp. 338-353.
15. L. P. Chen, Y. Chai, R. C. Wu, and J. Wang (2012), "Stability and stabilization of a class of nonlinear fractional-order systems with Caputo derivative", *IEEE Transactions on Circuits and Systems*, Vol. 59, No. 9, pp. 602-606.
16. L. Stefanini , B. Bede (2009), "Generalized Hukuhara differentiability of interval-valued functions and interval differential equations", *Nonlinear Analysis: Theory, Methods Applications*, Vol. 71, pp. 1311-1328.
17. L. Stefanini (2008), "A generalization of Hukuhara di§erence, Soft Methods for Handling Variability and Imprecision", *Series on Advances in Soft Computing*, Vol. 48, Springer.
18. L. Stefanini (2007), "On the generalized LU-fuzzy derivative and fuzzy differential equations", Proceedings of the *2007 IEEE International Conference on Fuzzy Systems, London*, pp. 710-715.
19. L.C. Barrosa, R.C. Bassanezia, P.A. Tonelli (2000), "Fuzzy modelling in population dynamics", *Ecological Modelling* 128 (2000), pp. 27-33.
20. M. Mazandarani, M. Najariyan (2014), "Differentiability of type-2 fuzzy number-valued Functions", *Commun Nonlinear Sci Numer Simul*, Vol. 19, No. 3, pp. 710-725.
21. M. Mazandarani, N. Pariz, A. V. Kamyad (2017), "Granular Differentiability of Fuzzy- Number-Valued Functions", *Journal of IEEE Transaction on Fuzzy Systems*, Vol.26, Issue 1, pp. 310-323, DOI: 10.1109/TFUZZ.2017.2659731.
22. Miao Yu, Xinge Ding, Hao Sun, Keshu Yu, Dongwei Zhao (2020), "Role of fuzzy fractional differential equation in the construction of low carbon economy statistical evaluation system", *Alexandria Engineering Journal*, Vol. 59, Issue 4, pp. 2765-2775.
23. N.T.K Son, H.T.P. Thao, H.V. Long (2021), "Fractional calculus of linear correlated fuzzy-valued functions related to Frechet differentiability", *Fuzzy Sets and Systems*, Vol. 419, pp. 35-66, https://doi.org/10.1016/j.fss.2020.10.019
24. P. Diamond (2000), "Stability and periodicity in fuzzy differential equations", *IEEE Trans. Fuzzy Systems*, 8 (2000), pp. 583-590.
25. P. Diamond (1999), "Time-dependent differential inclusions, cocycle attractors and fuzzy differential equations", *IEEE Trans. Fuzzy System*, 7 (1999), pp. 734-740.
26. P.R Agarwal,V. Lakshmikantham, J.J. Nieto (2010), "On the concept of solution for fractional differential equations with uncertainty", *Nonlinear Anal. Theory Methods Appl*., pp. 2859-2862.
27. Podlubny (1998), "Fractional Differential Equations", *Mathematic in Science and engineering*, Vol. 198.
28. S. Ji, G. Li, M. Wang (2011), "Controllability of impulsive differential systems with nonlocal conditions", *Appl. Math. Comput.* 217 (2011), pp. 6981-6989.
29. S. Kumar, N. Sukavanam (2012), "Approximate controllability of fractional order semilinear systems with bounded delay", *J. Differ. Equ.* 252 (2012), pp. 6163-6174.
30. Tony Thomas, S.K.Thangarasu, T. Sowmithra (2021), "Simulation and experimental validation

of electro hydraulic servo system using fuzzy logic controller", *AIP Conference Proceedings 2336*, 040021 (2021), DOI: https://doi.org/10.1063/5.0045724.
31. Yonghong Shen (2021), "Calculus for linearly correlated fuzzy number-valued functions", *Fuzzy Sets Syst*, DOI: https://doi.org/10.1016/j.fss.2021.02.017.
32. Yonghong Shen (2020), "First-order linear fuzzy differential equations on the space of linearly correlated fuzzy numbers", *Fuzzy Sets and Systems*.

KHÔNG GIAN CÁC HÀM SỐ MỜ TƯƠNG QUAN TUYẾN TÍNH

Abstract: *Trong bài báo này, tôi giới thiệu không gian không gian số mờ có giá trị tương quan tuyến tính $R_{F(A)}$. Nó là một không gian con của không gian các số mờ . Đầu tiên chúng tôi cung cấp một số thông tiên cơ bản về nguồn gốc hình thành, cách xác định các phép toán, các định nghĩa metric trên không gian $R_{F(A)}$. Sau đó, tôi đưa ra một số loại đạo hàm bậc một đã được nghiên cứu trong không gian này cụ thể ở đây là đạo hàm Fréchet. Cuối cùng, một số định nghĩa về đạo hàm bậc phân thứ, cụ thể là đạo hàm bậc phân thứ Fréchet Caputo, Fréchet Riemann-Liouville, Fréchet Caputo-Fabrizio cũng như một số tính chất của nó.*

Từ khóa*: Đạo hàm bậc phân thứ Fréchet Caputo, đạo hàm bậc phân thứ Fréchet Riemann-Liouvill, đạo hàm bậc phân thứ Fréchet Caputo-Fabrizio fractional derivative, không gian các hàm số mờ tương quan tuyến tính.*

OVERVIEW OF UNIVERSITY MANAGEMENT INFORMATION SYSTEM

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Abstract: *The paper presents an overview of the university information management system (UMIS). Management information system (MIS) provides necessary information for the management and administration of an organization/enterprise. A university is an educational organization that needs a UMIS to increase efficiency in implementation and management of activities. The structure and construction cycle for an UMIS is also presented in this paper. The outcome of this study provides a useful methodology for successfully building and implementing a UMIS at the university.*

Keywords: *Management, Information, System, Management Information System (MIS), university, university management information system (UMIS), decision making, system cycle.*

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1. INTRODUCTION

The business information of modern organizations, especially university institutions have become quite enormous and challenging than their concern is how information gathered, stored, disseminated and utilized. Therefore, it requires an information management system that supports management work, more rapid and automated decisions, and to reduce uncertainties. The system also provides enough information for the University to plan activities, manage and evaluate their effectiveness. It provides a foundation for improving university capacity, training quality and competitiveness.

Over many years, building software applications have been carried out in a manner that each business application is built as an independent unit, for instance, student management application, training management application, enroll management application. These applications functioned independently and are not shared database. This approach reveals the following disadvantages:

1. Software functionality depends primarily on the software provider's professional

knowledge. And in certain cases, the requirements of the university are not fulfilled.

2. The database is not shared, which leads to fragmented information, reduced personal responsibility, wasted work, redundancy of data and especially inconsistent information.

3. Data is scattered, not consistently managed. The interface is not user-friendly, each software has a different interface. Therefore, users have a lot of difficulty in finding information.

4. Information security policies are not applied to all university's operational data; they are held by individuals. Then the usage data is difficult and not guaranteed.

As a result, the specification of the university management information system has become important and urgent. This paper presents an overview of the university information management system, the components and the cycle of building a university information management system.

2. UNIVERSITY MANAGEMENT INFORMATION SYSTEM

2.1 Management Information System

2.1.1. Definition of system

The word system is derived from the Greek word Systema, which means an organized relationship between any set of components to achieve common cause or objective. According to Longman Dictionary, a system is a group of related parts that work together as a whole for a particular purpose. As a similar definition, a system is a group of elements that are interconnected and work together towards a common goal [1]. According to the above system interpretations, the components of a system interact with one another to achieve a certain purpose. The system collects data from users, then converts it into information useful to decision makers. As a result, a well-developed and interactive system provides the best information and utility for managers. In order to receive a comprehensive concept and the use of the system, needs to put the system in the context of the system. According to [1], there are three systems in an organization:

- Management system: including persons, vehicles, methods of decision-making.
- Information system: including persons, vehicles and methods of information processing.
- Operational system: including persons, vehicles, and methods of implementing decisions.

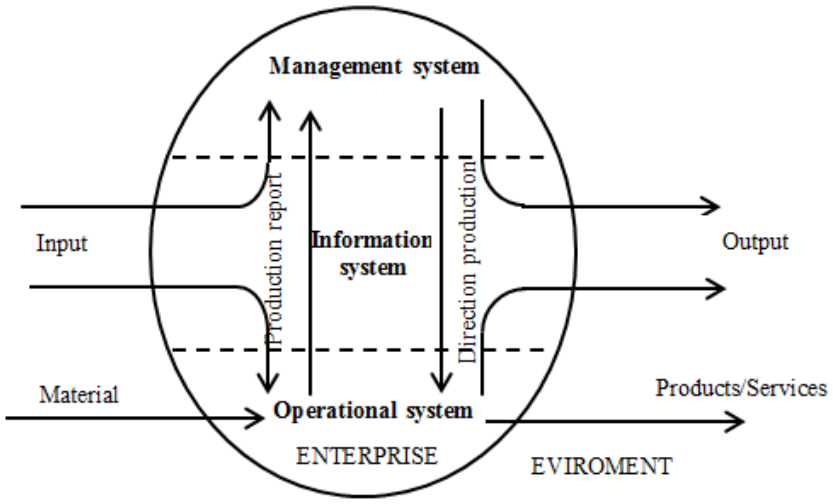

Figure 1. Systems of an organization [1]

Figure.1 shows the intermediary role of information systems within an organization (enterprise). The management system is the center of the organization, the role of that system is the decision-making process. The operational system is the consequence of making decisions: investment, production, inspection, etc. The information system acts as an intermediary between the management organization and the operating system, with the main role of collecting, processing and communicating data. In fact, there is no clear border between the component systems because the components of the above three systems exist in each management function of each organization.

2.1.2. Management Information System.

The term "Management information system" has three subject areas: management, information and system. Management is defined as the process of planning, organizing, implementing and controlling operations in the enterprise [2]. Similarly, management has been defined as the process that addresses the methods, techniques and effective use of organizational resources to achieve established outcomes [3]. The information refers to a data flow that was processed in the form and that is meaningful to the user. And the organization is an assemblage of different but interrelated and interdependent components that works as a whole to achieve common interest [4]. Judging from these definitions, Management information system (MIS) can be defined as "A system to convert data from internal and external sources into information and to communicate that information, in an appropriate form, to managers at all levels, in all functions to enable them to make timely and effective decisions for planning, directing and controlling the activities for which they are responsible" [5]. Thus, MIS is an information system that provides necessary information for the management and administration of an organization. The core of a MIS is a database containing information that reflects the current state and operations of the organization. The

system collects information from the organization's environment, coordinates with the information in the database, and then gives the results that managers need. The database is constantly updated to ensure that the information accurately reflects the current situation of the organization. MIS is generally categorized at low and high levels [1]:

- **Low Level (Operational Level):** The system responsible for printing a number of transaction tables and documents in accordance with the traditional manual processing model**.** As a result, the system was often called the data processing system which usually commands the processing system, the equipment management system, the accounting system, etc.

- **High Level (Executive Level):** The system must provide strategic and planning information to assist managers in making the right decisions in managing the business of the organization**.** Consequently, the system has been called the Decision Support System. The characteristics of a decision support system are the database, models, methods and when models and methods chosen to apply to the database, the results presented according to the criteria diverse requirements of users.

Determining the functions of the MIS system is an important basis for successfully building a MIS for an organization. Pride et al. identified five important functions for MIS [6]

- **Collecting data:** The collection of data that is necessary for decision making in short-term and long-term perspectives.

- **Storing data**: Keeping the data in an effective format in order to ensure that they can be the right of data can be retrieved in a minimum duration of time whenever necessary.

- **Updating data:** Ensuring that changes related to the data that has been stored are reflected on the system in an instant manner.

- **Processing data into information**: Application of various analytical methods with the assistance of information technology in order to transform raw data into meaningful intelligence.

- **Presenting information to users:** Increasing the level of data presentability that can be used for decision-making by stakeholders**.**

2.1.3. University management information system

In the university, there are many activities that cannot be handled with simple processing applications like admission, registration, conduction of examination, keeping track of the employees and students and managing both employees and student accounts. A university is an educational organization that needs a MIS to manage thousands of students and staff more efficiently. The system, called education management system that can be defined by UNESCO as “A system for the collection, integration, processing, maintenance and dissemination of data and information to support decision-making, policy-analysis and formulation, planning, monitoring and management at all levels of an education system. It is a system of people, technology, models, methods, processes, procedures, rules and

regulations that function together to provide education leaders, decision-makers and managers at all levels with a comprehensive, integrated set of relevant, reliable, unambiguous and timely data and information to support them in completion of their responsibilities" [7].

As defined by UNESCO's Education Management System, a MIS for universities provides the university's operating procedures, processes and collects data on teachers, students and other managers. All of the data relevant to the concerned entities are aggregated, collected and organized, managed and processed which is then shared within the organization and is used by the concerned authorities and management at all grades to get the beneficial decisions for the university. As such, the MIS for the university contains all relevant information required by university managers at all levels to support all their activities. Alternatively, Hazem M. El-Bakry and Nikos E Mastorakis gave the definition of the university management system as "UMIS refers broadly to a computer-based system 'collection of hardware, software, people, data, and information' that provides managers with the tools for organizing, evaluating and efficiently running their departments" [8]. In this paper, the authors also highlight four elements of the UMIS described in Figure 2.

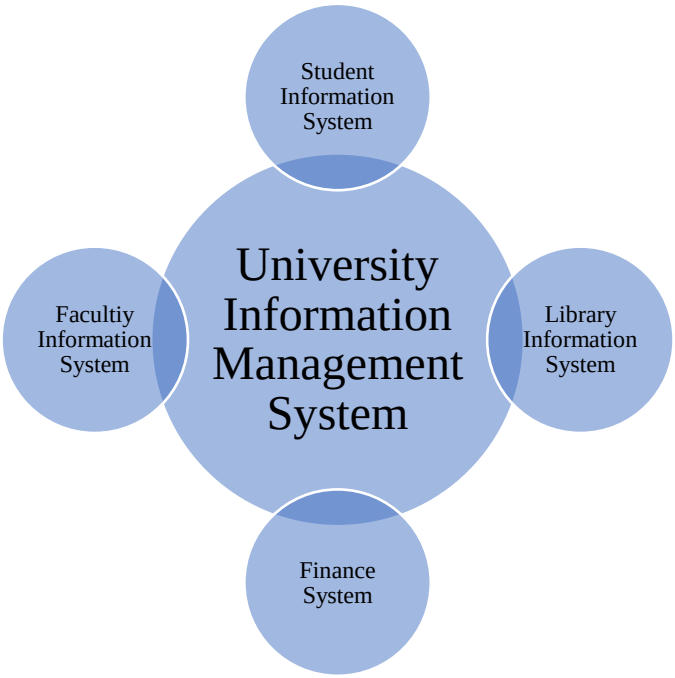

Figure 2. A Prototypical University Management Information System [8]

Student Information System (SIS)

SIS is the information system responsible for managing students' data within the university. SIS typical student record includes ID, SSN (Social Security Number), Name, Age, Gender, Address (Street, City, Country), Email, Username, Password, DOB (Date of Birth), Faculty, Year, Department.

Faculty Information System

The Faculty Information System is responsible for managing and automating managerial activities related to Instructors, Employees, Courses, and the intersection between them. A typical faculty information system database record includes Faculty data; ID, Name, Departments, Courses data; Course ID, Name, Description, Instructors data; ID, SSN (Social Security Number), Name, Age, Gender, Address (Street, City, Country), Email, Username, Password, DOB (Date Of Birth), Faculty, Year, Department; and Employees data; same as instructor's data with customized data about job.

Library Information System

The Library Information System is responsible for managing and automating libraries within the university. The system database record reflects the managerial tasks performed by librarians in order to effectively manage libraries. A typical Library Information System record will include Book ISBN, Name, Author(s), Keyword(s), and data like Section, List of all the books, List of books available, List of borrowed books, who is borrowing, when they should return, etc.

Finance System

Finance system is responsible for managing financial issues related the university. A typical Finance System record will include tuition, salary and other financial data relevant to the university's professional activities.

The UMIS system proposed as figure 2 has met most the goals of a UMIS such as: containing information about learners, lecturers, managers, training facilities, information on professional activities, finance and decision support for all levels of management. However, the system specification is still not specific, some subsystems have not fully demonstrated its function. For example, in a student management system, detailed records of what learners have already learned (at the level of learning objects, rather than a module or program), course registration new, the portfolio of skills development has not been clearly described. In the current context, when online learning becomes popular, it not only exists in parallel but in certain cases (e.g., epidemics, disasters,) has replaced face-to-face learning. Thus, when building the UMIS in particular and the educational information management system in general, the online learning management system can be organized as a component of the system or in each component system required contains the information and transaction supported for online training management.

2.1.4. The cycle of building a university information management system.

A UMIS is also a MIS, thus the process of building a university information management system is similar to the process of management information system. This problem given by O'Brien et al who explained a five-step process called the information development cycle, which includes the steps of: investigation, analysis, design, implementation and maintenance [9]. Dr. Abzetdin Adamov, Chief Information Officer, Head of Computer Engineering Department, in the presentation about University

Management Information System sited the implementation of a UMIS includes problem recognition, investigation requirement determination, system design, development and construction, implementation, evaluation and evolution. Similarly, to, Nguyen Van Ba has specified the system development cycle includes the following phases [1]:

Phase 1: Survey and evaluate the current situation: This phase is also known as problem recognition and investigation. The aims of this phase are:

- Approach the expertise and the operating environment of the current system.
- Research the functions, tasks, and how the current system works.
- Indicate the advantages that need to be inherited and the disadvantages of the whole system that need to be studied and overcome.

Phase 2: Requirement determination

In this phase, requirements of new system need cited clearly. It includes following works:

- Determine the scope of the new system (the system is for the whole organization or only involves a few departments, covers the entire management or only deals with a few specific management tasks).
- Define goals and priorities of the new system. The goals are Business benefits: increase processing capacity, meet business requirements, accurate, safe and confidential; Economic benefits: reduced staffing, reduced operating costs, increased income; Benefits of use: fast, convenient; Overcoming the disadvantage of the older system: supporting long-term development strategy, meeting imposed priorities and constraints. The priorities are constraints on system architecture, on equipment usage, on cost, location and implementation timeline.
- Outline the solution and consider the feasibility: The solution current step is the raw level, including Main functions of the system: input, output, key methods to meet user requirements; Overall knowledge of the system, including software architecture (subsystems, main modules.) and hardware architecture (network, computers, other devices.). The feasibility can be considered on professional feasibility (Providing the right necessary business information on time of request), technically feasible (The responsiveness of technical requirements) and economically feasible (The responsiveness of economic solution).

Phase 3: System analysis of functions and data

The objectives of this phase are functional models and the conceptual schema of data. Functional models of the system describe the work the system does. There are some models and means of describing the function, for example: functional diagrams, system flowcharts, data flow diagrams. The conceptual schema of the data is established according to the entity relationship model (E/R) and then completed according to the relational model.

Phase 4. System design

This phase makes the system implementation decisions that meet the given requirements in phase 2, phase 3, as well as adapting to the current conditions. The outputs of this phase are the overall system architecture, interface of information exchange, control and security, physical database, and modular system.

Phase 5. System installation

The installation phase consists of two main tasks: programming and testing. The result of this stage is that the system is executable. System testing requires a test plan that consists of several key activities and steps for programs, system, and user acceptance testing.

Phase 6. Implementation, evaluation and maintenance

In this phase, the system is used by the end users. Sometime, the system is put into a Beta stage where users' feedback is received and based on the feedback, the system is corrected or improved before a final release or official release of the system. Maintenance is necessary to eliminate the errors in the working system during its working life and to tune the system to any variation in its working environment. Some small defects of the system are found, then changes are made to remove them. The system planner must always plan for resource availability to carry on these maintenance functions.

3. CONCLUSION

The findings of this paper clearly show that a MIS is very necessary for an organization/enterprise. The system gathers data from a range of sources, compile and present it in an appropriate form. MIS helps managers at all levels, in all functions create reports that provide them a comprehensive overview of all the information. It also enables them to make timely and effective decisions for planning, directing and controlling the activities for which they are responsible.

The business information on the modern organizations, especially university has become quite enormous and challenging then requires a UMIS. All of the data relevant to the university are collected, organized, managed and processed that can be shared within the university’s departments. They are also used by managers at all levels to take the beneficial decisions for the university.

The building a UMIS is a cycle comprises phases: Survey and evaluate the current situation, requirement determination, system analysis of functions and data, system design, system installation and implementation, evaluation and maintenance. The building at UMIS is a cycle, this means that, these phases are not done linearly, they can go back and forth many times. For example, some defects are discovered during a testing in the installation phase, the corresponding analysis or design phase is reviewed and corrected.

In addition, the preparation of infrastructure, technology, human resources are also an important factor determining the success of UMIS implementation. The issue of training, development and use of available human resources should be carefully considered in the UMIS documents.

REFERENCES

1. Gabriel, J. M. O. (2013), *The Systems Concept: An unpublished Lecture note giving to B.sc year 3 Students of Faculty of Management Sciences*, Rivers State University of Science and Technology, Port Harcour.
2. Hazem M. El-Bakry and Nikos E Mastorakis, *E-learning and management information systems for E-universities,* Available at https://www.researchgate.net/ on 28 April 2015, accessed on 15, May 2021.
3. Kumar, P. K. (2006), *Information Systems Decision-Making*, Available at http://www.indianmba.com/ on 12 October 2006, accessed 1 May 2021.
4. Nguyễn Văn Ba (2009), *Phân tích và thiết kế hệ thống thông tin,* Nxb. Đại học Quốc gia Hà Nội.
5. Obrien et al (2010), *Introduction to Information Systems,* Publisher: McGraw-Hill/Irwin.
6. Ottih, L. O. (1995), *Management Information Systems*, Owerri: New African.
7. Pride et al (2018), *Foundations of Business,* Publisher: Cengage Learning International Edition ISBN-13: 978-1-337-38692-0, ISBN: 1-337-38692-8
8. Terry Lucey (2004), *Management Information Systems*, Publisher: Cengage Learning EMEA.
9. UNESCO (2008), *Education for All by 2015: will we make it?*, Publisher: Oxford University.

