Vietnam Atomic Energy Institute

ANNUAL REPORT 2023

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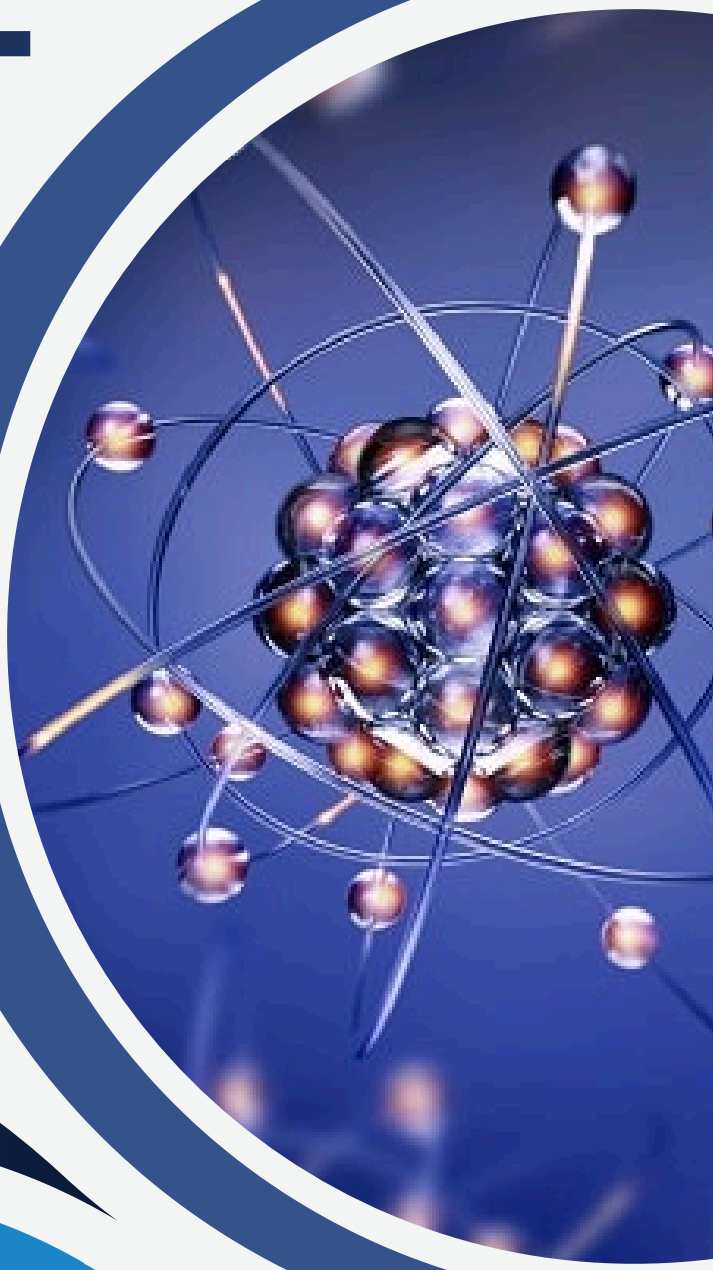

VIETNAM ATOMIC ENERGY INSTITUTE

ANNUAL REPORT 2023

Hanoi, November 2024

The VINATOM Annual Report for 2023 has been prepared as an account of works carried out at VINATOM for the period 2023. Many results presented in the report have been obtained in collaboration with scientists from national and overseas universities and research institutions.

ANNUAL REPORT 2023

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PREFACE

The Annual Report for 2023 aims to summarize the significant activities of the Vietnam Atomic Energy Institute (VINATOM) during the period 1 January to 31 December 2023.

The first main part of this publication seeks to provide the **status of the Institute and illustrative descriptions of VINATOM's activities and results** of research, services, and applications.

The second part presents the **reports of scientific research projects at ministerial and institutional levels** which are accomplished and accepted during the year concerned. The research reports are categorized into the following subjects:

1. Research Reactor, Nuclear Power Technology, Nuclear Safety, Nuclear Power Technology
2. Instrumentation, Nuclear Electronics
3. Industrial Applications
4. Applications in Ecology, Environment and Geology
5. Applications in Biology, Agriculture and Medicine
6. Radiation Safety and Radioactive Waste Management
7. Radiation Technology
8. Radiochemistry and Materials Science
9. Computation and other related topics.

The reports are expected to offer all readers an insight into the Institute's accomplishments in research and development throughout the year.

A **photo collection covering VINATOM's 2023 remarkable events** is added into this publication as a vivid description of what we have been through.

We sincerely thank those making great contributions and giving concern to the publication. We highly appreciate your continued trust, cooperation, and support.