KHÁI QUÁT VỀ HỆ THỐNG THÔNG TIN QUẢN LÝ

Tóm tắt: *Bài báo trình bày tổng quan về hệ thống quản lý thông tin trường đại học (UMIS). Hệ thống thông tin quản lý (MIS) cung cấp thông tin cần thiết cho việc quản lý, điều hành của một tổ chức / doanh nghiệp. Trường đại học là một tổ chức giáo dục cần có UMIS để tăng hiệu quả trong việc thực hiện và quản lý các hoạt động chuyên môn giáo dục. Cấu trúc và chu trình xây dựng một UMIS cũng được trình bày trong bài báo này. Kết quả của nghiên cứu này cung cấp một phương pháp hữu ích để xây dựng và triển khai thành công UMIS trong trường đại học.*

Từ khóa: *Quản lý, Thông tin, Hệ thống, Hệ thống Thông tin Quản lý (MIS), trường đại học, hệ thống thông tin quản lý trường đại học (UMIS), ra quyết định, chu trình hệ thống.*

INVESTIGATION OF NONLINEAR ABSORPTION OF STRONG ELECTROMAGNETIC WAVE IN TWO - DIMENSIONAL GRAPHENE BY USING QUANTUM KINETIC EQUATION METHOD

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Abstract: *Quantum theory of nonlinear absorption of strong electromagnetic wave (EMW) by confined electrons in two - dimensional (2D) graphene without magnetic field has been studied by using the quantum kinetic equation in assumption of electron - optical phonon scattering. The analytic expression of absorption coefficient is obtained in 2D graphene. The results in this case are compared with the case of the bulk semiconductors show the difference and the novelty of the results. The results numerically calculated and plotted show the dependence of absorption coefficient on the photon energy of the electronmagnetic wave and the temperature of the system in 2D graphene.*

Keywords: *Absorption coefficient, Quantum kinetic equation, 2D Graphene, confined electron, Electron - phonon scattering, Electromagnetic wave.*

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1. INTRODUCTION

Quite recently, there has been considerable interest in the behavior of low-dimensional systems, in particular, new two dimensional electron gas (2DEG) systems such as quantum wells, superlattices, silence,… Specially, graphene, as a perfect two-dimensional electron gas (2DEG) system, has been extensively studied both experimentally and theoretically . Since the discovery in 2004 [1] Graphene , it is composed of a single layer of carbon atoms in two dimensional (2D) honeycomb lattice and a unit cell that contains two carbon atoms. Futhermore, electrons in Graphene show relativistic behavior and can be viewd as massless charged fermions in 2D space [1, 2] such as photons or neutrinos. We are aware that although many efforts have been reported to explain different properties of Graphene using a linear response method [3], a detailed consideration of the EMW absorption in Graphene is still

lacking. Therefore, studying the absorption effect is timely and expected to increase our understanding of this new interesting 2D material.

In this paper we theoretically study the nonlinear absorption of strong electromagnetic wave (EMW) in 2D Graphene without magnetic field by using quantun kinetic equation method. We will consider the problem in case of the system is subjected to an EMW with the electric field vector $E = E_0 \sin \Omega t$ (E_0 and Ω are the amplitude and the frequency, respectively). The results show that the 2D Graphene has various characteristic behaviors different from traditional 2D systems such as quantum well, doped superlattice, … [4, 5]. The purpose of this paper is to give clearity expression of nonlinear absorption coefficient EMW in 2D Graphene.

The paper is organized as follows: In the next section we outline a quantum kinetic equation for electrons confined in 2D Graphene. The analytical expression for the nonlinear absorption coefficient in the case of the electron – optical phonon interaction is obtained in Sec. III. The numerical results and brief review are presented in Sec. IV. Finally, conclusions are given in Sec. V.

2. QUANTUM KINETIC QUATION FOR ELECTRONS IN 2D GRAPHENE

2.1. Electron structure and Hamiltonian of the electron – phonon system in 2D Graphene without magnetic field

In this report, we use quantum kinetic equation method to obtain nonlinear absorption coefficient in 2D Graphene in the presence of electromagnetic wave. We consider a 2D Graphene subjected to plane (x – y). The wave function and the corresponding energy [3] are given by the formula below:

$$\Psi_{n,\mathbf{k}}(\mathbf{r}) = \frac{1}{L\sqrt{2}} \begin{bmatrix} e^{-i\theta_{\mathbf{k}}} \\ n \end{bmatrix} \exp(i\mathbf{k}\cdot\mathbf{r}) \tag{1}$$

With L^2 is the area of the system, $n = +1$, and -1 denote the conduction and valence bands, respectively, and

$$k_x = k\cos\theta_{\mathbf{k}} \quad k_x = k\sin\theta_{\mathbf{k}} \quad k = \sqrt{k_x^2 + k_y^2} \tag{2}$$

The corresponding energy is given by

$$\varepsilon_{n,\mathbf{k}} = n\gamma k \tag{3}$$

With $\gamma = 6.46\text{eV}.\overset{0}{\text{A}}$ is a band parameter.

The Hamiltonian of the electron – optical phonon system in 2D Graphene in the second quantization presentation can be written as:

$$\mathrm{H} = \sum_{n,\mathbf{k}} \varepsilon_{n,\mathbf{k}} \left(\mathbf{k} - \frac{e}{c}\mathbf{A}(t) \right) a^{+}_{n,\mathbf{k}} a_{n,\mathbf{k}} + \sum_{\mathbf{q}} \hbar\omega_{\mathbf{q}} \left(b^{+}_{\mathbf{q}} b_{\mathbf{q}} + \frac{1}{2} \right) + \sum_{n,n'} \sum_{\mathbf{k},\mathbf{q}} C(\mathbf{q}) a^{+}_{n,\mathbf{k}+\mathbf{q}} a_{n,\mathbf{k}} \left(b^{+}_{\mathbf{q}} + b_{\mathbf{q}} \right) \tag{4}$$

where: $\varepsilon_{n,\mathbf{k}}$ is energy of electron (3), $\mathbf{k},\mathbf{q}$ respectively are wave vectors of electron, phonon, $|n,\mathbf{k}\rangle, |n',\mathbf{k}+\mathbf{q}\rangle$ are electron states before and after scattering, respectively. $a^+_{n,\mathbf{k}}, a_{n,\mathbf{k}}\left(b^+_{\mathbf{q}}, b_{\mathbf{q}}\right)$ are the creation and annihilation operators of electron (phonon).

$|C(\mathbf{q})|^2 = \frac{\hbar D^2_{op}}{2\rho L^2 \omega_{\mathbf{q}}}$ is the electron - optical phonon interaction constant, $\rho = 7.7\times10^{-8}\text{g/cm}^2$ is mass density of 2D Graphene, $D_{op} = 1.4\times10^{-9}\text{eV/cm}$ is deformed potential of optical phonon.

2.2. Quantum kinetic equation for electrons in 2D Graphene

When a high-frequency electromagnetic wave is applied to the system in the y direction with electric field vector $\mathbf{E} = \mathbf{E}_0 \sin\Omega t$ (where $\mathbf{E}_0$ and Ω are the amplitude and the frequency of the electromagnetic wave), the quantum kinetic equation of average number of electron $f_{n,\mathbf{k}} = \left\langle a^+_{n,\mathbf{k}} a_{n,\mathbf{k}} \right\rangle_t$ is:

$$i\hbar \frac{\partial f_{n,\mathbf{k}}(t)}{\partial t} = \left\langle \left[a^+_{n,\mathbf{k}} a_{n,\mathbf{k}}, \mathrm{H} \right] \right\rangle_t . \tag{5}$$

Starting from the Hamiltonian (4) and using the commutative relations of the creation and the annihilation operators, we obtain the quantum kinetic equation for electrons in 2D Graphene :

$$\begin{aligned}\frac{\partial f_{n,\mathbf{k}}(t)}{\partial t} = -\frac{1}{\hbar^2}\sum_{n,n'}\sum_{\mathbf{k},\mathbf{q}}|C(\mathbf{q})|^2 \Big\{ & \Big[f_{n,\mathbf{k}}(t_1) N_{\mathbf{q}} - f_{n',\mathbf{k}+\mathbf{q}_y}(t_1)\left(N_{\mathbf{q}}+1\right)\Big] \\ & \times \exp\left[\frac{i}{\hbar}\left(\varepsilon_{n',\mathbf{k}+\mathbf{q}} - \varepsilon_{n,\mathbf{k}} - \hbar\omega_{\mathbf{q}}\right)(t-t_1) - \frac{ie}{m_e c}\int_{t_1}^{t} \mathbf{q}\cdot\mathbf{A}(t_2)\,dt_2 \right] \\ & - \Big[f_{n',\mathbf{k}+\mathbf{q}}(t_1)(t_1) N_{\mathbf{q}} - f_{n,\mathbf{k}}\left(N_{\mathbf{q}}+1\right)\Big] \\ & \times \exp\left[\frac{i}{\hbar}\left(\varepsilon_{n',\mathbf{k}+\mathbf{q}} - \varepsilon_{n,\mathbf{k}} - \hbar\omega_{\mathbf{q}}\right)(t-t_1) - \frac{ie}{m_e c}\int_{t_1}^{t} \mathbf{q}\cdot\mathbf{A}(t_2)\,dt_2 \right] \Big\}\end{aligned} \tag{6}$$

Where $\mathbf{A}(t) = \frac{\mathbf{E}_0 c}{\Omega}\cos\Omega t$ is vector potential, c being light velocity.

Obtaining explicit solutions from Eq. (6) is seen to be very difficult. In this paper, the first-order tautology approximation method is used to solve this equation. In detail, in Eq. (6), we use the approximation:

$$f_{n,\mathbf{k}}(t_1) \approx \overline{f}_{n,\mathbf{k}} \quad f_{n,\mathbf{k}+\mathbf{q}}(t_1) \approx \overline{f}_{n,\mathbf{k}+\mathbf{q}} \quad f_{n,\mathbf{k}-\mathbf{q}}(t_1) \approx \overline{f}_{n,\mathbf{k}-\mathbf{q}}$$

where $\overline{f}_{n,\mathbf{k}}$ is the time - independent component of the electron distribution function. The approximation is also applied for a similar exercise in bulk semiconductor [6, 7]. As the result, the expression for the unbalanced electron distribution function can be obtained :

$$f_{n,\mathbf{k}}(t)=\frac{1}{\hbar\Omega}\sum_{n,n'}\sum_{\mathbf{k},\mathbf{q}}\left|C(\mathbf{q})\right|^2\sum_{k,\ell=-\infty}^{+\infty}J_{k+\ell}\left(\frac{e\mathbf{E}_0\cdot\mathbf{q}}{m\Omega^2}\right)J_k\left(\frac{e\mathbf{E}_0\cdot\mathbf{q}}{m\Omega^2}\right)\frac{\exp\left(-i\ell\Omega t\right)}{\ell}$$
$$\times\left[\frac{\overline{f}_{n,\mathbf{k}}N_{\mathbf{q}}-\overline{f}_{n',\mathbf{k}+\mathbf{q}}\left(N_{\mathbf{q}}+1\right)}{\varepsilon_{n',\mathbf{k}+\mathbf{q}}-\varepsilon_{n,\mathbf{k}}-\hbar\omega_{\mathbf{q}}-\ell\hbar\Omega+i\hbar\delta}+\frac{\overline{f}_{n,\mathbf{k}}\left(N_{\mathbf{q}}+1\right)-\overline{f}_{n',\mathbf{k}+\mathbf{q}}N_{\mathbf{q}}}{\varepsilon_{n',\mathbf{k}+\mathbf{q}}-\varepsilon_{n,\mathbf{k}}+\hbar\omega_{\mathbf{q}}-\ell\hbar\Omega+i\hbar\delta}\right.$$
$$\left.+\frac{\overline{f}_{n',\mathbf{k}-\mathbf{q}}N_{\mathbf{q}}-\overline{f}_{n,\mathbf{k}}\left(N_{\mathbf{q}}+1\right)}{\varepsilon_{n,\mathbf{k}}-\varepsilon_{n',\mathbf{k}-\mathbf{q}}-\hbar\omega_{\mathbf{q}}-\ell\hbar\Omega+i\hbar\delta}-\frac{\overline{f}_{n',\mathbf{k}-\mathbf{q}}\left(N_{\mathbf{q}}+1\right)-\overline{f}_{n,\mathbf{k}}N_{\mathbf{q}}}{\varepsilon_{n,\mathbf{k}}-\varepsilon_{n',\mathbf{k}-\mathbf{q}}+\hbar\omega_{\mathbf{q}}-\ell\hbar\Omega+i\hbar\delta}\right] \quad (7)$$

where $N_{\mathbf{q}}$ is the time-independent component of the phonon distribution function, $J_k\left(x\right)$ is the Bessel function and the quantity δ is infinitesimal and appears due to the assumption of an adiabatic interaction of the electromagnetic wave.

2.3. The nonlinear absorption coefficient of strong electromagnetic wave in 2d graphene

The carrier current density formula in 2D Graphene takes the form :

$$\mathbf{J}\left(t\right)=\frac{e\hbar}{m}\sum_{n,\mathbf{k}}\left[\mathbf{k}-\frac{e}{\hbar c}\mathbf{A}\left(t\right)\right]f_{n,\mathbf{k}}\left(t\right) \quad (8)$$

Because the motion of electrons is confined along the z direction in a 2D Graphene, we only consider the in plane (x, y) current density vector of electrons $\mathbf{J}\left(t\right)$. Substituting Eq. (7) into Eq. (8), we find the expression for current density vector:

$$\mathbf{J}\left(t\right)=-\frac{e^2\mathbf{E}_0n_0}{m_e\Omega}\cos\Omega t+\mathbf{J}_0\left(t\right) \quad (9)$$

here:

$$\mathbf{J}_0\left(t\right)=-\frac{e}{m_e\Omega}\sum_{n,n'}\sum_{\mathbf{k},\mathbf{q}}\left|C(\mathbf{q})\right|^2\mathbf{q}\cdot N_{\mathbf{q}}\sum_{k,\ell=-\infty}^{+\infty}J_{k+\ell}\left(\frac{e\mathbf{E}_0\cdot\mathbf{q}}{m\Omega^2}\right)J_k\left(\frac{e\mathbf{E}_0\cdot\mathbf{q}}{m\Omega^2}\right)\frac{\exp\left(-i\ell\Omega t\right)}{\ell}$$
$$\times\left[\frac{\overline{f}_{n',\mathbf{k}+\mathbf{q}}}{\varepsilon_{n',\mathbf{k}+\mathbf{q}}-\varepsilon_{n,\mathbf{k}}-\hbar\omega_{\mathbf{q}}-k\hbar\Omega}+\frac{\overline{f}_{n',\mathbf{k}+\mathbf{q}}}{\varepsilon_{n',\mathbf{k}+\mathbf{q}}-\varepsilon_{n,\mathbf{k}}+\hbar\omega_{\mathbf{q}}-k\hbar\Omega}\right.$$
$$\left.+\frac{\overline{f}_{n',\mathbf{k}-\mathbf{q}}}{\varepsilon_{n,\mathbf{k}}-\varepsilon_{n',\mathbf{k}-\mathbf{q}}-\hbar\omega_{\mathbf{q}}-k\hbar\Omega}-\frac{\overline{f}_{n',\mathbf{k}-\mathbf{q}}}{\varepsilon_{n,\mathbf{k}}-\varepsilon_{n',\mathbf{k}-\mathbf{q}}+\hbar\omega_{\mathbf{q}}-k\hbar\Omega}\right] \quad (10)$$

And $\sum_{n,\mathbf{k}} f_{n,\mathbf{k}}(t) = n_0$ is electron density of 2D Graphene.

By using the electron - optical phonon interaction factor in Eq. (4) and the Bessel function [8, 9], from the expression for the current density vector Eq. (10) we establish the nonlinear absorption coefficient of the electromagnetic wave :

$$\begin{aligned}\alpha &= \frac{8\pi}{c\sqrt{\chi_\infty}E_0^2}\left\langle \mathbf{J}(t)\cdot\mathbf{E}_0 \sin\Omega t\right\rangle_t \\ &= \frac{8\pi^2\Omega}{c\sqrt{\chi_\infty}E_0^2}\sum_{\mathbf{q}}\left|C(\mathbf{q})\right|^2 N_{\mathbf{q}} \sum_k kJ_k^2\left(\frac{e\mathbf{q}\cdot\mathbf{E}_0}{m_e\Omega^2}\right)\sum_{n',n,\mathbf{k}}\overline{f}_{n,\mathbf{k}}(t)\delta\left(\varepsilon_{n',\mathbf{k}+\mathbf{q}}-\varepsilon_{n,\mathbf{k}}+\hbar\omega_{\mathbf{q}}-k\hbar\Omega\right)\end{aligned} \tag{11}$$

where $\langle X\rangle_t$ means the usual thermodynamic average of X at moment t, and χ_∞ is the high-frequency dielectric constants, $\delta(x)$ is the Dirac delta function. For simplicity, in this paper, we limit the problem to the cases of $k = 0, \pm 1$, this means that the processes with more than one photon are ignored:

$$J_{\pm1}\left(\frac{e\mathbf{q}\cdot\mathbf{E}_0}{m_e\Omega^2}\right) = \frac{1}{4}\left(\frac{e\mathbf{q}\cdot\mathbf{E}_0}{m_e\Omega^2}\right)^2 \tag{12}$$

When the temperature of the system is high (T > 50K), the electron – optical phonon interaction is higher than other interactions. In this case, electron gas is assumed that non-generated gas and abided by the Maxwell – Boltzmann distribution. Let assume that phonon is not dispersive means is the optical phonon frequency non-dispersion:

$$\hbar\omega_{\mathbf{q}} = \hbar\omega_0 \quad N_{\mathbf{q}} = \frac{k_B T}{\hbar\omega_0} \tag{13}$$

After some calculation, we find the expression for absorption coefficient:

$$\alpha = \frac{e^2 n_0 D_{op}^2 k_B T}{8c\sqrt{\chi_\infty}\rho\omega_0^2\Omega^3 m_e^2\gamma}\exp\left(\frac{\hbar\Omega-\hbar\omega_0}{2k_B T}\right)\int_0^{+\infty} q^2\exp\left(-\frac{\gamma q}{2k_B T}\right)dq \tag{14}$$

We use the integral results in [9]:

$$\int_0^{+\infty} x^n \exp(-\mu x)\,dx = n!\,\mu^{-n-1} \tag{15}$$

Finally, inserting (15) into (14) we find the explicit expression for the absorption coefficient is written as:

$$\alpha = \frac{16 n_0 e^2 D_{op}^2 (k_B T)^7}{c\sqrt{\chi_\infty}\rho\omega_0^2\Omega^3\gamma^7 m_e^2}\exp\left(\frac{\hbar\Omega-\hbar\omega_0}{2k_B T}\right) \tag{16}$$

As one can see, Eq. (16) is more simple than traditional two dimensional semiconductors, it depends only on the temperature of the system and the energy photon (

$\hbar\Omega$) of electromagnetic wave. In the following, we will give physical conclusions to above results by carrying out a numerical evaluation and a graphic consideration using a computational method.

2.3. Numerical results and discussion

In this section, we give a deeper insight to the absorption coefficient for the case of a special 2D Graphene. For this section, the parameters used in computational calculations are as follows [1, 5] in Table I:

Table 1. The parameters

Symbols	Units	Values
ρ	g/cm^2	7,7.10^{-8}
D_{op}	eV/cm	1,4.10^{-9}
k_B	J/K	1,3807.10^{-23}
$\hbar\omega_o$	meV	162
c	m/s	3.10^8
$\hbar$	J.s	1,05459.10^{-34}
χ_∞		10,9
γ	eV. $\overset{o}{A}$	6,46
n_0		10^{12}

2.4. The dependence of absorption coefficient on temperature

The effect of temperature on the absorption coefficient due to optical phonon scattering is illustrated in Fig. 1. As can be seen from this figure that the absorption coefficient α depends strongly and non-linearly on temperature of the system.

We can see that absorption coefficient reaches at the saturated value in the low-temperature regime and increases quickly when temperature is high (T > 100K). This is in good agreement with previous results by using similar method in other two-dimensional systems [11, 12, 13]. This coefficient absorption is the same as the results which gained in bulk semiconductors [6, 7]. In addition, we survey influent of EMW on absorption

coeffiecient in 3 diffient single values of photon energy, it can be obviously seen that when photon energy increases the absorption coefficient value move up as the same tendency [11].

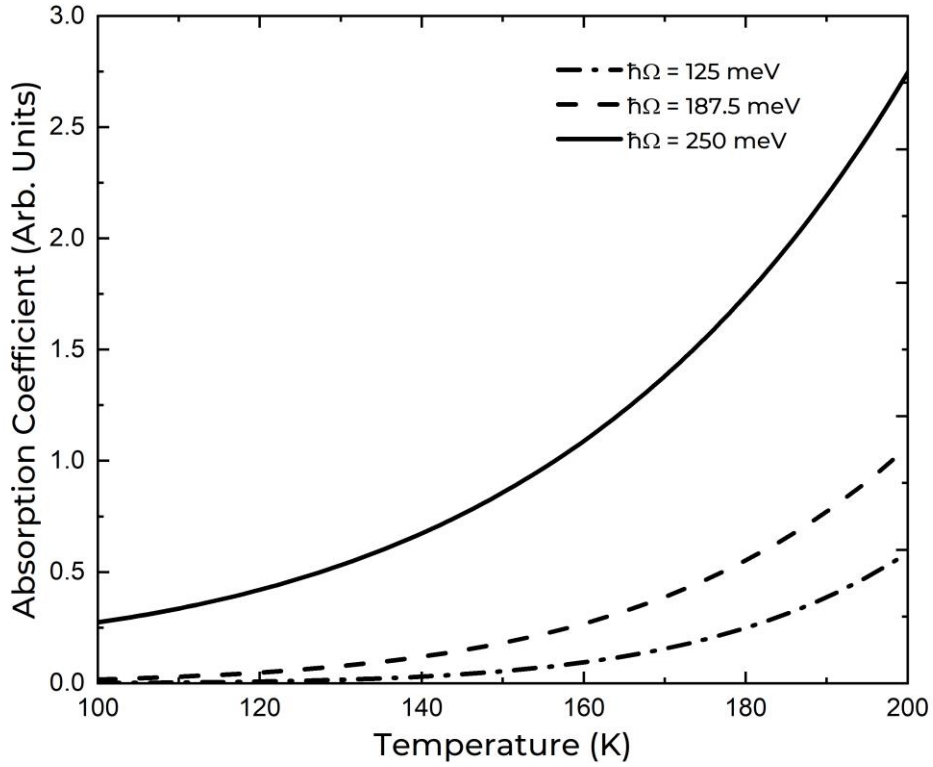

Fig. 1. The dependence of α on T at 3 diffirent values of photon energy $\hbar\Omega$

2.5. The dependence of absorption coefficient on photon energy

In order to analyse the physical expression of absorption coefficient in system parameters, we investigate and graph the influence of absorption coefficient on photon energy and 3 different cases of Temperture. The solid line means the highest temperature value case (T=220K), the dotted-line stands for the lowest temperature value case (T=180K) and the one case left is dashed-line (T=190K). We can easily obtain that the absorption coefficient goes up gradually as the Temperature rises. Then, when the photon energy stays in low value domain, the 3-line graph chance to one curve which mean the absorption coefficient is independent from the temperature when low photon energy.

Furthermore, also in considering of low photon energy regime, the absorption coefficient graph is almost linear line. The above analysis is the physical expression of absorption coefficient in photon energy and temperature. This is diffirent from that for Quantum Wells – another 2D system [11] (in Quantum Wells, the absorption coefficient reaches one maximun peak). This results from the difference between the electron structure of Graphene and Quantum Wells. This prediction would give a good suggestion for further experiments in the future. We can use this effect as one of the criteria for 2D Graphene

fabrication technology.

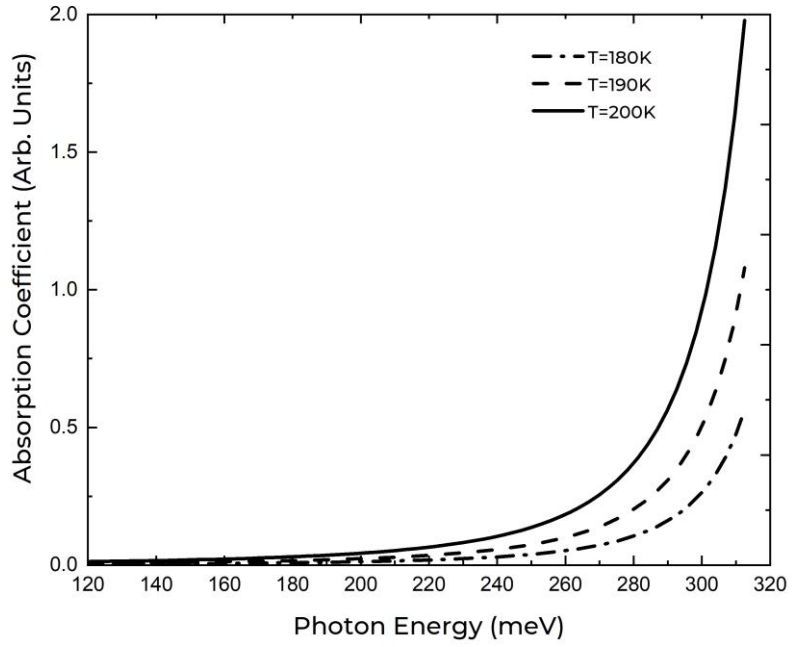

Fig. 2. The dependence of α on photon energy at 3 diffirent values of temperature.

3. CONCLUSION

In this work, we have studied the linear absorption coefficient, as well as the differences in monolayer Graphene in the presence of an external electromagnetic wave. By using Quantum Kinetic Equation method, we obtained the expression of the absorption coefficient due to the propagation of EMW in system, which can be changed by the photon energy of external EMW and the temperature of system. An strong increase of absorption coefficient towards higher temperature domain. In addition, the results show the dependence of the absorption coefficient on photon energy is quite strong in high temperature range. These theoretical results show a potential of 2D Graphene as a new two – dimensional material gas for designing nano-electronic and optical devices as a promising alternative to other traditional semiconductors.

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REFERENCES

1. Bau Quang Nguyen, Hung Manh Do and Ngoc Bich Nguyen (2009), "Nonlinear Absorption Coefficient of a Strong Electromagnetic wave caused by confined Electrons in Quantum Wells", *J. Kor. Phys. Soc.*, Vol. 54, No. 2, pp. 765-773.
2. E. M. Epstein (1975), *Sov. Communicacattion of HEE of USSR*, Ser, p.785.
3. H. B. Dwight (2006), *Tables of Integrals and Other Mathematical Data.*, Vol. 50, JSTOR.

4. N. Q. Bau and T. C. Phong (1998), "Calculations of the absorption coefficient of a weak emw by free carriers in quantum wells by the kubo-mori method", *J. Phys. Soc. Jpn*.
5. N. Q. Bau, N. V. Nhan, and T. C. Phong (2002), "Calculations of the absorption coefficient of a weak electromagnetic wave by free carriers in doped superlattices by using the Kubo-Mori method", *J. Kor. Phys. Soc.*, p.149.
6. Nguyen Quang Bau and Nguyen Thi Thanh Nhan (2014), "Negative Absorption Coefficient of a weak Electromagnetic Wave caused by electrons confined in Rectangular Quantum Wires in the presence of Laser Radiation", *J. Kor. Phys. Soc.*, Vol.64, No.4, pp. 572-578.
7. Novoselov, K. S. et al (2005), "Two-dimensional gas of massless Dirac fermions in graphene", *Nature.*, Vol 438, pp. 197–200.
8. Novoselov, K.S., A. K. Geim, S. V. Morosov, D. Jiang, Y. Zhang and S. V. Dubonos (2004), "Electric Field Effect in Atomically Thin Carbon Films", *Science.*, Vol. 306, pp. 666.
9. T. Ando (2006), "Screeing Effect and Impurity Scattering in Monolayer Graphene", *J. Phys. Soc. Jpn*, Vol. 75, pp. 074716.
10. V. L . Malevich and E. M. Epstein (1974), *Sov. Quantum Electronic 1*, p.1468.

NGHIÊN CỨU VỀ HẤP THỤ PHI TUYẾN SÓNG ĐIỆN TỪ MẠNH TRONG GRAPHENE HAI CHIỀU BẰNG PHƯƠNG PHÁP PHƯƠNG TRÌNH ĐỘNG LƯỢNG TỬ

Tóm tắt: *Nghiên cứu lý thuyết lượng tử hấp thụ phi tuyến sóng điện từ mạnh (EMW) trong Graphene hai chiều (2D) bằng phương trình động lượng tử với giả thiết cơ chế tán xạ electron-phonon quang. Thu được biểu thức giải tích cho hệ số hấp thụ trong Graphene 2D. Các kết quả là mới mẻ và được so sánh với trường hợp trong bán dẫn thấp chiều truyền thống để thấy sự khác biệt. Kết quả thu nhận được tính toán số và vẽ đồ thị biểu thị sự phụ thuộc của hệ số hấp thụ vào năng lượng photon của sóng điện từ và nhiệt độ của hệ Graphene 2D.*

Từ khóa: *Hệ số hấp thụ, phương trình động lượng tử, 2D Graphene, electron giam cầm, tán xạ electron-phonon, sóng điện từ.*

THE INVESTIGATION OF NONLINEAR ABSORPTION OF STRONG ELECTROMAGNETIC WAVE IN GaAs/AlGaAs SEMI-PARABOLIC QUANTUM WELLS

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Abstract: *Quantum theory of nonlinear absorption of a strong electromagnetic wave (EMW) by confined electrons in asymmetric semi-parabolic quantum wells has been studied by using the quantum kinetic equation in assumption of electron - optical phonon scattering. The analytic expression of absorption coefficient is obtained in semi-parabolic quantum wells. The results in this case are compared with the case of the bulk semiconductors show the difference and the novelty of the results. The results numerically calculated for GaAs/AlGaAs in order to show the dependence of absorption coefficient on the photon energy of the temperature, the size of the asymmetric semi-parabolic quantum wells.*

Keywords: *Absorption coefficient, Quantum kinetic equation, asymmetric semi-parabolic quantum wells, electron - phonon scattering, electromagnetic wave.*

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1. INTRODUCTION

Quite recently, there has been considerable interest in the behavior of low-dimensional systems, since the motion of electrons is restricted,… The confinement potential of the system has changed the electron mobility significantly. The effect of electromagnetic wave absorption is an interesting topic for physicists. The absorption of electromagnetic wave in bulk semiconductor and low-dimensional system has been investigated [1]. The absorption of electromagnetic wave in two-dimensional system is calculated using the Kubo-Mori method [2],[3]. The absorption coefficient has been obtained using quantum kinetic method in low dimensional systems such as quantum wells, superlattices, quantum wires [4],[5]. In term of quantum wells, the potential confinement plays a crucial role in carrier characteristic such as the wave function and energy spectrum of the electron in the system. Considering each types of confinement potential, there are various researches and results obtained, such as infinite confinement potential [6],[7], parabolic confinement potential [8],[9]. Besides,

the semi-parabolic confinement potential quantum wells have not been investigated clearly. Therefore, we choose the asymmetric semi-parabolic quantum wells to calculate the nonlinear absorption of a strong electromagnetic wave using quantum kinetic method. The paper is calculated in case of electron-optical phonon scattering with the close to threshold condition. That is still open for study.

In this paper we theoretically study the nonlinear absorption of strong electromagnetic wave (EMW) in an asymmetric semi-parabolic quantum well without magnetic field by using quantum kinetic equation method. We will consider the problem in case of the system is subjected to an EMW with the electric field vector $E = E_0 \sin \Omega t$ (E_0 and Ω are the amplitude and the frequency, respectively. The problem is considered in case of electron-optical phonon scattering with the close to threshold limitation. The purpose of this paper is to show the analytical expression of nonlinear absorption coefficient strong electromagnetic wave in semi-parabolic quantum wells. Numerical calculations are carried out with GaAs/AlGaAs semi-parabolic quantum wells.

The report is separated into four sections as follows: The first one is the introduction of the report. In the next section we construct the quantum kinetic equation for electrons confined in asymmetric semi-parabolic quantum wells. The analytical expression for the nonlinear absorption coefficient in the case of the electron – optical phonon interaction is also presented in Sec. II. The numerical results and brief review are indicated in Sec. III. Finally, conclusions are given in Sec. V.

2. THEORETICAL FRAMEWORKS

2.1. Electronic structure in an asymmetric semi-parabolic quantum wells

We consider an asymmetric semi-parabolic quantum wells subjected to the (x-y) plane with the infinite semi-parabolic confinement potential can be written as

$$V(z) = \begin{cases} 1/2\, m^* \omega_p^2 z^2 & 0 \le z \le L \\ \infty & z < 0;\ z > L \end{cases}, \tag{1}$$

where m^* is the effective mass of the electron, ω_p is the frequency of the semi-parabolic potential in quantum wells and L is the well-width. z axis is the growth direction of the semi-parabolic quantum wells. The effective mass Hamiltonian for the electron in the system is given by $H_e = -\frac{\hbar^2}{2m^*}\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right) + V(z)$. The eigenfuntions and eigenenergies can be obtained by solving the Schrodinger equation for H_e [10][11].

$$\begin{cases} \psi_{n,k_\perp}(z) = \varphi_n(z) U_c(r) \exp\left(i k_\perp r_\perp\right) \\ \varepsilon_{n,k_\perp} = E_n + \hbar^2 / 2m^* . |k_\perp|^2 \end{cases}, \tag{2}$$

where $U_c(r)$ is the periodic part of the Bloch function, $k_\perp, r_\perp$ is the wave vector and

coordinate in the (x-y) plane ($k_\perp = \sqrt{k_x^2 + k_y^2}$ and $r_\perp = \sqrt{r_x^2 + r_y^2}; r = \sqrt{r_\perp^2 + r_z^2}$). Besides, $\varphi_n(z)$ and E_n are the solutions of the one-dimensional Schrodinger equation $H_z\varphi_n(z) = E_n\varphi_n(z)$ as

$$\begin{cases} \varphi_n(z) = \sqrt{1/\beta\sqrt{\pi}2^{2n}(2n+1)!}\exp\left(-1/2\beta^2 z^2\right)H_{2n+1}(\beta z) \\ E_n = (2n+3/2)\hbar\omega_p \end{cases}, \quad (3)$$

where $\beta = \sqrt{m^*\omega_p/\hbar}$, $H_{2n+1}(\beta z)$ is the Hermite function and $n = 0,1,2,...$ refers to quantum index.

2.2. Quantum kinetic equation for electrons in asymmetric semi-parabolic quantum wells

The Hamiltonian of the electron – optical phonon system in asymmetric semi-parabolic quantum wells in the second quantization presentation can be written as:

$$\begin{aligned} H = &\sum_{n,\mathbf{k}_\perp} \varepsilon_{n,\mathbf{k}_\perp}\left(\mathbf{k}_\perp - \frac{e}{c}\mathbf{A}(t)\right)a^+_{n,\mathbf{k}_\perp}a_{n,\mathbf{k}_\perp} + \sum_{\mathbf{q}}\hbar\omega_{\mathbf{q}}\left(b^+_{\mathbf{q}}b_{\mathbf{q}} + \frac{1}{2}\right) \\ &+ \sum_{n,n'}\sum_{\mathbf{k}_\perp,\mathbf{q}} C(\mathbf{q})I_{n,n'}(q_z)a^+_{n,\mathbf{k}_\perp+\mathbf{q}}a_{n,\mathbf{k}_\perp}\left(b^+_{\mathbf{q}} + b_{\mathbf{q}}\right) \end{aligned} \quad (4)$$

where $\varepsilon_{n,\mathbf{k}_\perp}$ is energy of electron (2), $\mathbf{k}_\perp, \mathbf{q}$ respectively are wave vectors of electron, phonon, $|n,\mathbf{k}_\perp\rangle, |n',\mathbf{k}_\perp+\mathbf{q}\rangle$ are electron states before and after scattering, respectively. $a^+_{n,\mathbf{k}_\perp}, a_{n,\mathbf{k}_\perp}\left(b^+_{\mathbf{q}}, b_{\mathbf{q}}\right)$ are the creation and annihilation operators of the electron (phonon). $|C(q)|^2 = \frac{2\pi e^2\hbar\omega_o}{V_o\kappa\mathbf{q}^2}\left(\frac{1}{\chi_\infty} - \frac{1}{\chi_0}\right)$ is the electron - optical phonon interaction constant. Here, e, ω_o, V_o, κ refer to the electron charge, optical phonon frequency, the normalized volume and deformation potential constant of the quantum wells, respectively. χ_∞ and χ_0 are the high and static-frequency dielectric constants. $\mathbf{A}(t)$ is the vector potential of an electromagnetic wave. $I_{n,n'}(q_z)$ is the form factor in the semi-parabolic quantum wells is given as follow

$$I_{n,n'}(q_z) \equiv I_{n,n'} = \frac{2}{L}\int_0^L \psi^*_n(z)\psi_{n'}(z)\exp(iq_z z)dz, \quad (5)$$

When a high-frequency electromagnetic wave is applied to the system in the y direction with electric field vector $\mathbf{E} = \mathbf{E}_0\sin\Omega t$ (where $\mathbf{E}_0$ and Ω are the amplitude and the frequency of the electromagnetic wave), the quantum kinetic equation of average number of electron $f_{n,\mathbf{k}_\perp} = \left\langle a^+_{n,\mathbf{k}_\perp}a_{n,\mathbf{k}_\perp}\right\rangle_t$ is:

$$i\hbar\frac{\partial f_{n,\mathbf{k}_\perp}(t)}{\partial t}=\left\langle\left[a^{+}_{n,\mathbf{k}_\perp}a_{n,\mathbf{k}_\perp},H\right]\right\rangle_t, \tag{6}$$

Starting from the Hamiltonian (4) and using the commutative relations of the creation and the annihilation operators, we obtain the quantum kinetic equation for electrons in semi-parabolic quantum wells:

$$\begin{aligned}f_{n,\mathbf{k}_\perp}(t)=&\frac{1}{\hbar\Omega}\sum_{n,n'}\sum_{\mathbf{k}_\perp,\mathbf{q}}\left|C(\mathbf{q})\right|^2\sum_{k,\ell=-\infty}^{+\infty}J_{s+\ell}\left(\frac{e\mathbf{E}_0\cdot\mathbf{q}}{m\Omega^2}\right)J_s\left(\frac{e\mathbf{E}_0\cdot\mathbf{q}}{m\Omega^2}\right)\frac{\exp(-i\ell\Omega t)}{\ell}\\&\times\left[\frac{\bar{f}_{n,\mathbf{k}_\perp}N_{\mathbf{q}}-\bar{f}_{n',\mathbf{k}_\perp+\mathbf{q}}(N_{\mathbf{q}}+1)}{\varepsilon_{n',\mathbf{k}_\perp+\mathbf{q}}-\varepsilon_{n,\mathbf{k}\perp}-\hbar\omega_{\mathbf{q}}-\ell\hbar\Omega+i\hbar\delta}+\frac{\bar{f}_{n,\mathbf{k}_\perp}(N_{\mathbf{q}}+1)-\bar{f}_{n',\mathbf{k}_\perp+\mathbf{q}}N_{\mathbf{q}}}{\varepsilon_{n',\mathbf{k}_\perp+\mathbf{q}}-\varepsilon_{n,\mathbf{k}_\perp}+\hbar\omega_{\mathbf{q}}-\ell\hbar\Omega+i\hbar\delta}\right.\\&\left.+\frac{\bar{f}_{n',\mathbf{k}_\perp-\mathbf{q}}N_{\mathbf{q}}-\bar{f}_{n,\mathbf{k}_\perp}(N_{\mathbf{q}}+1)}{\varepsilon_{n,\mathbf{k}_\perp}-\varepsilon_{n',\mathbf{k}_\perp-\mathbf{q}}-\hbar\omega_{\mathbf{q}}-\ell\hbar\Omega+i\hbar\delta}-\frac{\bar{f}_{n',\mathbf{k}_\perp-\mathbf{q}}(N_{\mathbf{q}}+1)-\bar{f}_{n,\mathbf{k}_\perp}N_{\mathbf{q}}}{\varepsilon_{n,\mathbf{k}_\perp}-\varepsilon_{n',\mathbf{k}_\perp-\mathbf{q}}+\hbar\omega_{\mathbf{q}}-\ell\hbar\Omega+i\hbar\delta}\right]\end{aligned} \tag{7}$$

where $N_{\mathbf{q}}$ is the time-independent component of the phonon distribution function, $J_s(x)$ is the Bessel function and the quantity δ is infinitesimal and appears due to the assumption of an adiabatic interaction of the electromagnetic wave.

2.3. The nonlinear absorption coefficient of strong electromagnetic wave in asymmetric semi-parabolic quantum wells

The carrier current density formula in semi-parabolic quantum wells takes the form :

$$\mathbf{J}_\perp(t)=\frac{e\hbar}{m^*}\sum_{n,\mathbf{k}_\perp}\left[\mathbf{k}_\perp-\frac{e}{\hbar c}\mathbf{A}(t)\right]f_{n,\mathbf{k}_\perp}(t), \tag{8}$$

Because the motion of electrons is confined along the z direction in quantum wells, we only consider the in plane (x-y) current density vector of electrons $\mathbf{J}(t)$. By using the electron - optical phonon interaction factor in Eq. (4) and the Bessel function, from the expression for the current density vector Eq. (8) we establish the nonlinear absorption coefficient of the electromagnetic wave:

$$\alpha=\frac{8\pi}{c\sqrt{\chi_\infty}E_0^2}\left\langle\mathbf{J}(t)\cdot\mathbf{E}_0\sin\Omega t\right\rangle_t, \tag{9}$$

where $\delta(x)$ is the Dirac delta function. When the temperature of the system is high (T > 50K), the electron – optical phonon interaction is higher than other interactions. We consider the electron gas to be non-degenerate $\bar{f}_{n,k_\perp}=f_o^*\exp\left(\frac{\varepsilon_{n,k_\perp}}{k_BT}\right)$ with

$f_o^* = \dfrac{f_o e^{3/2}\pi^{3/2}\hbar^3}{V_o m^{*3/2}(k_B T)^{3/2}}$. Let assume that phonon is not dispersive means is the optical phonon frequency non-dispersion: $\hbar\omega_{\mathbf{q}} = \hbar\omega_0$ and $N_{\mathbf{q}} = \dfrac{k_B T}{\hbar\omega_0}$.

After some calculation, we obtain the expression for absorption coefficient:

$$\alpha = \frac{e^2 f_o^* (k_B T)^2}{4\pi c\sqrt{\chi_\infty}\rho\omega_p^2\Omega^3 m^{*2} d}\left(\frac{1}{\chi_\infty}-\frac{1}{\chi_0}\right)\sum_{n,n'}\left|I_{n,n'}\right|^2$$
$$\times\left\{\left[\exp\left(\frac{\hbar\Omega-\hbar\omega_0}{2k_B T}\right)-1\right]\left[\frac{3e^2E_0^2k_B T}{8m^{*2}\Omega^4}\left[\frac{\omega_0-\Omega}{2k_B T}+\frac{\pi^2\left(n'^2-n^2\right)}{2m^* d^2}+1\right]+1\right]\right. \quad , \quad (10)$$
$$\left.+\left[\exp\left(\frac{\hbar\Omega+\hbar\omega_0}{2k_B T}\right)-1\right]\left[\frac{3e^2E_0^2k_B T}{8m^{*2}\Omega^4}\left[-\frac{\omega_0+\Omega}{2k_B T}+\frac{\pi^2\left(n'^2-n^2\right)}{2m^* d^2}+1\right]+1\right]\right\}$$

Eq. (10) is different compared to the symmetric parabolic quantum wells case, due to the analytical difference in eigenfuntions Ψ and eigenenergies ε which are characterized of the potential confinement in asymmetric semi-parabolic quantum wells. In the following, we will give physical conclusions to above results by carrying out a numerical evaluation and a graphic consideration using a computational method.

2.4. Numerical results and discussion

In this section, we give a deeper insight to the absorption coefficient for the case of a specific GaAs/AlGaAs asymmetric semi-parabolic quantum wells. For this section, the parameters used in computational calculations are as follows [2, 3].

2.4.1. The dependence of absorption coefficient on temperature

The dependence of absorption coefficient on temperature of the quantum well due to optical phonon scattering is illustrated in Fig.1. As can be seen from this figure that the absorption coefficient α depends significantly and non-linearly on temperature of the system. We can see that absorption coefficient increases gradually when temperature is low (T < 100K) that is a good agreement with the results obtained in case of parabolic quantum wells [12] or doped superlattices [3][6]. If temperature is high (T > 100K) the value of the absorption coefficient grows up linearly as the temperature increases. This is a difference compared to case of symmetric quantum wells while the absorption coefficient remains stably in high temperature domain. In addition, the absorption coefficient reaches a peak at 140K - 170K in case of doped superlattices [6]. Although the absorption coefficients both increase nonlinearly on temperature but different in value. That might because of the dissimilarity between analytical expression of the energy spectrums and wave functions of electrons in semi-parabolic quantum well and in others symmetrical quantum wells and two-dimensional systems.

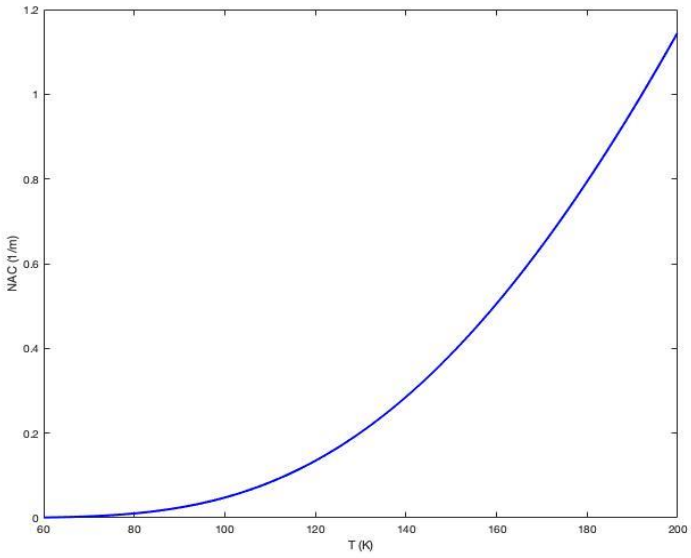

Fig. 1. The dependence of α on Temperature

2.4.2. The dependence of absorption coefficient on size of the quantum wells

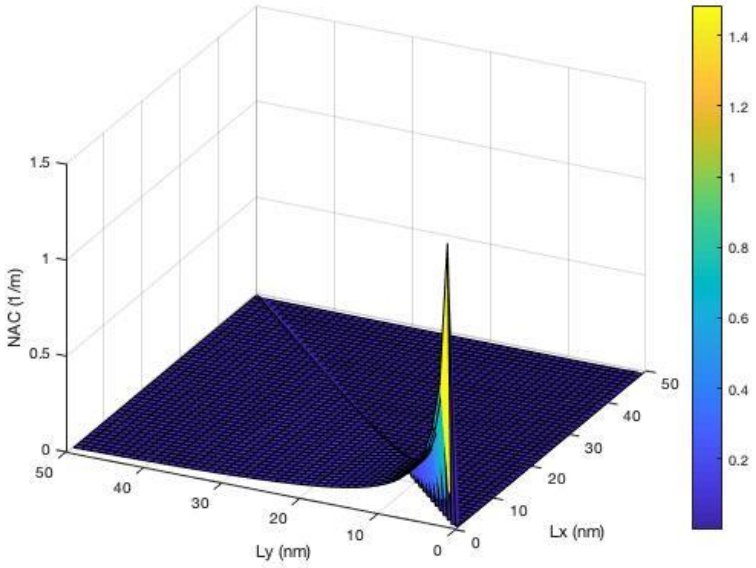

Fig. 2. The dependence of α on the well-width L.

In order to analyze the physical expression of absorption coefficient in quantum wells parameters, we investigate and graph the influence of absorption coefficient on the well-width L. In this case, we set the temperature at 100K and consider the square quantum well $L_x = L_y = L$. As can be seen from the graph, the absorption coefficient also depends nonlinear on well-width. The value of α is big when the quantum well is narrow (L < 10nm).

Then, the more well-width increases the more absorption coefficient decreases. This is due to the quantum size effect, when the size of the system increase to the bulk case, the quantum effect vanishes and it leads to the decrease in the value of coefficient. Besides, the EMW along y-axis makes the absorption coefficient depends strongly on well-width along direction y but not remarkable on well-width along x direction. This results would give a good suggestion for further experiments in the future. We can use this effect as one of the criteria for semi-parabolic quantum wells fabrication technology.

3. CONCLUSION

In this work, we have studied the nonlinear absorption coefficient of a strong electromagnetic wave in a GaAs/AlGaAs asymmetric semi-parabolic quantum well. By using the quantum kinetic equation method, we obtained the expression of the absorption coefficient due to the propagation of EMW in the system. Numerical results show that, towards lower temperature domain, the absorption coefficient remains stable and increases strongly when higher temperature (T > 100K). In addition, we investigate the impact of the size of quantum wells on absorption coefficient. The absorption coefficient decreases nonlinearly on the well-width which is a good agreement with the quantum size effect. Then, the influence of the electromagnetic wave is also mentioned with the difference in each direction of the well-width. These theoretical results show a potential of the asymmetric semi-parabolic quantum wells as a new two – dimensional material gas for designing optical devices as a promising alternative to other traditional semiconductors.

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REFERENCES

1. C. J. Zhang and K. X. Guo (2006), "Polaron effects on the second-order susceptibilities in asymmetrical semi-parabolic quantum wells", *Physica E*, **Vol.33**, pp.363-366.
2. F. M. Ashimzade, Kh. A. Hasanov and M. M. Babayev (2006), "Negative magnetoresistance of an electron gas in a quantum well with parabolic potential", *Phys. Rev. B*, **Vol.73**, pp.235-349.
3. G. M. Schmelev, L. A. Chaikovskii and N. Q. Bau (1978), "HF conduction in semiconductor superlattices", *Sov. Phys. Tech. Semicond* , **Vol.12**.
4. H. V. Phuc, N. N. Hieu, L. Dinh, T. C. Phong (2015), "Nonlinear absorption in parabolic quantum well via two-photon absorption process", *Opt. Commun.*, **Vol.335**, pp. 37-41.
5. N. Q. Bau and D. M. Hung (2010), "Calculation of the nonlinear absorption coefficient of a strong electromagnetic wave by confined electrons in doping superlattices", *Prog. Electromagn. Res. B*, **Vol.25**, pp. 39-52 .
6. N. Q. Bau and T. C. Phong (1998), "Calculations of the absorption coefficient of a weak EMW by free carriers in quantum wells by the Kubo-Mori method", *J. Phys. Soc. Jpn*., **Vol.67**, pp. 3875-3880.
7. N. Q. Bau, N. V. Hieu and N. V. Nhan (2012), "The quantum acoustomagneto-electric field in a

quantum well with a parabolic potential", *Superlatt. Microstruct.*, **Vol.52**, pp. 921-930.
8. N. Q. Bau, N. V. Nhan and T. C. Phong (2002), "Calculations of the absorption coefficient of a weak electromagnetic wave by free carriers in doped superlattices by using the Kubo-Mori method", *J. Korean. Phys. Soc*., **Vol.41**, pp.149.
9. N. Q. Thang, N. V. Nghia and N. Q. Bau (2018), "The influence of electromagnetic wave on the acoustomagnetoelectric effect in a quantum well with infinite potential", *Key Eng. Mater*, **Vol.789**, pp. 6-13

A. Petrin (2011), *Wave propagation,* IntechOpen, Chap.22, pp. 461-482.

10. V. L. Malevich and E. M. Epstein (1974), "Nonlinear optical properties of conduction electrons in semiconductors", *Sov. Quantum Electronic*, **Vol.1**, pp.14-68.
11. X. Q. Yu and Y. B. Yu (2013), "Optical absorptions in asymmetrical semi-parabolic quantum wells", *Superlatt. Microstruct.*, **Vol.63**, pp.225-232.

NGHIÊN CỨU VỀ HẤP THỤ PHI TUYẾN SÓNG ĐIỆN TỪ MẠNH TRONG HỐ LƯỢNG TỬ BÁN PARABOL BẤT ĐỐI XỨNG GaAs/AlGaAs

Tóm tắt: *Nghiên cứu lý thuyết lượng tử hấp thụ phi tuyến sóng điện từ mạnh trong hố lượng tử bán parabol bất đối xứng bằng phương trình động lượng tử với giả thiết cơ chế tán xạ electron-phonon quang. Thu được biểu thức giải tích cho hệ số hấp thụ trong hố lượng tử bán parabol bất đối xứng. Các kết quả là mới mẻ và được so sánh với trường hợp trong bán dẫn thấp chiều truyền thống để thấy sự khác biệt. Kết quả giải tích cũng được đưa vào tính toán số với hố lượng tử GaAs/AlGaAs, thu được đồ thị sự phụ thuộc của hệ số hấp thụ phi tuyến vào nhiệt độ và độ rộng của hố lượng tử.*

Từ khóa: *Hệ số hấp thụ, phương trình động lượng tử, hố lượng tử bán parabol bất đối xứng, tán xạ electron-phonon, sóng điện từ.*

STUDY ON APPLICATION OF $BiFeO_3$ IN TREATING METHYLENE BLUE IN TEXTILE DYEING WASTEWATER

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Abstract: *This study presents the process of synthesizing $BiFeO_3$ by the Gel – Polymer combustion method under optimal condition, selected through the investigation of influencing factors and the characteristic of materials, including the Gel formation temperature (80°C), the molar ratio of Bi/Fe (1/1), the molar ratio of the mixture metal/PVA (1/3), pH=1, and the sample is heated at 500°C for 2 hours. Application of $BiFeO_3$ on removal 100ml of textile dyeing wastewater at concentration 5ppm methylene blue shows relatively good results y at different dilution conditions (f = 2, 5, 10) is 49-65% removal efficiency. The highest efficiency has been obtained in condition the sample was diluted 10 times in 120 minutes contact time under ultraviolet light (wavelength λ = 285nm).*

Keywords: *Methylene blue, modified materials, textile dyeing, $BiFeO_3$.*

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1. INTRODUCTION

The textile dyeing industry is considered one of the industries with the largest amount of wastewater. The massive development of the textile dyeing industry has been causing serious impacts on the environment. Textile dyeing industry wastewater contains a variety of aromatic compounds that are persistent in the environment. Moreover, in an anaerobic environment, some dyes will be reduced to form aromatic cyclic amines, which are toxic substances that cause cancer and mutations in both humans and animals. Methylene blue is a dark green heterocyclic aromatic compound that was synthesized more than 120 years ago and is widely used in the textile industry. Methylene blue in textile dyeing wastewater is very difficult to be decomposed; it not only affects the beauty of the environment but also affects the production, daily life, and health of humans, animals, and plants. In order to contribute to finding an effective method for treating methylene blue in textile dyeing

wastewater, based on the knowledge from previous successful studies on the application of modified materials in textile dyeing wastewater pollution treatment. This study conducted the synthesis of $BiFeO_3$ materials for methylene blue treatment in textile dyeing wastewater.

2. MATERIALS AND METHODS

2.1. Object and scope

- Synthesis of BiFeO3 materials by gel-polymer combustion method
- Application of treating textile dyeing wastewater containing methylene blue in the laboratory.

2.2. Methodology

2.2.1. Methods of sampling and preservation of samples

Methods of sampling and preservation of samples following QCVN 40:2011/BTNMT: Regulation on the technical process of industrial wastewater monitoring. National standard TCVN 6663-32008 on Water quality - Sampling - Part 3 Guidelines for storage and handling of samples.

2.2.2. Materials synthesis method

a) The process of synthesizing materials is carried out according to the following diagram:

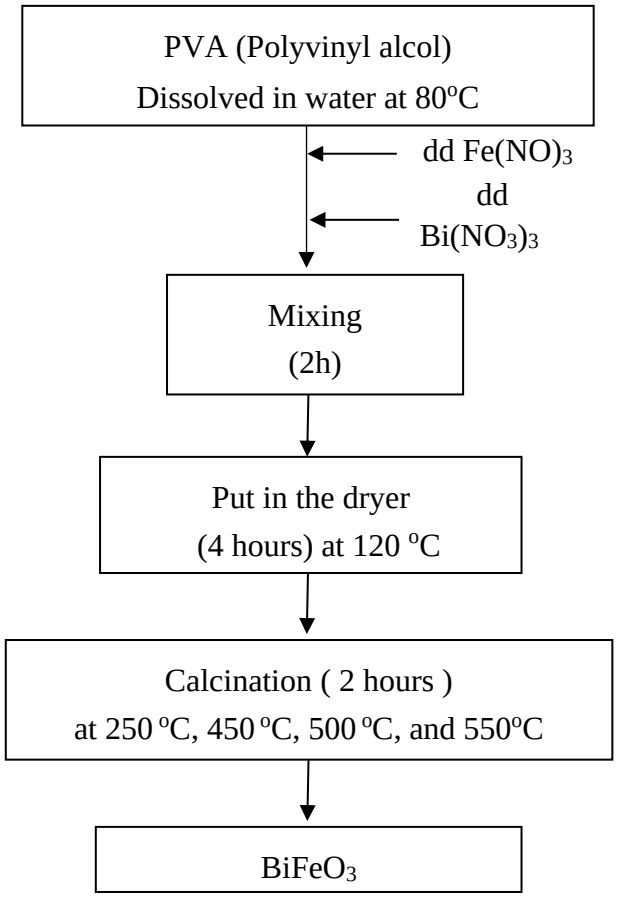


Figure 1. Schematic diagram of BiFeO3 synthesis by gel-polymer combustion method

b) The process of investigating factors affecting the synthesis of materials:

Surveyed factors: calcination temperature and Bi/Fe ratio

- The calcination temperature affects the phase formation of $BiFeO_3$, and the samples are heated at the following temperatures: 250 ^oC, 450 ^oC, 500 ^oC, and 550^oC in the same period (2 hours). Then, the phase composition was analyzed at different temperatures on the X-ray diffraction pattern recorded on the Siemens D5000 machine.

- Metal Ratio: studied at the following ratio: 5/1, 3/1, 1/1, 1/3, 1/5, respectively. Subsequently, the phase composition was analyzed at different temperatures on the X-ray diffraction pattern recorded on the Siemens D5000 machine.

Table 1. Chemicals to study the effect of metal molar ratio

Bi/Fe ratio	**5/1**	**3/1**	**1/1**	**1/3**	**1/5**
$V_{Bi(NO3)3}$(10g/l)	10,45 ml	6,27 ml	20,9 ml	2,09 ml	2,09 ml
$V_{Fe(NO3)3}$(10g/l)	0,56 ml	0,56 ml	5,6 ml	1,68 ml	2,8 ml
m_{PVA}	0,079 g	0,053 g	0,026g	0,053 g	0,079 g
pH = 1	Adjusting by HNO_3				

c) Investigation of material morphological and structure

- Scanning electron microscopy (SEM): Using magnetic diffraction electron microscope on Hitachi S-4800 (Japan).

- Ronghen diffraction method (X-Ray): Using Siemens D5000 to record X-ray diffraction.

2.2.3. Method for determining methylene blue

- Methylene blue content was determined by the colorimetric method at wavelength λ = 660 nm. Methylene blue standard series were diluted with increasing concentrations from the working solution at 100ppm.

Table 2. Chemicals and procedure for methylene blue calibration

No.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
$V_{xanhmetylen}$	0	1	1,5	2	2,5	3	3,5	4
C (ppm)	0	1	1,5	2	2,5	3	3,5	4
Leveled by distilled water								
Stabilized for 15 min, measured Abs at wavelength λ = 660nm								

From the known concentration of the standard series and the corresponding Abs value measured, we can establish the equation in the form y = ax + b

In which, y: Optical absorbance; x: Methylene blue concentration (ppm)

2.2.4. Process of applying methylene blue treatment

0.025g of $BiFeO_3$ synthesized under optimal conditions was added to the environmental or standard sample. Methylene blue was decomposed in 30, 45, 60, 90, and 120 minutes under ultraviolet light with wavelength λ = 285 nm (the whole reaction system is placed on a magnetic stirrer). After 30 minutes, the light and stirrer were stopped. 5ml of material was taken into the centrifuge tube and centrifuged for 10 min at 4000 rpm. Then, the sample was transferred to a quartz cell photometrically and measured at wavelength λ = 660nm.

The methylene blue degradation efficiency was calculated using the formula:

$$H(\%) = \frac{Co - Ct}{Co} x\ 100$$

Where: C_o: Initial methylene blue concentration (ppm)

C_t: Concentration of methylene blue at time t (ppm)

2.3. Results

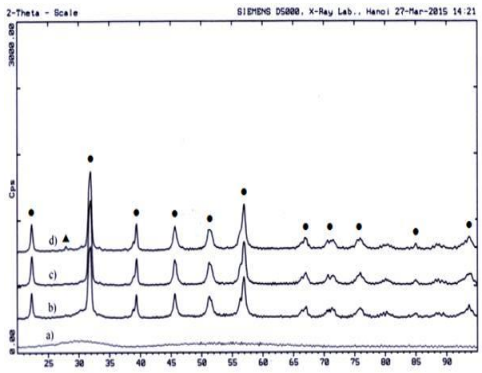
2.3.1. Survey results of influencing factors

2.3.1.1. Effect of heating temperature

The results of the phase composition of the heated samples at different temperatures were shown in Figure 2. According to the XRD Diagram, the heat supplied to the BFO material at 250°C is not enough to form crystals $BiFeO_3$. At 450°C, the crystalline phase of $BiFeO_3$ has been formed. Continuing to raise the temperature to 500°C, the crystalline phase was unique, unchanged, shown more clearly, and crystallized better. When the temperature was raised to 550°C, a small fraction of the β-Bi_2O_3 phase appeared because the perovskite structure was broken in the air. Therefore, the calcination temperature at 500°C was the optimal and selected temperature for the synthesis of materials.

2.3.1.2. Effect of metal ratio

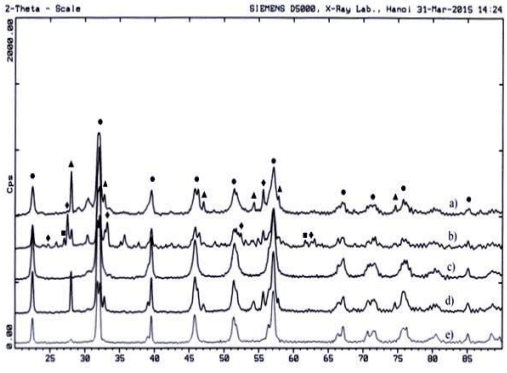
The results of phase composition analysis of the samples at different Bi/Fe ratios were shown in Figure 3. XRD diagram showed that at molar ratios 5/1, 3/1, 1/3, 1/5 in addition to the $BiFeO_3$ perovskite phase, there were additional phases of β-Bi_2O_3, $Bi_{36}Fe_2O_{57}$, α-Bi_2O_3 due to the lack or excess of iron and bismuth, so it could not enter the bond to form the $BiFeO_3$ perovskite phase. To make a single-phase of $BiFeO_3$, the Bi/Fe ratio = 1/1 was optimal.



●$BiFeO_3$ ▲β-Bi_2O_3 ♦$Bi_{36}Fe_2O_{57}$ ▪α-Bi_2O_3

Figure 2. XRD pattern of samples calcined at different temperatures:

a- 250ºC. b-450ºC c, 500 ºC d, 550 ºC



●$BiFeO_3$ ▲β-Bi_2O_3 ♦$Bi_{36}Fe_2O_{57}$ ▪α-Bi_2O_3

Figure 3. XRD pattern of samples with different Bi/Fe ratios.

a-5/1; b-3/1; c-1/1; d-1/3; e-1/5

2.3.2. Results of the investigation of the morphology and structure of materials

The sample materials were fabricated under optimal conditions: the gel-forming temperature was 80°C, the Bi/Fe ratio was 1/1, the molar ratio of the mixture metal/PVA=1/3, pH=1, samples were calcined at 500°C for 2 hours. Phase compositions were determined on Siemens D 5000 and micromorphology was determined on S 4800 machines.

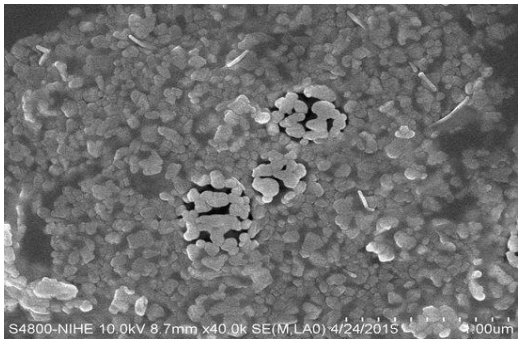


Figure 4. SEM pic of $BiFeO_3$ synthesized under optimal conditions.

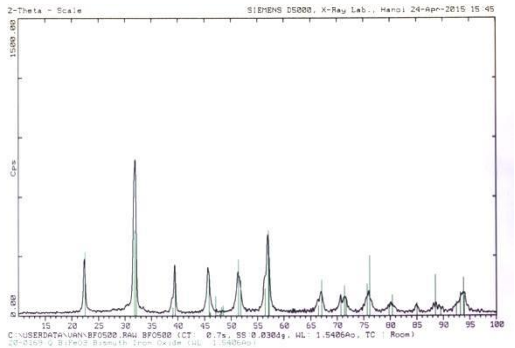


Figure 5. X-ray diffraction pattern of $BiFeO_3$ samples synthesized at optimal conditions

Based on the X-ray diffraction pattern (Figure 5) and SEM image (Figure 4), it showed that the synthesized sample under optimal conditions was a single-phase $BiFeO_3$ with a relatively uniform perovskite structure, particle size < 50 nm.

2.3.3. Results of photocatalytic activity of BFO on the degradation of methylene blue

Under the effect of ultraviolet light with wavelength λ = 285 nm, the BFO material was activated and became an active catalyst promoting the decomposition of methylene blue according to the reaction equation:

$C_{16}H_{18}N_3SCl + 51/2\ O2 \rightarrow HCl + H_2SO_4 + 3HNO_3 + 16\ CO_2 + 6\ H_2O$

2.3.3.1. Preparation of methylene blue standard curve

The optical measurement results (Abs) of the standard sample series were as follows

Table 4. *Optical measurement results of the standard series*

No.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
C (ppm)	0	0,5	1	1,5	2	2,5	3	3,5
Abs	0,074	0,165	0,253	0,337	0,435	0,525	0,609	0,697

Construction of a methylene blue standard curve with the standard curve equation:

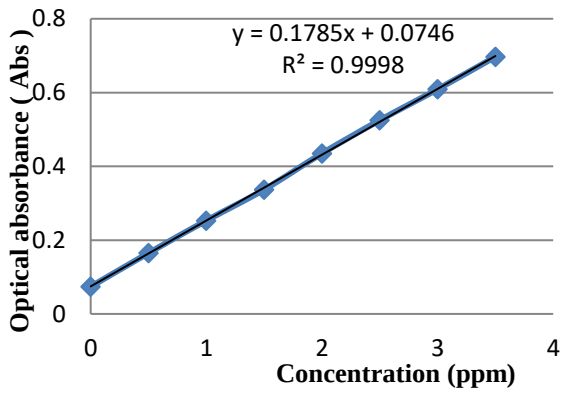
$y = 0,178x + 0,074$ ($r^2 = 0,999$)

Where:

y: Optical absorbance (Abs)

x: Methylene blue concentration (ppm)

Figure 6. Methylene blue standard curve



2.3.3.2. Application of treating methylene blue in standard samples

The experiment was performed with 100 ml of standard methylene blue solution with a concentration of 5 ppm. Results showed that methylene blue was almost completely decomposed in 60 minutes.

Table 5. Results on photocatalysis degradation of methylene blue

Degradation time T (min)	**Methylene blue concentration C (ppm)**	**Treating efficiency H (%)**
30	4,980	80,07
45	1,880	95,25
60	0,310	98,76
90	0,125	99,05
120	0,125	99,05

2.3.3.3. Application of treating methylene blue in environmental samples

a, Determination of methylene blue content in environmental samples

After the sample was collected, the input content was analyzed.

Table 6. Methylene blue content in the input sample

No.	**Diluted 10 times**	**Diluted 5 times**	**Diluted 2 times**
Abs	0,563	1,082	2,635
$y = 0,178x + 0,074$ ($r^2 = 0,999$) Where: y: Optical absorbance x: Methylene blue concentration (ppm)			
C (ppm)	2,747	5,663	14,388
C environmental sample = 28,19 ppm			

b, Treatment of methylene blue in the environment with $BiFeO_3$

100ml of environmental samples were performed at different dilutions: 2, 5 and 10 times. The results on the degradation of methylene blue in environmental samples by photocatalysis over periods were shown in Table 7.

Table 7. Results on photocatalysis degradation of methylene blue in environmental samples

Time (min)	**Diluted 2 times (MT2)**			**Diluted 5 times (MT5)**			**Diluted 10 times (MT10)**		
	Abs	**C (ppm)**	**H (%)**	**Abs**	**C (ppm)**	**H (%)**	**Abs**	**C (ppm)**	**H (%)**
30	1,743	9,376	34,61	0,701	3,522	37,79	0,382	1,730	37,01
45	1,436	7,652	46,63	0,582	2,854	49,60	2,289	1,208	56,03
60	1,403	7,466	47,93	0,518	2,494	55,95	0,284	1,180	61,14
90	1,362	7,236	49,53	0,517	2,489	56,04	0,246	0,966	64,82
120	1,360	7,225	49,61	0,517	2,489	56,04	2,245	0,961	65,03

At all three dilutions, the strongest treatment occurred at the first 30 min and gradually decreased at subsequent time intervals. After 90 minutes, the photocatalytic ability with the environmental samples increased insignificantly.

Compared with the results from the standard sample treatment, the material content = 0.025g $BiFeO_3$ had a treating efficiency of more than 98% for the standard sample with a methylene blue concentration of 5ppm over a period of 60 minutes. The difference of this result could be due to:

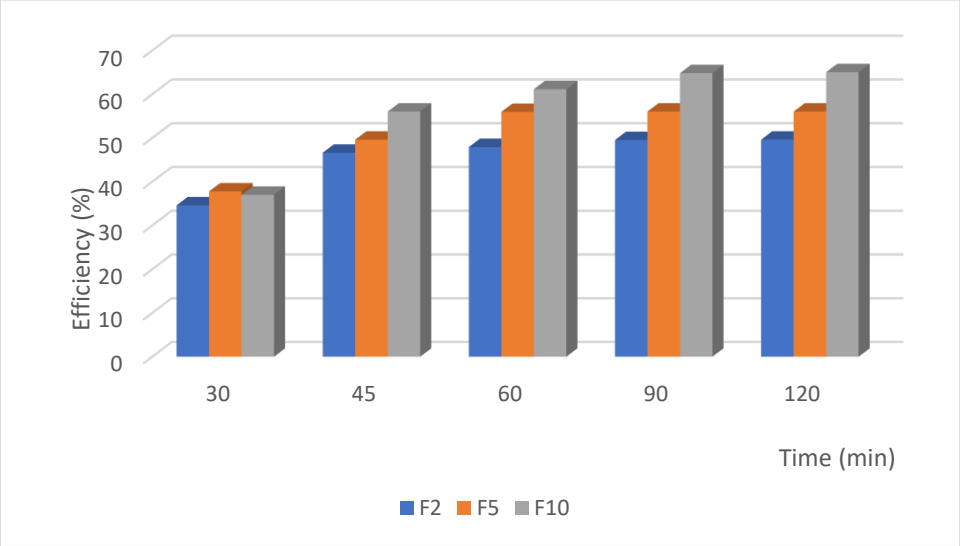


Figure 7. Graph showing the time dependence of the methylene blue degradation efficiency for the 3 dilutions of 2, 5, 10 times.

- The interfering factors affecting the optical measurement process have not been removed from all the environmental samples.

- In the environmental samples, there were many types of dyes, which affected the photocatalytic ability of the material.

3. CONCLUSION

Among all material synthesis methods, the selection of the Gel - Polymer combustion method to synthesize $BiFeO_3$ was very appropriate and effective. During the synthesis process, the optimal conditions to synthesize $BiFeO_3$ have been studied and found to be: the Bi/Fe ratio was 1/1, the sample heating temperature was 500°C. $BiFeO_3$ synthesized by the Gel - Polymer combustion method under optimal synthesis conditions has given certain efficiency. The material was synthesized in a single phase, particle size <50 nm. The photocatalytic properties of the material with standard methylene blue were very good. The decomposition efficiency H was more than 99%. Initial assessment showed that the ability to treat methylene blue by the photocatalytic properties of the material in textile dyeing wastewater had a certain efficiency (H = 49-65%), but the efficiency was not high.

REFERENCES

1. Duong Thi Lim (2014), *Nghiên cứu tổng hợp một số oxit hỗn hợp kích thước nanomet hệ đất hiếm-mangan và khảo sát khả năng hấp thụ đối với amoni, asen, sắt, mangan trong nước sinh hoạt*, Luận án tiến sỹ hóa học, Viện hàn lâm khoa học và công nghệ Việt Nam, Hà Nội.

2. Nguyen Duc Nghia (2007), *Hóa Học nano*, Nxb. Khoa học tự nhiên và công nghệ Hà Nội, Hà Nội.

3. Dang Tran Phong, Trang Hieu Hue (2005), *Xử Lý nước cấp, nước thải dệt nhuộm, nhà xuất bản khoa học kỹ thuật Hà Nội.*

4. Hoang Thi Thu Thuy (2013), *Nghiên cứu xử lý thuốc nhuộm xanh metylen bằng bùn đỏ từ nhà máy ALUMIN Tân Rai – Lâm Đồng*, Luận văn thạc sỹ khoa học, Đà Nẵng.

5. Cao Huu Truong, Hoang Thi Linh (1995), *Hóa học thuốc nhuộm, nhà xuất bản khoa học kỹ thuật công nghệ Hà Nội.*

NGHIÊN CỨU ỨNG DỤNG XỬ LÝ XANH METYLEN TRONG NƯỚC THẢI DỆT NHUỘM BẰNG VẬT LIỆU $BiFeO_3$

Tóm tắt: *Nghiên cứu trình bày quy trình tổng hợp vật liệu $BiFeO_3$ bằng phương pháp đốt cháy Gel – Polyme trong điều kiện tối ưu được lựa chọn qua quá trình khảo sát các yếu tố ảnh hưởng và cấu trúc, hình thái vật liệu như: nhiệt độ tạo Gel ở 80^oC, tỷ lệ mol kim loại Bi/Fe là 1/1, tỷ lệ mol hỗn hợp kim loại/PVA=1/3, pH=1, nung mẫu ở 500^oC trong 2 giờ. Kết quả ứng dụng vật liệu $BiFeO_3$ xử lý 100ml nước thải dệt nhuộm có chứa dung dịch xanh metylen nồng độ 5ppm cho kết quả tương đối tốt với hiệu suất xử lý mẫu ở các điều kiện pha loãng khác nhau (f = 2, 5, 10) là 49 – 65%. Hiệu suất xử lý cao nhất ở điều kiệnpha loãng 10 lần với thời gian 120 phút phân hủy dưới ánh sáng UV có bước sóng λ = 285nm.*

Từ khoá: *Methylene xanh, xử lí vật liệu, dệt nhuộm, $BiFeO_3$.*

INVESTIGATING THE DIVERSITY OF MICROBIOTA IN VERMICOMPOST APPLIED TO THE PRODUCTION OF ORGANIC FERTILIZERS CONTAINING MICROORGANISMS

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Abstract: *Vermicompost contains beneficial bacteria, vermicompost is a finely divided peat-like material with high porosity, good ventilation, drainage, water-holding capacity, microorganism activity, Excellent nutritional status and buffering capacity thus provide the physiological properties required for soil fertility and plant growth. Worm manure enhances soil biodiversity by promoting entry and enhances plant growth directly by producing plant growth-regulating hormones and enzymes. Due to its inborn biological, biochemical and physicochemical properties, vermicompost can be used to promote sustainable agriculture and also for the safe management of agricultural, industrial, and domestic wastes. In Vietnam, the production of vermi-compost still takes place with a small scale, the product of vermi-compost is still small and can only be used for ornamental plants and high-value crops. Research and production of vermi-compost to put into agricultural production is very necessary*

Keywords: *Vermicompost, Earthworms, Beneficial bacteria, Biofertilizer*

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1. INTRODUCTION

Earthworms affect the microbial community, the physical and chemical properties of the soil. They break down large soil particles and leaf carcasses and thus increase the availability of organic matter for microbial decomposition and turn organic waste into valuable vermi-compost by crushing and decomposing them with the help of aerobic and anaerobic microorganisms (Maboeta MS, 2003). Earthworms activity is found to enhance the beneficial microflora and suppress harmful pathogenic microbes (Lavelle P, 1992). Vermicomposting is an efficient nutrient recycling process that involves harnessing earthworms as versatile natural bioreactors for organic matter decomposition. Due to

richness in nutrient availability and microbial activity vermicomposts increase soil fertility, enhance plant growth and suppress the population of plant pathogens and pests. This study we are investigating the diversity of microbiota in vermicompost applied to the production of organic fertilizers containing microorganism.

2. CLASSIFICATION OF WORMS

Earthworms, grouped under phylum annelida are long, narrow, cylindrical, bilaterally symmetrical, segmented soil dwelling invertebrates with a glistening dark brown body covered with delicate cuticle. They are hermaphrodites and weigh over 1,400–1,500 mg after 8–10 weeks. Their body contains 65% protein (70–80% high quality 'lysine rich protein' on a dry weight basis), 14% fats, 14% carbohydrates, and 3% ash. Their life span varies between 3–7 years depending upon the species and ecological situation. The gut of earthworm is a straight tube starting from mouth followed by a muscular pharynx, oesophagus, thin walled crop, muscular gizzard, foregut, midgut, hindgut, associated digestive glands, and ending with anus. The gut consisted of mucus containing protein and polysaccharides, organic and mineral matter, amino acids and microbial symbionts viz., bacteria, protozoa and microfungi. The increased organic carbon, total organic carbon and nitrogen and moisture content in the earthworm gut provide an optimal environment for the activation of dormant microbes and germination of endospores etc. A wide array of digestive enzymes such as amylase, cellulase, protease, lipase, chitinase and urease were reported from earthworm's alimentary canal. The gut microbes were found to be responsible for the cellulase and mannose activities (Munnoli PM, 2010).

Table 1. Types and ecology of earthworms, their characteristic features and beneficial traits

Species	**Ecological category**	**Ecological niche**	**Characteristic features**	**Beneficial trait**
Eisenia foetida,	Epigeics	Superficial soil layers, leaf litter, compost	Smaller in size, body uniformly pigmented, active gizzard, short life cycle, high reproduction rate and regeneration, tolerant to disturbance, phytophagous	Efficient bio-degraders and nutrient releasers, efficient compost producers, aids in litter comminution and early decomposition
Lumbricus rubellus, *L. castaneus,* *L. festivus,*				

Eiseniella tetraedra, Bimastus minusculus, B. eiseni, Dendrodrilus rubidus, Dendrobaena veneta, D. octaedra				
Aporrectodea caliginosa,	Endogeics	Topsoil or subsoil	Small to large sized worms, weakly pigmented, life cycle of medium duration, moderately tolerant to disturbance, geophagous	Brings about pronounced changes in soil physical structure, can efficiently utilize energy from poor soils hence can be used for soil improvements
A. trapezoides, A. rosea, Millsonia anomala,				
Octolasion cyaneum,	Polyhumic endogeic	Top soil (A1)	Small size, unpigmented, forms horizontal burrows, rich soil feeder	
O. lacteum, *Pontoscolex corethrurus,*	Mesohumic endogeic	A and B horizon	Medium size, unpigmented, forms extensive horizontal burrows, bulk (A_1) soil feeder	

Allolobophora chlorotica,				
Aminthas sp.	Oligohumic endogeic	B and C horizon	Very large in size, unpigmented, forms extensive horizontal burrows, feeds on poor, deep soils	
L. terrestris,	Anecics	Permanent deep burrows in soil	Large in size, dorsally pigmented, forms extensive, deep, vertical permanent burrows, low reproductive rate, sensitive to disturbance, phytogeophagous, nocturnal	Forms vertical burrows affecting air-water relationship and movement from deep layers to surface helps in efficient mixing of nutrients
L. polyphemus,				

The effects of vermi-compost on pH, conductivity (EC), C: N ratio and other nutrients have been noted. Earthworm activity reduces the pH and C: N ratio in the stool (Gandhi M, 1997). Chemical analysis showed vermicompost had a lower pH, EC, organic carbon (OC) (Nardi S, 1983), C:N ratio (Riffaldi R, 1983) nitrogen and potassium and higher amounts of total phosphorous and micronutrients compared to the parent material (Hashemimajd K, 2004). (Lazcano C, Comparison of the effectiveness of composting and vermicomposting for the biological stabilization of cattle manure, 2008) and concomitant production of CO2 (Elvira C, 1998). Vermicomposting of paper mill and dairy sludge resulted in 1.2–1.7 fold loss of organic carbon as CO2 (Elvira C, 1998), In contrast to the parent material used, vermicomposts contain higher humic acid substances (Albanell E, 1988), Humic acid substances occur naturally in mature animal manure, sewage sludge or paper-mill sludge, but vermicomposting drastically increases the rate of production and their amount from 40–60 percent compared to traditional composting. The enhancement in humification processes is by fragmentation and size reduction of organic matter, increased microbial activity within earthworm intestine and soil aeration by earthworm feeding and movement (Dominguez J, 2004). EC indicates the salinity of the organic amendment. Minor production of soluble metabolites such as ammonium and precipitation of dissolved salts during vermicomposting lead to lower EC values. Compared to the parent material used, vermicomposts contain less soluble salts and greater cation exchange capacity (Holtzclaw KM, 1979). C:N ratio is an

indicator of the degree of decomposition. During the process of biooxidation, CO2 and N is lost and loss of N takes place at a comparatively lower rate. Comparison of compost and vermicompost showed that vermicompost had significantly less C:N ratios as they underwent intense decomposition .

3. MICROBIOTA AND RELATIONSHIP WITH EARTHWORMS

Interactions between earthworms and microorganisms seem to be complex. Earthworms ingest plant growth-promoting rhizospheric bacteria such as Pseudomonas, Rhizobium, Bacillus, Azosprillium, Azotobacter, etc. along with rhizospheric soil, and they might get activated or increased due to the ideal micro-environment of the gut. Therefore earthworm activity increases the population of plant growth-promoting rhizobacteria (PGPR) (Sinha et al. 2010). This specific group of bacteria stimulates plant growth directly by solubilization of nutrients (Ayyadurai N, 2007), production of growth hormone, 1-aminocyclopropane-1-carboxylate (ACC) deaminase (Correa JD, 2004), nitrogen fixation (Han J, 2005), and indirectly by suppressing fungal pathogens. Antibiotics, fluorescent pigments, siderophores and fungal cell-wall degrading enzymes namely chitinases and glucanases produced by bacteria mediate the fungal growth-suppression. Earthworms are reported to have association with such free living soil bacteria and constitute the drilosphere. Earthworm microbes mineralize the organic matter and also facilitate the chelation of metal ions (Pizl V, 1993), Gut of earthworms L. terrestris, Allolobophora caliginosa and Allolobophora terrestris were reported to contain higher number of aerobes compared to soil. Earthworms increased the number of microorganisms in soi1 as much as five times and the number of bacteria and ‘actinomycetes’ contained in the ingested material increased upto 1,000 fold while passing through their gut (Edwards CA, 1988). Similar increase was observed in plate counts of total bacteria, proteolytic bacteria and actinomycetes by passage through earthworms gut. Similarly microbial biomass either decreased or increased or remained unchanged after passage through the earthworm gut. An oxalate-degrading bacterium Pseudomonas oxalaticus was isolated from intestine of Pheretima species and an actinomycete Streptomyces lipmanii was identified in the gut of Eisenia lucens (E, 1980).

Table 2. *The biodiversity of vermicompost bacteria and their beneficial characteristics*

Vermicompost earthworm	**Names of bacteria**	**Beneficial traits**	**References**
Pheretima sp.	*Pseudomonas oxalaticus*	Oxalate degradation	Khambata and Bhat, 1953
Unspecified	*Rhizobium trifolii*	Nitrogen fixation and growth of leguminous plants	Buckalew et al. 1982

Vermicompost earthworm	**Names of bacteria**	**Beneficial traits**	**References**
Lumbricus rubellus	*R. japonicum, P. putida*	Plant growth promotion	Madsen and Alexander 1982
L. terrestris	*Bradyrhizobium japonicum*	Improved distribution of nodules on soybean roots	Rouelle, 1983
Aporrectodea trapezoids,	*P. corrugata 2*14OR	Suppress *Gaeumannomyces graminis* var. *Tritd* in wheat	Doube et al. 1994
A. rosea			
A. trapezoids,	*R. meliloti* L5-30R	Increased root nodulation and nitrogen fixation in legumes	Stephens et al. 1994b
Microscolex dubius			
Eisenia foetida	*Bacillus* spp., *B. megaterium,*	Antimicrobial activity against *Enterococcus faecalis*DSM 2570, *Staphylococcus aureus* DSM 1104	Vaz-Moreira et al. 2008
	B. pumilus, B. subtilis		
L. terrestris	Fluorescent pseudomonads,	Suppress *Fusarium oxysporum* f. sp. *asparagi* and *F. proliferatum* in asparagus, *Verticillium dahlia* in eggplant and *F. oxysporum* f. sp. *lycopersici* Race 1 in tomato	Elmer, 2009
	Filamentous actinomycetes		
Eudrilus sp.	Free-living N_2 fixers,	Plant growth promotion by nitrification, phosphate solubilisation	Gopal et al. 2009

Vermicompost earthworm	Names of bacteria	Beneficial traits	References
		and plant disease suppression	
	Azospirillum, *Azotobacter*, Autotrophic *Nitrosomonas*, *Nitrobacter*, Ammonifying bacteria, Phosphate solubilizers, Fluorescent pseudomonads		
E. foetida	Proteobacteria, Bacteroidetes,	Antifungal activity against *Colletotrichum coccodes, R. solani, P. ultimum, P. capsici* and *F. moliniforme*	Yasir et al. 2009a
	Verrucomicrobia, Actinobacteria, Firmicutes		
Unspecified	*Eiseniicola composti* YC06271^{T}	Antagonistic activity against *F. moniliforme*	Yasir et al. 2009b

Earthworms harbor ‘nitrogen-fixing’ and ‘decomposer microbes’ in their gut and excrete them along with nutrients in their excreta (Singleton DR, 2003). Earthworms stimulate and accelerate microbial activity by increasing the soil microbial population, number of microorganisms and biomass, by improving aeration through burrowing operations. Worm manure has diversified the original microbial community of the waste. Actinobacteria and Gammaproteobacteria are abundant in vermi-compost, while conventional compost contains a lot of Alphaproteobacteria and Bacteriodetes, typical phylogenetic groups of non-cured compost (Vivas A, 2009). Total bacterial counts exceeded 10- 10/ g of vermicompost and it included nitrobacter, azotobacter, rhizobium, phosphate solubilizers and actinomycetes. Molecular and culture-dependent analyses of bacterial community of vermicompost showed the presence of α-Proteobacteria, β-Proteobacteria, γ-Proteobacteria, Actinobacteria, Planctomycetes, Firmicutes and Bacteroidetes.

4. ROLE OF VERMICOMPOST IN PLANT GROWTH PROMOTION

Vermicompost produced from different parent material such as food waste, cattle manure, pig manure, etc., when used as a media supplement, enhanced seedling growth and

development, and increased productivity of a wide variety of crops (Edwards CA, 1988). Vermicompost addition to soil-less bedding plant media enhanced germination, growth, flowering and fruiting of a wide range of green house vegetables and ornamentals (Atiyeh et al. 2000a, b, c), marigolds (Atiyeh RM, 2001), pepper, strawberries and petunias (Chamani E, 2008). Vermicompost application in the ratio of 20:1 resulted in a significant and consistent increase in plant growth in both field and greenhouse conditions, thus providing a substantial evidence that biological growth promoting factors play a key role in seed germination and plant growth . Investigations revealed that plant hormones and plant-growth regulating substances (PGRs) such as auxins, gibberellins, cytokinins, ethylene and abscisic acid are produced by microorganisms.

Earthworms produce plant growth regulators. Since earthworms increase the microbial activity by several folds they are considered as important agents which enhance the production of plant growth regulators. Plant growth stimulating substances of microbial origin were isolated from tissues of Aporrectodea longa, L. terrestris and Dendrobaena rubidus. The use of vermi compost in plant breeding promotes rooting of the plant, increasing the number of roots and biomass. The hormone-like effects of worm fertilizers on plant metabolism, growth and development causing dwarfism, root stimulation, elongation, and early flowering are believed to be due to the presence of metabolites of microorganisms. (Tomati U, 1987). Earthworm casts stimulated growth of ornamental plants and carpophore formation in Agaricus bisporus when used as casing layer in mushroom cultivation.The intestinal microorganisms of earthworms enrich the worm feces with light-sensitive and water-soluble plant growth hormones that are absorbed into humic acids in the vermi compost. . They are extremely stable and help them survive longer in the soil thereby affecting plant growth. This was confirmed by the presence of the exchangeable auxin group in the macroscopic structure of extracting humic acid from vermi-compost. Application of vermi-compost increased plant spread (10.7%), leaf area (23.1%), dry matter (20.7%) and increased total strawberry yield (32.7%).

5. CONCLUSION

Vermicompost is a low-cost, environmentally friendly waste management technology that dominates both worms and related microorganisms and has many advantages over the preferred method of composting traditional heat. Worm fertilizers are an excellent source of bio-fertilizers and their addition improves the physiological and biological properties of agricultural soils. Worm manure amplifies the diversity and populations of beneficial microbial communities. Though there are a few reports that indicate that the bacteria are less harmful. Other plant growth-promoting beneficial bacteria in vermi-compost aggravate these harms. Vermicomposts with excellent physio-chemical properties and buffering ability, fortified with all nutrients in plant available forms, antagonistic and plant growth-promoting bacteria are fantabulous organic amendments that act as a panacea for soil reclamation, enhancement of soil fertility, plant growth, and control of pathogens, pests and nematodes for sustainable agriculture.

REFERENCES

1. Albanell E, P. J. (1988), "Chemical changes during vermicomposting (Eisenia fetida) of sheep manure mixed with cotton industrial wastes", *Biol Fertil Soils*, pp. 266–269.
2. Atiyeh RM, A. N. (2001), "The influence of earthworm-processed pig manure on the growth and productivity of marigolds", *Bioresour Technol.*, pp. 103–108.
3. Ayyadurai N, R. N. (2007), "Functional characterization of antagonistic fluorescent pseudomonads associated with rhizospheric soil of rice (Oryza sativa L.)", *J Microbiol Biotechnol*, pp. 919–927.
4. Chamani E, J. D. (2008), "Vermicompost Effects on the Growth and Flowering of Petunia hybrida 'Dream Neon Rose'", *American-Eurasian J Agric And Environ Sci.*, pp. 506–512.
5. Correa JD, B. M. (2004), "Screening for plant growth promoting rhizobacteria in Chamaecytisus proliferus (tagasaste), a forage tree-shrub legume endemic to the Canary Islands", *Plant Soil.*, pp. 75–84.
6. Dominguez J, E. C. (2004), "Vermicomposting organic wastes: A review", In: Shakir Hanna SH, Mikhail WZA, *Soil Zoology for sustainable Development in the 21st century*, pp. 369–395.
7. E, C. (1980), "Studies on the intestinal actinomycete flora of Eisenia lucens (Annelida, Oligochaeta)", *Pedobiologia*, pp. 411–416.
8. Edwards CA, B. I. (1988), "The potential of earthworm composts as plant growth media", In: Edwards CA, Neuhauser E, editors, *Earthworms in Waste and Environmental Management.*, pp. 21–32.
9. Elvira C, S. L. (1998), "Vermicomposting of sludges from paper mill and dairy industries with Eisenia andrei: a pilot-scale study", *Bioresour Technol.*, pp. 205–211.
10. Gandhi M, S. V. (1997), "Composting of household wastes with and without earthworms", *Environ Ecol*, pp. 432–434.
11. Han J, S. L. (2005), "Characterization of a novel plant growth-promoting bacteria strain Delftia tsuruhatensis HR4 both as a diazotroph and a potential biocontrol agent against various pathogens", *Syst Appl Microbiol.*, pp. 66–76.
12. Hashemimajd K, K. M. (2004), "Comparison of vermicompost and composts as potting media for growth of tomatoes", *J Plant Nutr*, pp. 1107–1123.
13. Holtzclaw KM, S. G. (1979), "Analytical properties of the soluble metal-complexing fractions in sludge-soil mixtures", IV. Determination of carboxyl groups in fulvic acid, *Soil Sci Soc Am J*, pp. 318–323.
14. Lavelle P, M. A. (1992), "Small-scale and large-scale effects of endogeic earthworms on soil organic matter dynamics in soils of the humid tropics", *Soil Biol Biochem*, pp. 1491–1498.
15. Lazcano C, G.-B. M. (2008), "Comparison of the effectiveness of composting and vermicomposting for the biological stabilization of cattle manure", *Chemosphere*, pp. 1013–1019.
16. Lazcano C, G.-B. M. (2008), "Comparison of the effectiveness of composting and vermicomposting for the biological stabilization of cattle manure", *Chemosphere*, pp. 1013–1019.

17. Lazcano C, G.-B. M. (2008), "Comparison of the effectiveness of composting and vermicomposting for the biological stabilization of cattle manure", *Chemosphere*, pp. 1013–1019.

18. Maboeta MS, V. R. (2003), "Vermicomposting of industrially produced wood chips and sewage sludge utilizing Eisenia foetida", *Ecotoxicol Environ Saf*, pp. 265–270.

19. Munnoli PM, D. S. (2010), "Dynamics of the soil-earthworm-plant relationship: A review", *Dynamic soil, dynamic plant*, pp. 1–21.

20. Nardi S, D. G. (1983), "Humus production from farmyard wastes by vermicomposting", *Proc. Int. Symp. On Agricultural and Environmental Prospects in Earthworm Farming*, pp. 87–94.

21. Pizl V, N. A. (1993), "Interactions between microfungi and Eisenia andrei (Oligochaeta) during cattle manure vermicomposting", *Pedobiologia*, pp. 895–899.

22. Riffaldi R, L.-M. R. (1983), "Osservazioni preliminari sul ruolo dell Eisenia foetida nell'umificazione del letame", *Agrochimica*, pp. 271–274.

23. Singleton DR, H. P. (2003), "Identification of uncultured bacteria tightly associated with the intestine of the earthworm Lumbricus rubellus (Lumbricidae; Oligochaeta)", *Soil Biol Biochem*, pp. 1547–1555.

24. Tomati U, G. A. (1987), "The presence of growth regulators in earthworm worked waste", In: Bonvicini Paglioi AM, Omodeo P, editors. *On Earthworms. Proceedings of International Symposium on Earthworms, Selected Symposia and Monographs, Union Zoologica Italian*, pp. 423–435.

25. Vivas A, M. B.-R. (2009), "Assessing the impact of composting and vermicomposting on bacterial community size and structure, and functional diversity of an olive-mill waste", *Bioresour Technol.*, pp. 1319–1326.

KHẢO SÁT SỰ ĐA DẠNG CỦA HỆ VI SINH VẬT TRONG PHÂN TRÙN QUẾ DÙNG ĐỂ SẢN XUẤT PHÂN HỮU CƠ CÓ CHỨA VI SINH VẬT

Tóm tắt: *Phân trùn quế có chứa các vi khuẩn có lợi, phân trùn quế là một loại vật liệu dạng than bùn đã được chia mịn, có độ tơi xốp cao, thông gió tốt, thoát nước, khả năng giữ nước, hoạt động của vi sinh vật, tình trạng dinh dưỡng và khả năng đệm tuyệt vời do đó cung cấp các đặc tính sinh lý cần thiết cho độ phì nhiêu của đất và sự phát triển của cây trồng. Phân giun giúp tăng cường đa dạng sinh học của đất bằng cách thúc đẩy sự xâm nhập và tăng cường sự phát triển của thực vật trực tiếp bằng cách sản xuất các hormone và enzyme điều hòa sinh trưởng thực vật. Do các đặc tính sinh học, sinh hóa và lý hóa bẩm sinh của nó, phân trùn quế có thể được sử dụng để thúc đẩy nông nghiệp bền vững và cũng để quản lý an toàn chất thải nông nghiệp, công nghiệp và sinh hoạt. Ở Việt Nam, việc sản xuất phân vermi vẫn diễn ra với quy mô nhỏ lẻ, sản phẩm từ phân vermi còn ít và chỉ được sử dụng làm cây cảnh và các loại cây trồng có giá trị kinh tế cao. Việc nghiên cứu và sản xuất phân vermi-compost để đưa vào sản xuất nông nghiệp là rất cần thiết.*

Từ khóa: *Phân trùn quế, trùn quế, vi khuẩn có lợi, phân bón sinh học.*

NEW UPDATE INFOMATION ON SMALL MAMMALS CHECKLIST IN NGOC SON – NGO LUONG NATURE RESERVE, HOA BINH PROVINCE

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***Abstract**: We updated checklist on small mammals of Ngoc Son – Ngo Luong Nature Reserve (NS–NL NR), Hoa Binh province, lie in Pu Luong – Cuc Phuong limestone karst of the northern Vietnam. Based on the specimens in field survey combined with data from previous publications, 54 small mammal species in 10 families and 3 orders documented in this area. In which, Sphaerias blanfordi, Cynopterus sphinx, Hipposideros gentilis, Hipposideros larvatus, Murina cyclotis are common species in Bat fauna, Leopodamys subanus, Maxomys surifer, Rattus tanezumi are the popular species in Rodent fauna. However, illegal exploitation, hunting and human activities effect negative to the biodiversity values. Therefore, the conservation of biodiversity is required.*

***Keywords**: Small mammals, checklist, limestone karst, Vietnam.*

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1. INTRODUCTION

Ngoc Son – Ngo Luong Nature Reserve was established under the Decision No. 2714/QD–UB dated December 28, 2004 of the People's Committee of Hoa Binh Province. The area covers over 19,254 ha, stretching over 7 communes in 2 districts of Tan Lac and Lac Son (Ngoc Son – Ngo Luong Nature Reserve Managgement Board, 2010; Do A. T. et al., 2008). The nature reserves are located in the South–west of Hoa Binh province, has a border with Pu Luong Nature Reserve, Thanh Hoa province in north–west and Cuc Phuong National Park, Ninh Binh province in south–east (Do A. T et al., 2008). It forms part of the Pu Luong (Thanh Hoa) – Cuc Phuong (Ninh Binh) Limestone landscape, contribute to conserve the biodiversity in limestone ecosystem in northern of Vietnam (Pham Q. T., 2013). The limestone mountainous ecosystem is typical of the transitional area from Northwest Mountain to the Red River Delta. There are little is known about the biodiversity of Ngoc Son Ngo Luong Nature Reserve (BirdLife International & FIPI, 2001; FIPI, 2005). There

are eight major subformations belong to six formations in area, in which tropical evergreen seasonal lowland forest on limestone and tropical evergreen seasonal submontane forest on limestone are the largest area (Phung V. P. et al., 2014). About 235 higher vascular plants, of which 37 threatened plants species were recored (Nguyen Q. H. et al., 2012). 85 species belonging to 20 families, 3 orders, of which 23 species of threatened reptiles and amphibians were recorded (Thao A. T., 2015). Besides, this place is home of endangered mammals such as small carnivore and flying squirrel, especially the presence of a population of The Delacour's langur *Trachypithecus delacouri*, endemic to Vietnam (Daniel et al., 2011, Cano 2013, Le et al., 2008). This species also has been recorded in Pu Luong Nature Reserve and Cuc Phuong National Park (Birdlife, 2001). However, the study about the small mammal fauna is still limited. Some preliminary survey has been carried on here (Do T. & Duong A.T., 2003, Cano & Pham Q. T., 2010). Total 68 mammals were recorded, of which 40 species are listed in the Vietnam Red Book. Recently, there have been some updated studies on the fauna in Ngoc Son– Ngo Luong Nature Reserve (Phạm Q.T., 2013; Dong T.H., 2015). About 94 species of mammals belonging to 28 families and 9 orders were recorded, of which 46 species are endangered. However, the bat fauna was not covered by the study should be inherited from the previous literature. There are little study about small mammals, especially bat fauna is conducted in here. So in order to update and complete the small mammal fauna here, we conducted a survey to provide the most complete and up–to–date list of small mammals in this area, serving for biodiversity conservation.

2. MATERIAL AND METHODS

Survey site and effort

Fieldworks were conducted in Ngoc Son – Ngo Luong during 10–20 Junuary, 2009 and 1 – 12 June, 2019 by the Institute of Ecology and Biological Resources, Vietnam Academy of Science and Technology and Ha Noi Metropolitan University. This nature reserve is located in Tan Lac and Lac Son districts in the Southwestern of Hoa Binh Province, Vietnam stretching from 20°23' – 20°36' N and 105°07' –105°30' E (Do A.T. et al., 2008). Total survey efforts are shown in Tab 1.

Table 1. Total survey efforts in Ngoc Son– Ngo Luong Nature Reserve

Trapline	Coordinates	Elevation	D.O	MN	H	M	S	C	N.O
Trapline 1A	20°24’51.81” N 105°18’39.92” E	316	4			576	160	80	4
Trapline 2A	20°24’32.22” N 105°20’37.39” E	201	4	1296					4
Trapline 3A Dai Cave	20°24’8.33” N 105°22’27.83” E	216	4	1296					4
Trapline 4A	20°25’13.26” N 105°22’36.7” E	485	4	672					4

Thon Chieng Cave									
Trapline 5A	$20^0$26’39.97” N $105^0$15’39.61” E	233	4		72				4
Trapline 1B	$20^0$24’24.75” N $105^0$22’14.67” E	292	4	240					4
Trapline 2B	$20^0$27’28.3” N $105^0$30’8.95” E	500	2	672					2
Trapline 3B	$20^0$23’30,76” N $105^0$12’4.34” E	300	2		36	288	80	40	2
Trapline 4B	20°23'53.94"N 105°10’’56.65"E	320	1.5	672					1.5
Total			31.5	4.848	108	864	240	120	31.5

Notes: D.O. – daytime observation (hours); MN – mist nets (m2 / n / h); H – harp trap (m2 / n / h); M – mole–traps (trap nights); S – Sherman traps; C – cage traps (trap nights); N.O. – nighttime observations (hours).

Methodology

Different methods were used to collect specimens to give the diversity of small mammal fauna in the study site . During the survey, we conducted day and night time excursions and using specialized trap methods for small mammals. A few types of traps were used:

– Three kinds of Sherman live–traps (3×3×10 cm; 5 × 5 × 18 cm; 7 × 7 × 30 cm) were used to catch medium–sized rodents and shrews. Tomahawk cage traps (20 × 20 × 60 cm) and local cage traps (15 × 15 × 25 cm) were used to large–sized rodents and squirrels. Baits for trapping must be odiferous enough to draw rodents into the traps from some distance, sticky enough to as here to the trap, and stable enough to keep from rotting. Baits were changed every day after checking the traps.

– Two types of mole–traps – Japanese hand–made traps and Talpex traps. Mole traps were set on the trails along small trails where mole tunnels were observed.

– Different types of mist nets (2 × 3 m, 5 × 3 m and 12 × 4 m) and harp trap (1.5 × 1.5 m) were used to live capture bats. The nets and traps were set to cross trails in the forest, over small ponds and streams in the forest or near forest edges, at openings at the forest edges and the entrances of caves.

The external body measurements: head and body length (HB), tail length (TL), hind foot length (HF), ear length (E) and weight (Wt) were taken by tapeline and digital caliper. For bats, forearm (FA) and tibia (Tib) lengths also were measured (Kruskop, 2013).

Detailed identification followed Csorba et al., 2003; Francis, 2019; Wilson & Reeder, 2005, Lunde & Nguyen, 2001.

The nomenclature of mammals follows Csorba et al., 2003, Wilson & Reeder, 2005; Lunde & Nguyen, 2001; Dang et al., 2008; unless otherwise stated.

We used Sorensen –Dice coefficient to estimate the similarity about bat fauna among Ngoc Son–Ngo Luong Nature Reserve and Pu Luong Nature Reserve and Cuc Phuong National Park. We used the following index: SI = 2c/ (a+b), where: c = number of species in both A và B sites; a = number of species in A site; B = number of species in B site (Shannon & Wiener, 1963).

3. RESULT AND DISCUSSION

In total, 40 specimens were captured in 2009, 2019. Collected specimens, direct observation in the field, the materials retrieved from local households, and combination of previously published records shows that there are 54 species belonging to 10 families and 10 orders. (Tab 2).

Table 2. Small mammals recorded in NS – NL Nature Reserve

No.	Scientific name	2013, 2015	2009, 2019
	I. EULIPOTYPHIA Gregory, 1910		
	Erinaceidae		
1	*Hylomys suillus* Müller, 1840		S (new recorded)
	II. CHIROPTERA Blumbach, 1779		
	Pteropodidae Gray, 1821		
2	*Cynopterus brachyotis* (Müller, 1838)	R	
3	*Cynopterus sphinx* (Vahl, 1797)	R	S
4	*Eonycteris spelaea* (Dobson, 1871)		S (new recorded)
5	*Rousettus amplexicaudatus* (E. Geoffroy, 1810)	R	
6	*Rousettus leschenaulti* (Desmarest, 1820)	R	
7	*Sphaerias blanfordi* (Thomas, 1891)		S (new recorded)
	Megadermatidae H. Allen, 1864		
8	*Lyroderma lyra* E. Geoffroy, 1810	R	
	Hipposideridae Lydekker, 1891		
9	*Aselliscus stoliczkanus* (Dobson, 1871)	R	
10	*Coelops frithii* Blyth, 1848	R	
11	*Hipposideros armiger* (Hodgson, 1835)	R	
12	*Hipposideros gentilis* K. Andersen, 1918	R	S
13	*Hipposideros larvatus* (Horsfield, 1823)	R	S
14	*Hipposideros lylei* Thomas, 1913	R	
15	*Hipposideros turpis* Bangs, 1901	R	

	Rhinolophidae Gray, 1825		
16	*Rhinolophus affinis* Horsfield, 1823	R	
17	*Rhinolophus pearsonii* Horsfield, 1851	R	
18	*Rhinolophus pusillus* Temminck, 1834		S (new recorded)
19	*Rhinolophus rex paradoxolophus* Bourret, 1951	R	
	Emballonuridae Gervais, 1855		
20	*Taphozous melanopogon* Temminck, 1841	R	
	Verspertilionnidae Gray, 1821		
21	*Kerivoula picta* (Pallas, 1767)	R	
22	*Murina annamitica* Francis, Eger, 2012		S (new recorded)
23	*Murina cyclotis* Dobson, 1872		S (new recorded)
24	*Murina feae (Thomas, 1891)*		S (new recorded)
25	*Murina harrisoni* Csorba, Bates, 2005		S (new recorded)
26	*Murina huttoni* (Peters, 1872)		S (new recorded)
27	*Harpiocephalus harpia* (Temminck, 1840)		S (new recorded)
28	*Myotis chinensis* (Tomes, 1857)	R	
29	*Myotis sp.*		S (new recorded)
30	*Hypsugo pulveratus* (Peters, 1871)		S (new recorded)
31	*Ia io* Thomas, 1902	R	
32	*Scotomanes ornatus* (Blyth, 1851)	R	S
33	*Scotophilus heathii* Horsfield, 1831	R	
	Miniopteridae Dosson, 1875		
34	*Miniopterus fuliginosus* (Hodgson, 1835)	R	S
	III. RODENTIA Bowdich, 1821		
	Sciuridae Fischer de Waldheim, 1817		
35	*Ratufa bicolor* (Sparrman, 1778)	O	
36	*Belomys pearsonii* (Gray, 1842)	R	
37	*Hylopetes phayrei* (Blyth, 1859)	R	
38	*Petaurista philippensis* (Elliot, 1839)	S	
39	*Callosciurus erythraeus* (Pallas, 1779)	O	S
40	*Callosciurus inornatus* (Gray, 1867)	O	
41	*Dremomys pernyi* (Milne–Edwards, 1867)	R	
42	*Dremomys rufigenis* (Blanford, 1878)	R	
43	*Tamiops maritimus* (Bonhote, 1900)	O	
	Muridae Illiger, 1811		

44	*Bandicota indica* (Bechstein, 1800)	S, R	
45	*Berylmys bowersi* (Anderson, 1879)	S, R	S
46	*Chiropodomys gliroides* Blyth, 1856	S, R	
47	*Leopoldamys sabanus* (Thomas, 1887)	S, R	S
48	*Maxomys surifer* (Miller, 1900)	S, R	S
49	*Mus musculus* Linnaeus, 1758	S, R	
50	*Mus pahari* Thomas, 1916	S, R	S
51	*Rattus andamanensis* (Blyth, 1860)	S, R	
52	*Rattus argentiventer* (Robinson, Kloss, 1916)	S, R	
53	*Rattus nitidus* (Hodgson, 1845)	R	
54	*Rattus tanezumi* Temminck, 1844	S, R	S

Notes: S: specimens; O: observation; R: references

In the species composition, the Chiroptera and Rodentia orders are recorded the most species richness with 33 and 20 species respectively. In bat fauna, Vespertilionidae family is the most species diverse with 14 species, next to Hipposideridae family with 7 species. Based on survey effort time, *Hipposideros gentilis*, *Sphaerias blanfordi*, *Cynopterus sphinx* and *Hipposideros larvatus* were some most common species with the highest catch frequency. 10 specimens *Cynopterus sphinx* were captured and released including 3 males and 7 females, only two male and female kept as voucher specimens. In addition, some dominant vespertilionidae were also found such as *Murina cyclotis*, *Hypsugo pulveratus*. Some cave such as Dai Cave, Thon Chieng Cave are home to some populations such as *Hipposideros gentilis, Hipposideros larvatus*.

Murina feae

Hipposideros cineraceus

Eonycteris spelaea

Hypsugo pulveratus

Fig 1. Flying photo of some recorded bats in NS – NL NR (Sources: Dr. Nguyen Vu Khoi – WAR)

In the rodent fauna, the Muridae family is most richness with 11 species. *Maxomys surifer, Rattus tanezumi and Leopodamys sabanus* species were trapped with the highest catch frequency. In the field survey, 5 specimens of *Maxomys surifer*, *Rattus tanezumi* species and 4 specimens of *Leopodamys sabanus* were collected in limestone mountainous in elevation 300 – 450m otherwise other rodents such as *Mus pahari*, *Berylmys bowersi* trapped 1–2 specimens. Besides, we recorded 1 specimen *Hylomys suillus* species belong Eulipotyphla order, collected along streams. Compared with the previous study on the bat fauna of Pham T.T. et al., 2013 and Dong T.H. et al., 2015, This survey was new recorded *Hylomys suillus* species belong to Eulipotyphia order, 2 species *Eonycteris spelaea* and *Sphaerias blanfordi* in Pteropodidae family, 1 species in Rhinolophidae and 8 species in Verspertilionnidae (Tab 3, Fig 1).

The survey calculated the similarity of bat fauna between Ngoc Son– Ngo Luong NR, Pu Luong NR and Cuc Phuong National Park, located limestone karst in northern Vietnam. Compare with research of Vu Dinh Thong 2004, the Sorensen – Dice coefficient between Cuc Phuong NP and Pu Luong NR is the highest, about 0.47. Ngoc Son – Ngo Luong NR has a higher similarity with Cuc Phuong NP than Pu Luong NR, SI is around 0.29. Out of total 58 species of bats recorded in 3 regions, there are 9 species distributed in all 3 regions, mainly focusing on some common and dominant species such as *Murina cyclotis, Hipposideros larvatus, Cynopterus sphinx.*

Table 3. Comparing bat fauna recorded in Ngoc Son– Ngo Luong NR, Pu Luong NR and Cuc Phuong NP

		Cuc Phuong NP	Pu Luong NR	Ngoc Son– Ngo Luong NR
1	*Rousettus leschenaulti*	X	(X)	X
2	*Rousettus amplexicaudatus*	X		X
3	*Eonycteris spelaea*	X	X	X
4	*Cynopterus brachyotis*	X		X
5	*Cynopterus sphinx*	X	(X)	X
6	*Sphaerias blanfordi*			X
7	*Macroglossus minimus*	X		
8	*Megaderma spasma*	X		
9	*Lyroderma lyra*			X
10	*Aselliscus stoliczkanus*	X	X	X
11	*Hipposideros armiger*	X		X
12	*Hipposideros bicolor*	X	X	
13	*Hipposideros cineraceus*		X	
14	*Hipposideros fulvus*		X	
15	*Hipposideros gentili*			X

16	*Hipposideros larvatus*	X	X	X
17	*Hipposideros lylei*	X		X
18	*Hipposideros turpis*		X	X
19	*Coelops frithii*	X		X
20	*Rhinolophus affinis*	X	X	X
21	*Rhinolophus macrotis*		X	
22	*Rhinolophus malayanus*		X	
23	*Rhinolophus marshalli*	X		
24	*Rhinolophus pearsonii*	X	X	X
25	*Rhinolophus pusillus*	X		X
26	*Rhinolophus rex paradoxolophus*	X		X
27	*Rhinolophus rouxii*	X	X	
28	*[Rhinolophus subbadius]*		X	
29	*Rhinolophus thomasi*	X	X	
30	*Taphozous melanopogon*	X		X
31	*Kerivoula hardwickii*	X	X	
32	*Kerivoula picta*			X
33	*Murina aurata*		X	
34	*Murina tubinaris*		X	X
35	*Murina cyclotis*	X	X	X
36	*Murina anamitica*			X
37	*Murina feae*			X
38	*Murina harrisoni*			X
39	*Murina huttoni*			X
40	*Myotis chinensis*	X		X
41	*Myotis siligorensis*	X	X	
42	*Myotis ater*	X		
43	*Myotis daubentonii*	X		
44	*Myotis formosus*	X		
45	*Pipistrellus ceylonicus*		X	
46	*Pipistrellus paterculus*	X		
47	*Pipistrellus javanicus*	X	(X)	
48	*Pipistrellus coromandra*	X		
49	*Pipistrellus tenuis*	X	X	
50	*Pipistrellus cadornae*	X		
51	*Hypsugo pulveratus*	X		X
52	*Tylonycteris pachypus*	X		
53	*Ia io*	X		X
54	*Scotomanes ornatus*	X		X
55	*Scotophilus heathii*	X		X
56	*Miniopterus schreibersi*	X		

57	*Miniopterus australis*	X		
58	*Miniopterus fuliginosus*			X
	Total	***40***	**24**	**32**

Conservation infomation in Ngoc Son – Ngo Luong NR

From previous studies by Pham Thanh Tung 2013 and Dong Thanh Hai 2015, illegal logging is still the direct cause of biodiversity decline in the limestone landscape in southwestern Hoa Binh province. Large areas of shrubland as a result of over–harvesting, firewood, and grazing have been documented in a number of studies. (Pham T. T. et al., 2013; Phung V. P. et al., 2014). Besides, hunting still occurs in some communes in nature reserve, usually in the dry season, November, December. It is conducted by local ethnic people and neighborhoods nearby serving mainly food needs also business needs (Cano et al., 2013). The rangers also collaborated with local authorities confiscated guns and traps. Among small mammals, some species in Sciuridae family such as *Callosciurus erythraeus*, *Dremomys rufigenis* are subjects are regularly hunted for food and trade value. Besides, some squirrels, considered to be threatened in Vietnam Red Data Book as *Ratufa bicolor*, *Hylopetes alboniger*, *Petaurista philippensis,* are also frequently hunted (Vietnam Red Data Book, 2007).

Moreover, due to the increasing demand for wildlife consumption, local people are more likely to trap mammals for trading. In addition, they also trap animals for their daily food when they stay a long time in the forest for product exploitation. One of the forest products, orchids, is highly demanded and intensively exploited from forests. Moreover, wildlife trading is becoming more and more difficult to control because these activities are prohibited by laws, then local people and traders often make deals illegally. So, it is necessary to carry out frequent patrolling and monitoring programs to control the hunting activities of local people. These programs should be coordinated with other authorities such as commune policies and local forest protection forces. Communication and education activities on forest protection should continue to be updated and disseminated to local people, restaurant owners, and wildlife traders in several areas. Legal regulations and punishment should be strengthened for nature protection.

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REFERENCES

1. BirdLife International & the Forest Inventory and Planning Institute (2001), *Sourcebook of Existing and Proposed Protected areas in Vietnam: Second Edition*, Hanoi, Vietnam.
2. Cano L.S & Telleria J. L. (2013), "Local ecological knowledge as a tool for assessing the status of threatened vertebrates: a case study in Vietnam", *Oryx*, 47(2), pp. 177–183.

3. Cano L.S. & Pham Q.T. (2010), *An Approach to Key Extinguished, Threatened and Endangered Vertebrate Species in Ngoc Son Luong Nature Reserve of Hoa Binh Province*, Unpublished Report No. 7, Ngoc Son Ngo Luong Nature Reserve Project. FPSC/FPD Hoa Binh/AECID, Hoa Binh, Vietnam.
4. Csorba G., Ujhelyi P. & Thomas N. (2003), *Horseshoe Bats of the World (Chiroptera: Rhinolophidae)*, Bishop's Castle, Shropshire: Alana Books.
5. Dang N. C., Endo H., Nguyen T. S., Oshida T., Le X. C., Dang H. P., Lunde D.P., Kawada S. I., Hayashida A. & Sasaki M. (2008), *Checklist of Wild Mammal Species of Vietnam*, Hanoi: Institute of Ecology and Biological Resources, 400 p. [In Vietnamese].
6. Daniel Willcox, Do T. H. & Tran Q. P. (2011), *Report on the winter – spring survey for small carnivores and pangolins in the Ngoc Son – Ngo Luong Nature Reserve, Hoa Binh province*, Ninh Binh, Vietnam.
7. Do A.T., Phung V.P., Nguyen V.H. & Nguyen, D.M. (2008), Survey Report on Forest Type Survey. Unpublished Report No. 1, Ngoc Son Ngo Luong Nature Reserve Project. FPSC/FPD Hoa Binh/AECID/FFI, Hanoi, Vietnam.
8. Dong T.H. (2015), "Diversity of mammals In Ngoc Son – Ngo Luong Nature Reserve, Hoa Binh province", *Journal of Forest Science*, 4, pp. 4072–4083.
9. FIPI (FOREST INVENTORY AND PLANNING INSTITUTE) (2005), Feasibility Study to establish the Ngoc Son Ngo Luong Nature Reserve, Unpublished Report, Ministry of Agriculture and Rural Development, Hanoi, Vietnam. [In Vietnamese].
10. Francis C. M. (2019), *Field Guide to the Mammals of South–East Asia*, Second edition. Bloomsbury Publishing, London, 416 p.
11. Kruskop S.V. (2013), *Bats of Vietnam: Checklist and an Identification Manual*, Moscow: Joint Russian–Vietnamese Sciences and Technological Centre & Zoological Museum of Moscow State University, 299 p.
12. Le T.D., Huy L.T, Duc D.Q., Vinh L.T., L.Q. & Hao L.V. (2008), *Survey on Vertebrate Fauna of Ngoc Son–Ngo Luong Nature Reserve*, Unpublished Report No. 2, Ngoc Son Ngo Luong Nature Reserve Project. FPSC/FPD Hoa Binh/AECID/FFI, Hanoi, Vietnam.
13. Lunde D.P. & Nguyen T. S. (2001), *An Identification Guide to the Rodents of Vietnam*, New York: Center for Biodiversity and Conservation, American Museum of Natural History, 80 p.
14. Ngoc Son – Ngo Luong Nature Reserve Management Board (2010), Report on assessment of conservation needs of Ngoc Son – Ngo Luong Nature Reserve, Hoa Binh province.
15. Nguyen Q.H., Phan K.L., Nguyen T.H., Averyanov L., Nguyen S.K, Pham V.T., Nguyen V.T. & Nguyen T.V. (2012), "Contribution to assess the conservation status of some potential plant taxa in Ngoc Son – Ngo Luong Nature Reserve, Hoa Binh province", *Journal Science and Technology*, 42, pp. 77–89.
16. Pham Q.T. (2013), *Research on biodiversity management in the limestone landscape in the southwest of Hoa Binh province*, PhD thesis in Forestry, Forestry University, Hanoi.
17. Phung V.P., Do A.T. & Nguyen T.T. (2014), "Preliminary Study on Forest Vegetation Types in Ngoc Son Ngo Luong Nature Reserve, Hoa Binh Province", *VNU Science Journal: Natural*

Science and Technology, 30 (4), pp. 30–39.

18. Thao A.T. (2015), *Characteristic of the Reptile and amphibian fauna in the Ngoc Son – Ngo Luong Nature Reserve, Hoa Binh Province*, Thesis in Forestry, Forestry University, Hanoi.

19. Vietnam Red Data Book (2007), *Vietnam Red Data Book. Part1. Animals*, Hanoi, Publishing House of Natural Science and Technology, 515 p. [In Vietnamese].

20. Vu D. T. (2004), *A Preliminary Survey of the Bat Fauna of Pu Luong Nature Reserve, Thanh Hoa Province, North–central Vietnam, Pu Luong–Cuc Phuong Limestone Landscape Conservation Project*, International Wildlife Conservation Organization – Vietnam Program and Forest Protection Department, Hanoi.

21. Wilson D.E. & Reeder D.M. (eds.) (2005), *Mammal Species of the World: Taxonomic and Geographic Reference*, Third edition, Vols.1–2. Baltimore: Johns Hopkins University Press.

THÔNG TIN CẬP NHẬT VỀ KHU HỆ THÚ NHỎ TẠI KHU BẢO TỒN THIÊN NHIÊN NGỌC SƠN – NGỔ LUÔNG, TỈNH HOÀ BÌNH

Tóm tắt: *Điều tra bổ sung và cập nhật thành phần các loài thú nhỏ phân bố tại Khu bảo tồn thiên nhiên Ngọc Sơn – Ngổ Luông (KBTTN–NSNL), tỉnh Hòa Bình. KBTTN–NSNL nằm trong quần thể núi đá vôi Pù Luông – Cúc Phương của miền Bắc Việt Nam. Dựa trên các mẫu vật khảo sát thực địa kết hợp với các công bố trước đây, tổng số 54 loài thú nhỏ thuộc 10 họ và 3 bộ đã được ghi nhận ở khu vực này. Trong đó, Sphaerias blanfordi, Cynopterus sphinx, Hipposideros gentilis, Hipposideros larvatus, Murina cyclotis là những loài phổ biến trong khu hệ Dơi; Leopodamys subanus, Maxomys surife, Rattus tanezumi là những loài đặc trưng trong khu hệ Gặm nhấm. Tuy nhiên, dưới tác động của tình trạng khai thác bất hợp pháp, săn bắn và các hoạt động của con người đã và đang gây ảnh hưởng tiêu cực đến các giá trị đa dạng sinh học. Vì vậy, việc bảo tồn đa dạng sinh học vấn đề cấp bách hiện nay.*

Từ khoá: *Hệ thú nhỏ, danh sách, núi đá vôi, Việt Nam.*

RESEARCH ON ANSWER RESISTANCE (VEGETABLES-ECHINOCHLOA CRUS-GALLI) OF SOME NEW QUALITY RICE VARIETIES IN LABORATORY CONDITIONS

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Abstract: *Research and production of clean, high-quality and high-yield rice, sustainable environmental protection are the most important and important tasks of many countries in the world as well as in Vietnam today. Therefore, the research, selection and creation of rice varieties that are both high-yield and resistant to pests, weeds, and climate change, in order to minimize the use of herbicides and pesticides. Deeply protecting people's health and the environment sustainably is extremely necessary. Our research initially identified a number of rice lines / cultivars resistant to weeds (Echonochloa Crus-Galli) such as: BT7DB, Gia Loc 26, HT7DB, DH18, BC15-02, CL. 9DB, XH1, 18NP2, TD. This will be a rich and valuable starting material source, effectively serving the selection and creation of weed-resistant rice varieties in sustainable food production.*

Keywords: *Rice, antagonism, grass, environment.*

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1. INTRODUCTION

Vietnam is one of the leading major rice exporting countries in the world. However, Vietnam's main rice export markets are developing countries, including Southeast Asia (about 40-50%), African countries (about 20-30%), there are also other markets such as the Middle East and North America (FAO, 2013) [3]. One of the reasons that the rice export market in Vietnam is limited is the impact of biotic and abiotic adverse factors that reduce the yield and quality of rice. Among these unfavorable factors, weeds are a major biological limitation on rice production in Vietnam, especially increases the economic losses seriously (reducing about 30% - 50% of rice production in the Mekong Delta) (Chin, 2001) [2].

The use of herbicides can reduce weed control time and stabilize rice yields. However,

overuse of synthetic herbicides to kill weeds is currently a serious problem in Vietnam, leading to environmental pollution, especially the soil environment (imbalance of soil microbiota). , change the physical and chemical properties as well as reduce nutrients in the soil), agricultural products are unsafe and affect human health, in addition, some weeds have become resistant to drugs. herbicide (Khanh and Cs, 2013) [8] According to statistics since 1991, the amount of synthetic herbicide was 900 tons, in 2012 it was 42,000 tons, equivalent to 300 million USD (ILS, 2013) [4].

Weed inhibition through plant antagonism (Allelopathy) is one of the most optimal solutions to reduce dependence on synthetic herbicides (Rice, 1984) [6]. Thus, by this solution, it is possible to significantly increase the yield and quality of crops without losing environmental costs. Recent research directions on the evaluation and selection of rice varieties with potential for plant antagonism are currently of interest to domestic and foreign scientists. Stemming from the above reasons, we carried out the project "Research on resistance to weeds (Echinochloa Crus-Galli) of some new quality rice lines/cultivars under laboratory conditions"

The researches were carried out to evaluate the plant antagonistic potential of 20 new quality rice lines / cultivars in Vietnam under laboratory conditions from which to identify the rice varieties with weed resistance potential. in laboratory conditions, for weed control in the field. The research results of the topic will be an important database and material for the next scientific research on antagonism in rice, and also contribute to the selection of rice varieties with inhibitory ability. weeds, suitable for rice farming conditions in Vietnam, help farmers increase income, reduce poverty and ensure human health. In Vietnam, the research on plant antagonistic activity (Allelopathy) is a new area that has not been studied much. Therefore, this topic gives a new direction in plant breeding with potential for weed inhibition. Evaluation of a number of Ban Da rice varieties with potential for weed inhibition. Paving the way for further studies on plant antagonism (Allelopathy). The combination of antagonistic (inhibitory) activities (Allelopathy) with traditional herbicides instead of herbicides will reduce environmental pollution, increase crop quality and preserve health. healthy people with the goal of developing sustainable agricultural products. The rice lines and varieties with high antagonistic potential selected in this topic will be the starting materials for the selection and breeding of rice varieties with weed resistance.

2. MATERIALS AND METHODS

2.1.1. Preparation of rice landraces and barnyard grass seeds

Research material consists of 20 new quality rice lines/cultivars collected from many different ecological regions and selected from modern methods of Biotechnology. The list of collected lines/cultivars is shown in Table 1.

Barnyandgras seeds are collected in the fields of the Center for Technical Equipment Transfer and Agricultural Extension (Vinh Quynh, Thanh Tri, Hanoi, 2020). Seed preparation: Remove all badger seeds and flat seeds by placing them in water, collecting

firm seeds at the bottom.

Table 1. List of 20 new quality rice lines / cultivars used in the study

No	Line/breed name	No	Line/breed name
1	NPT3	11	18NP2
2	KD18DB	12	DH18
3	BT7DB	13	HYT100
4	HT7DB	14	CL.9DB
5	NPT4	15	CL.8DB
6	Gia Loc 26	16	XH1
7	BC15-02	17	XH3
8	TSL1	18	XH8
9	Thu Do 1	19	MT5
10	TD	20	MT6

2.1.2. Bioassay

Experimental conditions: After sowing rice-grass seeds into Petry dishes, transfer to the laboratory to ensure the following conditions: temperature 250C, light 4000 lux, lighting time 9.00 - 17.00 h. Experimental layout: The experiment was designed in a completely randomized block model with 3 replicates, 20 treatments on cage grass. The experiment is performed according to the following steps:

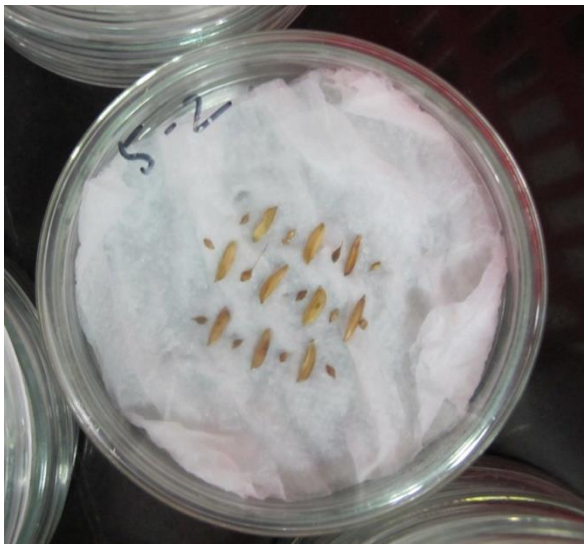

Figure 1. Diagram of sowing rice seed - grass seed

+ Prepare two types of petry dishes with diameters of 9 cm and 10 cm, respectively, that have been dried, lined with absorbent paper close to the bottom of the Petry dish with a diameter of 9 cm. Absorbent paper is used to maintain moisture inside the Petri dish to help the rice and grass seeds germinate.

+ Prepare 20 paddy seeds / 1 rice variety, 20 grass seeds for each rice variety and do not

treat any chemicals before using.

- Sowing seeds: Sowing method is conducted as follows: rice is sown in 3 rows, 4 seeds in the middle row and 3 seeds on each side. Grass seeds in the field are sown alternating between 2 grains of rice, so the middle row of rice will have 5 grass seeds and 4 grass seeds on the two sides.

For the control plate, only 13 seeds of grass in the field were sown.

- Add water: Each day add 5ml of water to each Petri dish.

Sampling and measurement of grass morphological parameters in the field

+ After 5 days of sowing, to measure morphological indicators of grass in the field, including: height of stems and length of roots.

2.1.3. Statistical analysis

+ Figures are calculated using Excel software.

+ Applying SAS software (2008) to analyze and compare experimental results.

The means were separated on the basis of the least significant differences (LSD) at the 0.05 probability level.

2.1.4. Results and Discussion

In the green soil environment, antagonists release antagonists from the roots into the environment, affecting the growth of surrounding plants. In the laboratory, young seedlings release plant antagonists through the root path into the blotting paper.

The results of the study to evaluate the antagonistic potential of the 20 new quality rice lines / cultivars under the laboratory conditions are shown in Table 2 and Figure 2.

Table 2. *Research results assessing the ability of 20 new quality rice lines / cultivars to inhibit grass in the laboratory conditions*

No	Name of rice strain / variety	Body length (cm)	Body length suppression%	Root length (cm)	Inhibition of root length%	Middle inhibitors jar (%)
1	HT7DB	4,57	24,34	2,56	57,85	45,37
2	BC15-02	4,36	28,05	2,12	65,10	46,05
3	KD18DB	4,30	21,98	2,26	61,11	40,54
4	BT7DB	4,15	30,72	2,07	67,15	48,35
5	NPT3	7,88	-31,95	3,32	42,96	5,46
6	NPT4	5,00	10,95	2,34	55,24	32,10
7	Gia Loc 26	3,65	29,65	2,05	65,07	47,75
8	Thu Đo 1	4,87	10,97	2,72	47,54	30,07
9	TSL1	4,95	12,15	2,64	48,97	31,16
10	CL.8DB	4,30	14,05	2,66	54,66	33,75
11	TD	4,66	21,00	2,07	63,05	41,55
12	18NP2	4,75	20,95	2,16	63,25	42,24

13	DH18	4,35	29,08	2,18	63,75	46,36
14	HYT100	4,68	18,00	2,54	55,98	36,72
15	CL.9DB	4,15	25.10	2,15	60,10	41,98
16	MT5	4,64	17,05	2,25	60,05	38,09
17	MT6	4,76	21,54	2,54	53,10	36,73
18	XH1	4,56	21,00	2,11	66,58	46,05
19	XH3	5,10	13,05	2,10	62,94	39,08
20	XH8	5,05	14,08	2,07	61,72	38,05
Control		5,86		5,35		
TB ức chế		4,32	18,00	2,34	57,94	38,17
$LSD_{0,05}$			0,76		0,95	0,83

Note: (-) Stimulate grass growth laboratory

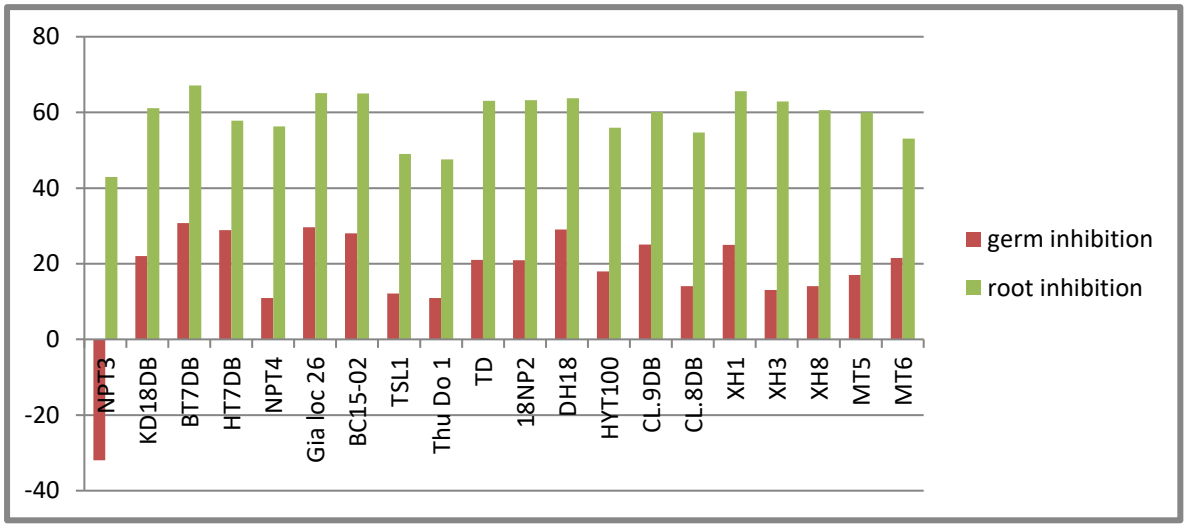

Figure 2. Diagram of percussion grass inhibition under conditions

Effects of 20 rice lines / cultivars on height development of plants and trees in cages.

The results obtained in Table 2 and Figure 2 we see:

The plant antagonists contained in the cultivated rice varieties released reduced the average height in the field grass by 30.72% (4.15 cm) compared to the control of 5.86 cm.

- According to the collected data, it is found that in each different rice variety, inhibition is different. The rice variety with the highest inhibitory ability to plant height is BT7ĐB (30.72%).

- The rice variety with the lowest inhibitory capacity is Thu Do variety (10.97%).

Among these, there are 11 varieties that reduce plant height by over 20% such as: BT7DB (30.72%), Gia Loc 26 (29.65%), HT7ĐB (28.84%), DH18 (29.08%). , BC15-02 (28.05%), Quality guarantee (25.10%), XH1 (25.00%), KD18DB (21.98%), 18NP2 (20.95%), TD (21.00 %), MT6 (21.54%).

- There are 8 rice varieties with inhibitory capacity of less than 20% such as HYT100 (18.00%), MT5 (17.05%), XH8 (14.08%), CL8.DB (14.05%), TSL1 (12.15%),

XH3 (13.05%), NPT4 (10.95%).

- NPT3 variety stimulates body height development -31.95% (7.88 cm).

- With the value of LSD.05 reaching 0.75, it shows that the formulas have different values and are significantly different from the control formulas at the 90% confidence level.

Effect of 20 rice lines / cultivars on the development of grass roots length.

- Through Table 2 and Figure 2, we see that the plant antagonists released from rice lines / cultivars reduced the average length of grass roots by 66.58% (2.10 cm) compared to control was 5.35 cm.

- The rice line with the highest ability to inhibit the root length is XH1 (66.58%).

- The variety with the lowest root length inhibition ability is NPT3 (42.90%).

- Out of a total of 20 rice lines / cultivars with: most of the lines / cultivars are more than 50% able to inhibit the weeds, arranged in the following order: XH1 (66.58%), Gia Loc 26 (65 , 07%), BT7DB (67.12%), BC15-02 (65.00%), DH18 (63.75%), XH3 (62.94%), 18NPT2 (63.25%), TD (63 , 05%), XH8 (61.72%), High quality (60.10%), MT5 (60.05%), HT7DB (57.85%), HYT100 (55.98%), NPT4 (56 , 25%), High quality (54.66%), MT6 (53.11%).

In addition, the remaining lines / cultivars inhibited more than 40% such as: TSL1 (48.97%), Thu Do 1 (47.54%), NPT3 (42.90%).

- Based on the results obtained above, we see that the inhibitory capacity is different for different varieties and the highest root length inhibitory line is XH1 (66.58%).

Most rice lines / cultivars have the ability to inhibit weed growth. The highest average inhibition was Gia Loc 26 (47.75%);

The lowest mean of inhibition was NPT3 (5.46%). There are 10 varieties with over 40% inhibitory ability: Gia Loc 26 (47.75%), BT7ĐB (48.35%), DH18 (46.38%), BC15-02 (46.05%), XH1 (46.05%), HT7DB (45.37%), 18NPT2 (42.24%), Special quality (41.98%), TD (41.55%), KD18DB (40.54%).

There are 9 varieties with inhibitory ability from 29% to less than 40%: XH3 (39.08%), MT5 (38.09%), XH8 (38.05%), MT6 (36.73%), HYT100 (36.72%), Quality 8 (33.75%), NPT4 (32.10%), TSL1 (31.16%), Capital 1 (30.07%).

- The results obtained in Table 2 Figure 2 shows that are consistent with the results reported by Olofsdotter and Navarez (1996) on the evaluation of the antagonistic potential of some rice varieties under the laboratory conditions. Fruit inhibits root length greater than tree height inhibition.

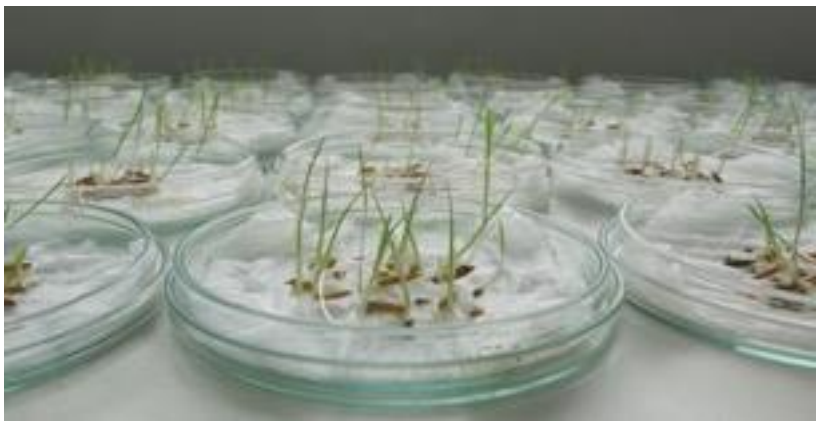

Figure 3. Growth of rice varieties and basal grass after 5 date of sowing on Petri dishes

Green plants produce many secondary substances including plant antagonists. Plant antagonists are capable of affecting the growth of neighboring plants. Both plants and weeds possess such substances. These substances are released from plants into the environment, in the soil by secreting their roots or by the decay products of their dead cells. Many rice varieties release plant antagonists and inhibit the growth of many plants under laboratory conditions.

3. CONCLUSION

From the above research results, we draw the following conclusions:

- The results of assessing the growth inhibition ability of 20 new quality rice lines / cultivars on caged grass by in-room experiments showed that the indigenous rice varieties were capable of inhibiting the growth of roots and height. tree

- The rice varieties have good ability to inhibit plant height growth such as: BT7DB, Gia Loc 26, HT7ĐB, DH18, BC15-02, CL.9DB, XH1, 18NP2, TD, MT6;

- Rice lines / cultivars have the ability to inhibit root length growth such as: XH1, Gia Loc 26, BT7DB, BC15-02, DH18, XH3, 18NP2, CL.9DB, XH1, TD;

Thus, through research, evaluation and survey, we found that the lines / cultivars have the ability to inhibit plant height and root length are: BT7DB, Gia Loc 26, HT7DB, DH18, BC15-02, CL.9DB, XH1, 18NP2, TD.

Thereby, continuing to evaluate plant antagonistic activity in net house conditions and in the field to accurately determine the varieties with the highest antagonistic potential with the highest wild type. Isolation, identification of antagonistic compounds related to the ability to inhibit weeds. Synthesize antagonistic compounds to create a basis for development of natural herbicides to help develop agriculture, increase productivity to serve people's life.

REFERENCES

1. Ahn J.K., Hahn. S.J., Kim. J.T., Khanh. T.D., Chung. I.M. (2005), *Evaluation of allelopathic potential among rice (Oryza sativa L.) germplasm for control of Echinochloa crus galli P.Beauv*

in the field. Crop Protection. 24:413-419.

2. Chin. D.V. (2001), "Biology and management of barnyard grass. red sprangletop and weedy rice". *Weed Biology and Management*. 1:37-41.
3. Khanh T.D., Cong L.C., Chung I.M., Xuan T.D. (2009), "Variation of weed-suppressing potential of Vietnamese rice cultivars against barnyard grass (*Echinochloa crus-galli*) in laboratory". *Greenhouse and field screenings. Journal of Plant Interactions*. 4:209-218.
4. Khanh T.D., Linh L.H., Linh T.H., Quan N.T., Trung K.H., Cuong D.M., Hien V.T.T., Ham L.H., Xuan T.D (2013). "Integration of allelopathy to control weeds in rice. In: Herbicides" – *Current Research and Case Studies in Use*. Andrew. J (eds). 75-99.
5. Khanh T.D., Xuan T.D., Chin D.V., Chung I.M., Abdelghany E.A., Tawata S. (2006), "Current status of biological control of paddy weeds in Vietnam". *Weed Biology and Management*. 6:1-9.
6. Khanh T.D., Xuan T.D., Chung I.M. (2007), "Rice allelopathy and possibility for weed management". *Annals of Applied Biology*. 151:325-339.
7. MARD –Ministry of Agriculture and Rural Development (2016). *Annual report of rice production*. December. 2016.
8. Rice E.L, (1984), Allelopathy.2nd ed. Academic Press Inc. Orlando. FL, p.422.

NGHIÊN CỨU KHẢ NĂNG KHÁNG CỎ DẠI (CỎ LỒNG VỰC-ECHINOCHLOA CRUS-GALLI) CỦA MỘT SỐ DÒNG GIỐNG LÚA CHẤT LƯỢNG MỚI TRONG ĐIỀU KIỆN PHÒNG THÍ NGHIỆM

Tóm tắt: *Nghiên cứu và sản xuất lúa gạo sạch, chất lượng và năng suất cao, bảo vệ môi trường bền vững là nhiệm vụ cấp thiết quan trọng hàng đầu của nhiều quốc gia trên thế giới cũng như ở Việt Nam hiện nay. Vì vậy việc nghiên cứu, chọn tạo ra các giống lúa vừa có năng suất chất lượng cao, vừa có khả năng kháng sâu bệnh, cỏ dại, chống biến đổi khí hậu, nhằm hạn chế tối đa sử dụng thuốc trừ cỏ, thuốc trừ sâu… bảo vệ sức khỏe người dân và môi trường bền vững là vô cùng cần thiết. Nghiên cứu của chúng tôi bước đầu đã xác định được một số dòng/giống lúa có khả năng kháng lại cỏ dại (cỏ lồng vực- Echonochloa Crus-Galli) như: BT7ĐB, Gia Loc 26, HT7ĐB, DH18, BC15-02, CL. 9ĐB, XH1, 18NP2, TD. Đây sẽ là nguồn vật liệu khởi đầu phong phú có giá trị, phục vụ đắc lực cho công tác chọn tạo các giống lúa có khả năng kháng cỏ dại trong sản xuất lương thực bền vững.*

Từ khóa: *Lúa gạo, đối kháng, cỏ lồng vực, môi trường.*

FROM UNIVERSITY PORTAL TO KNOWLEDGE MANAGEMENT SYSTEM

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Abstract: *Quality has always been an essentiality of a university. With the development of IT, especially web technology, Web Portal has become a management tool, aiding university in utilising resources, gaining a competitive advantage in university education. This paper presents Web Portal as a knowledge management system, a technological solution for university in targeting true education.*

Keywords*: Web portal, knowledge management system, knowlege sharing, KMS, knowledge management.*

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1. INTRODUCTION

Nowadays, with technological advances, a lot of services are digitalised which facilitate improving service quality and planning developmental strategy of organisations. University, as an institution providing multidisciplinary educational services, is in the process of implementing university autonomy model. To achieve this, intergrating the three fields Education, Research, Application in an organic body is vital and demands many resources that are being wasted in administrative activities. In such case, shifting activities into digitalisation does not only enhance efficiency but also help manager obtain more accurate and timely information, therefore formulating management policy suitable with the rapid change in the market economy. With the development of web technology, from simple informational website, universities have built web portal, the conversational gate between university, learner and related parties, allowing them to participate in a system operation process as a form of quality guarantee. This paper presents an approach to developing university's web portal as a digital knowledge management system, a technological solution for university in targeting true education.

2. DEFINITION

Before discoing on web portals as an essential knowledge management system in the universities, this paper starts with some basic definition of knowledge, knowledge management and web portal.

2.1.1. Data – Information - Knowledge.

To have a precise definition of knowledge management system (KMS), it is important, first look at knowledge contents. Knowledge is derived from data and information. Data is a collection of words, numbers, observations or facts, which are not meaningful. Data can be converted to information when it is put in a meaningful framework. Finally, knowledge is derived from information, which has been validated to be true. Maglitta [1] suggests that data is raw numbers and facts, information is processed data, and knowledge is "information made actionable". Chaffey and Wood [2] show the hierarchy in Figure 1, with the additional axes of meaning and value.

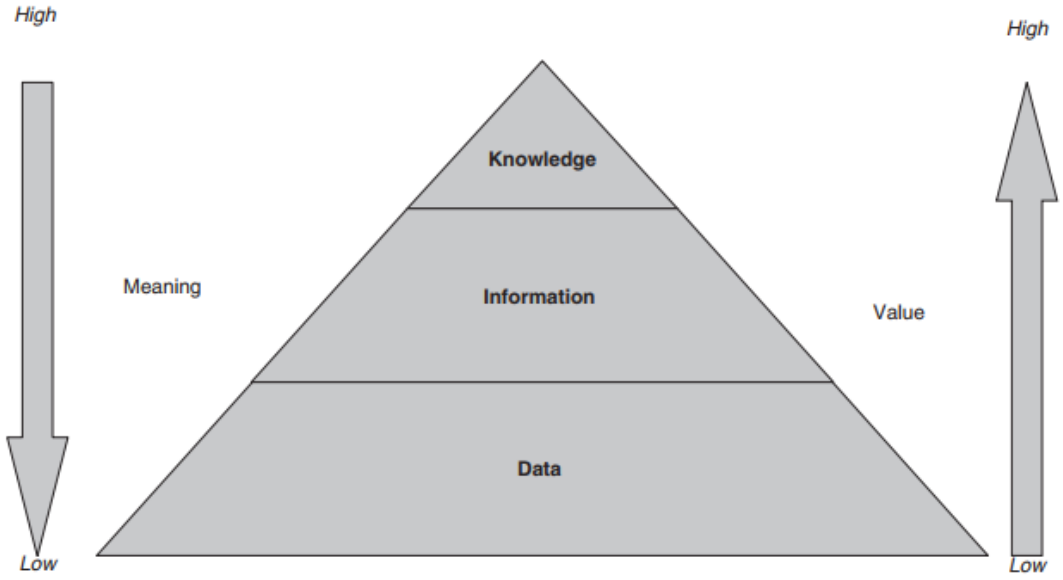

Figure 1. Data, information, and knowledge, according to Chaffey and Wood [2]..

2.1.2. Knowledge Management System

The term Knowledge Management - KM first appeared in the early 1990s. As Kimiz Dalkir [3] - a top-tier professional in knowledge management - defined: Knowledge management is initially considered as a process of methodical approach to understand the organisation, managing and spreading knowledge through an organisation in order to improve productivity and reduce unnecessary tasks.

As Kimiz Dalkir [3] - a top-tier professional in knowledge management - defined: Knowledge management is initially considered as a process of methodical approach to understand the organisation, managing and spreading knowledge through an organisation in order to improve productivity and reduce unnecessary tasks. An important issue related to knowledge management is understanding and integrating knowledge. This means knowledge

is only valuable and useful when shared. Computer network, with communication and information-sharing features, becomes a suitable environment for effective knowledge management. Knowledge system is established in organisations to aid collecting, integrating and spreading knowledge. These systems, in practice, are Knowledge Management System - KMS. Benbya et al. [4] divided KMS into four categories:

1- Content management tools: These tools mix and group knowledge from different originating sources.

2- Knowledge sharing tools: These tools provide the facility for sharing knowledge among people or organization.

3- Knowledge search and retrieval system: This provides the ability to search and retrieve knowledge from the systems.

4- General KMS: These types of systems provide the requirements for knowledge management in the organizations.

2.1.3. Portal as a Knowledge Management System

Web portals are general KMS that provide the facility for organizations or companies to share, create, exchange and reuse knowledge. Portals support knowledge management processes. Considering the technology of the knowledge management system, a portal is a network service that collects information from many sources into a single access point that is personalized. Azarbarzin [5] highlighted the differences between the website and web portal, as shown in Table 1:

Table 1. *Comparison between Website and Web Portal*

TT	Website	Web Portal
1	Website is owned by an organization or center.	Portal is user-centric, which means that a user can organize and offer information and data.
2	The user cannot interact with a website.	The user and portal can have two-way communication or interaction.
3	Website is not an essential knowledge domain.	Portal is the gateway to specific or special knowledge domain.
4	The information and sources on a website are, rarely updated.	The information sources on a web portal are updated, regularly by the owner.

Among the above differences, it can be seen that the unique feature that governs all other characteristics of the portal is personalization. Personalization is reflected in both aspects: the functionality dedicated to the individual user and the knowledge content with which that individual interacts.

2.2. Portals support for knowledge management processes

The web portal for university students is essential to learning. It is also important for the university portal to be integrated with the university IT infrastructure, both internal and external. A university portal can be viewed as a single point, which provides comprehensive access to information on courses, data search tools, educational resources, interactive teaching materials, communication tools, etc. It can act as a gateway, to provide access to learning resources for experts, teachers, or researcher, and allow interactive access to online information, and to other students.

A university portal potentially offers other stakeholders a vital link into the university. The new, wonderful, and challenging aspect of Web management posed by portals is the idea of creating and managing knowledge systems whose primary purpose is to sustain positive relationships between an institution's stakeholders and the institution [6]. Portals also represent new strategic means of increasing a university's competitive position by fostering innovation and research activities that can lead to greater acquisition of grants and improved prestige for the university.

Portals also serve to empower individuals within a more broadly defined university community. By providing easy accessibility to both explicit and tacit knowledge as well as communities of practice, people are not constrained by geographic or other physical barriers in terms of communicating and exploring new knowledge. "The portal will improve the efficiency of knowledge exchange and deliver a set of shared business objectives that include communications around best practices, a gateway to research on the use of teaching and learning through technology, professional development, policy development and review and resource development" [7].

2.3. Conceptual portal framework

Goodman et al. [8] mentioned that universities consider three aspects pertaining to use of the portals:

1 - Systems integration: By increasing the use of the Internet, universities have tried to have a more integrated IT system within their campuses. In this way, universities can transform more effectively and offer more varied services to the campus community.

2 - Utilization of e-business technology: Universities and other educational institutions have done likewise. In some countries, some important processes in e-business have been developed by educational institutions to offer better services to the staff and students.

3 - Provision for a wider use of data and services offered by existing systems: The knowledge and resources in the existing information systems of universities could be useful if the students and lecturers have easy access to them. Portals can be used to facilitate access to the required information.

The main reason for using the portals: efficiency because of its ease of development, easily customized interface, rich functionalities, and pluggable architecture. When users face

a problem, they search the relevant portal to find a solution. Portal framework can provide benefits, but it is clear that no framework can provide solutions to all problems. It is important to understand the of technology used and the framework before starting the development process

Allan et al [9] identified 5 standard features to consider when selecting a portal framework:

- Integration with the existing functionality
- Easy to develop new functionality
- Programming language independence
- Standards to access content
- Standards for interoperability and portability

Figure. 2 presents the conceptual framework with the basic knowledge management system that includes some main components of a portal administration, decision support, document management, Web management, content communication, and programs [10].

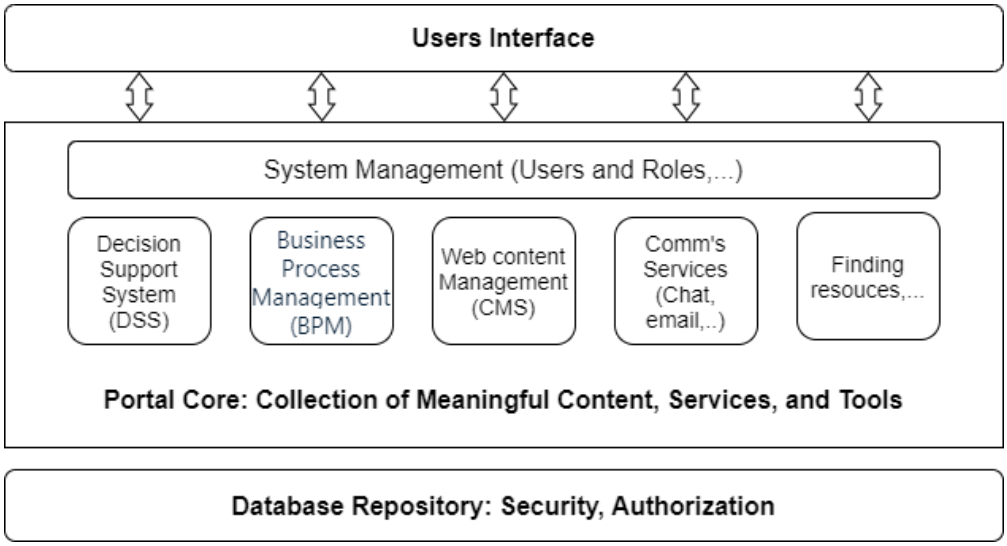

Figure 2. Conceptual Portal Framework [10]

2.4. Specification of some requirements of the University Portal.

Based on the characteristics and definition framework of web portal as a knowledge management system, we suggest some specifications for the aspects of university's web portal. These specifications are characterized requirements, guarantee stability and efficiency of web portal in the time of constantly and rapidly changing technology.

User Interface

- Web based: Responsive to popular web browsers such as Chrome, Firefox, .. Uses Unicode character codes.

- Install applications that have many frequent users on mobile devices using popular operating systems such as iOS, Android ,...
- User friendly interface. Restrict communication with users via symbols for internal use only, such as keys for entity.
- Data can be updated via forms or imported from spreadsheets. Reports can be printed directly in the web application and exported to Word, Excel or PDF files.
- User actions are minimized by maximizing automation. Uses the default based on context.

System Administration

- User logins only once for all applications
- Support storage access tracing, using system functions over time.
- Users are authorized to perform and only perform system functions corresponding to their rights and responsibilities.
- Users can and only can interact with data in accordance with their rights and responsibilities.
- Rights of system interaction (access to functions and data) change over time, according to user rights and responsibilities.
- Allow custom authorization of specific functions with corresponding data for each user group at the request of the school when needed.

Database

- Servers are installed to ensure high availability, minimizing the possibility of system interruption.
- Stored data must ensure integrity to guarantee system consistency according to the principle of "each event is only stored in one place".
- The system is open, has a customization mechanism that allows the addition of new features, or modifications when there are changes in policy and business.

Business Process Management

The following management functions, as shown in Table 2, need to ensure that the business process requirements are based on legal documents, in accordance with the actual conditions of the university. The work environment is designed for every user involved, in accordance with their position in the management process. In each module of the web portal, there are reports to support decision-making in related fields.

Table 2. *Business Process Management in University*

Business Process Management for	System Management	Decision Support	Business Process Management for Staffs

training management and learner support services	**(User and Roles)**	**System (DSS)**	
1. Curiculum Management			1. Office Management
2. Enrollment Management			2. Human Resource Management (HMR)
3. Training Management			3. QUALITY ASSURANCE MANAGEMENT
4. Examination and Evaluation Management			4. SCIENCE AND TECHNOLOGY MANAGEMENT
5. Progress Management			5. SCIENTIFIC JOURNAL
6. Student Management			6. COOPERATION DEVELOPMENT
7. Learning Management System (LMS)			7. Financial management
8. Library Management			8. Asset Management
9. Accomodation Management			

3. CONCLUSION

The quality of a university is not presented in the declaration of mission, vision and goals, but in the operation process of achieving such goals and undertaking the mission. Web portal, as a digital knowledge management system, fully and realistically reflect the operation of a university. As a result, web portal becomes a technical tool, proving the quality of the university. Technology is rapidly changing. Universities therefore have to constantly change their policy to suit the current practice and future development trend. The required characteristics of a web portal that this paper suggests are stable criterion for constructing a digital system, aiding university in sustainable development in a changing world.

REFERENCES

1. Maglitta J, «Smarten Up!,» *Computerworld,* vol. 29, n. 23, pp. 84-86, 1995.

2. D. Chaffey and S. Wood, Business Information Management: Improving Performance

using Information Systems, Harlow: FT Prentice Hall, 2005.

3. K. Dalkir, Knowledge Management in Theory and Practice, Boston: Elsevier Butterworth - Heinemann, 2005.

4. Benbya, Belbaly, Passiante, «Corporate portal: a tool for knowledge management synchronization.,» *International Journal of Information Management,* vol. 24, pp. 201-220.

5. Azarbarzin, «A Framework of Knowledge Portal for Malaysian,» 2008.

6. Richard N. Katz, "It's a Bird! It's a Plane! It's a … Portal?," in Web Portals and Higher Education: Technologies to Make IT Personal, ch. 1, EDUCAUSE and NACUBO, 2002.

7. Karen M. Vander Linde, and Sandy Johnson Jill Kidwell, Applying Corporate Knowledge Management Practices in Higher Education, Management Practices in Higher Education, Jan. 2000.

8. A. K. C. Goodman, «Frequently Asked Questions about Portals (FAQs),» *http://www.traffick.com/article.asp?aID=9,* 2002.

9. .J. Allan, A. Hardisty, S. Wilson and A. Powell, «Service Component Classification,» in *Proc. NeSC Workshop 14-17/7/2003, http://www.nesc.ac.uk/technical_papers/UKeS-2004-*.

10. Marjan Mansourvar,Norizan binti Mohd Yasin, «Web portal As A Knowledge Management System In The Universities,» *World Academy of Science, Engineering and Technology,* vol. 70, pp. 968-974, 2010.

TỪ CỔNG THÔNG TIN ĐIỆN TỬ TRƯỜNG ĐẠI HỌC ĐẾN HỆ QUẢN TRỊ TRI THỨC

Tóm tắt: *Chất lượng luôn là vấn đề then chốt của một trường Đại học. Cùng với sự phát triển của CNTT, đặc biệt là công nghệ Web, cổng thông tin điện tử đã trở thành công cụ quản trị giúp trường Đại học phát huy hiệu quả nguồn lực, đạt được lợi thế cạnh tranh trong giáo dục đại học. Bài báo này trình bày về Cổng thông tin điện tử với tư cách như một hệ quản trị tri thức, là một giải pháp công nghệ cho trường Đại học nhằm hướng tới nền giáo dục thực chất.*

Từ khóa*: Cổng thông tin điện tử, hệ quản trị tri thức, Web Portal, Knowledge Management system, knowlege sharing, KMS.*