The Editorial Board

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ABBREVIATIONS AND ACRONYMS

ANSN	Asian Nuclear Safety Network
CANTI	Center for Application of Nuclear Techniques in Industry
CNT	Center for Nuclear Technique
CNST	Research Center for Nuclear Science and Technology
Dr./PhD	Doctor of philosophy
EPC	Engineering, Procurement and Construction
FDG	Fluodeoxyglucose
FNCA	Forum for Nuclear Cooperation in Asia
FNPS	Floating nuclear power station
GMP	Good Manufacturing Practices
HIC	Hanoi Irradiation Center
IAEA	International Atomic Energy Agency
INST	Institute of Nuclear Science and Technology
ISI	Institute for Scientific Information
ITRRE	Institute for Technology of Radioactive and Rare Elements
JAEA	Japan Atomic Energy Agency
JINED	Japan International Nuclear Energy Development Company
NDE	Non-destructive Evaluation
NRI	Nuclear Research Institute
NTC	Nuclear Training Center
RCA	Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology for Asia and the Pacific
R&D	Research and Development
SMR	Small modular reactor
TC	Technical cooperation
VAEA	Vietnam Atomic Energy Agency
VARANS	Vietnam Agency of Radiation and Nuclear Safety
VietGAP	Vietnamese Good Agricultural Practices
VINAGAMMA	Research and Development Center for Radiation Technology
VINATOM	Vietnam Atomic Energy Institute
VND	Viet Nam Dong

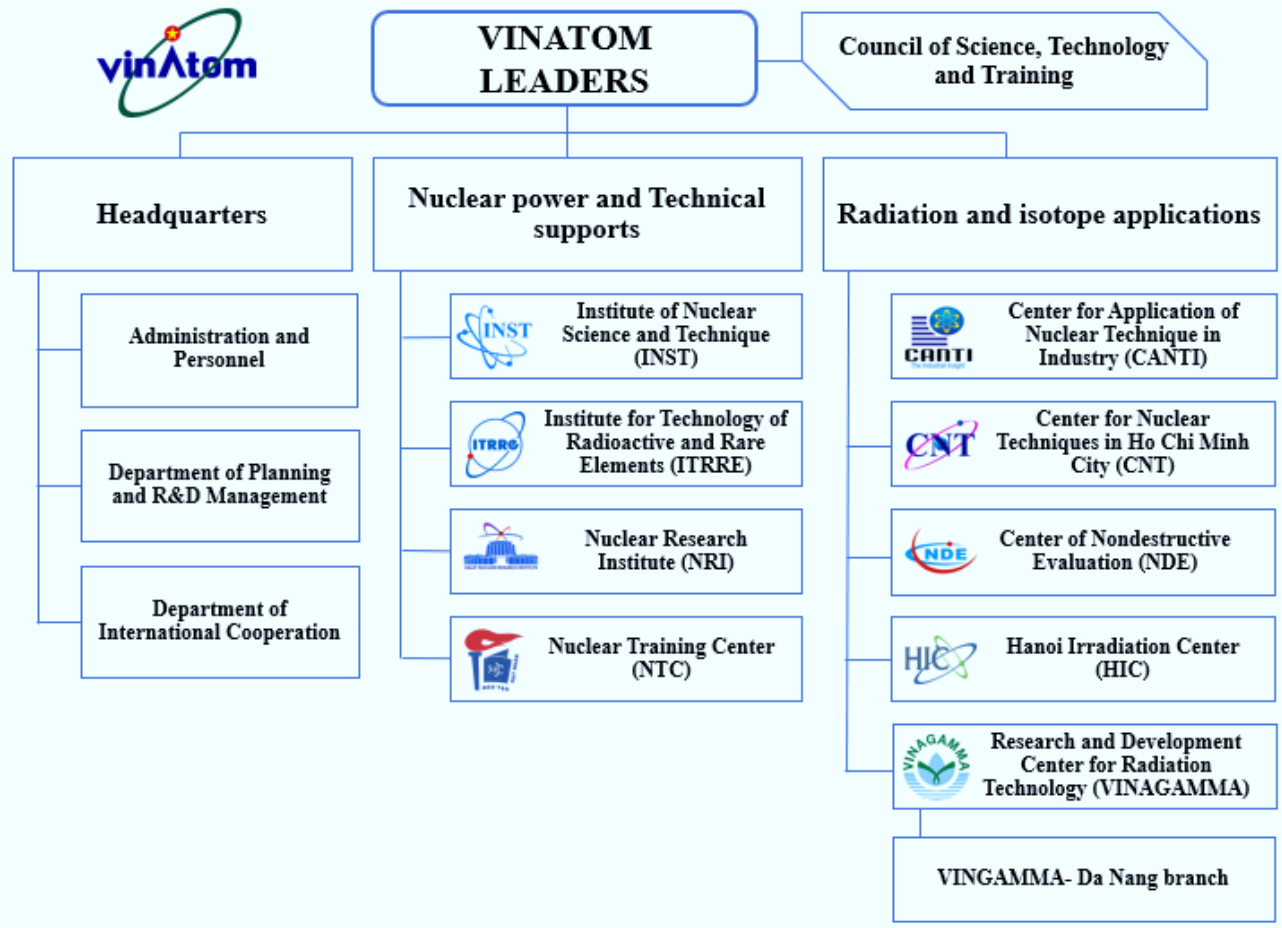
1- VINATOM 2023

1.1. VINATOM MEMBERS AND HUMAN RESOURCES

Vietnam Atomic Energy Institute, a scientific organization under Ministry of Science and Technology, performs the function of assisting the Minister in basic research, application and deployment of research results in the field of atomic energy, technical support for state management on atomic energy, radiation and nuclear safety, education and training in this field under the national laws. The current organizational structure of VINATOM is as follows:

COMPOSITION OF VINATOM LEADERS (2021-2023):

- Dr. TRAN Chi Thanh, President
- Dr. TRAN Ngoc Toan, Vice-President
- Dr. PHAM Quang Minh, Vice-President



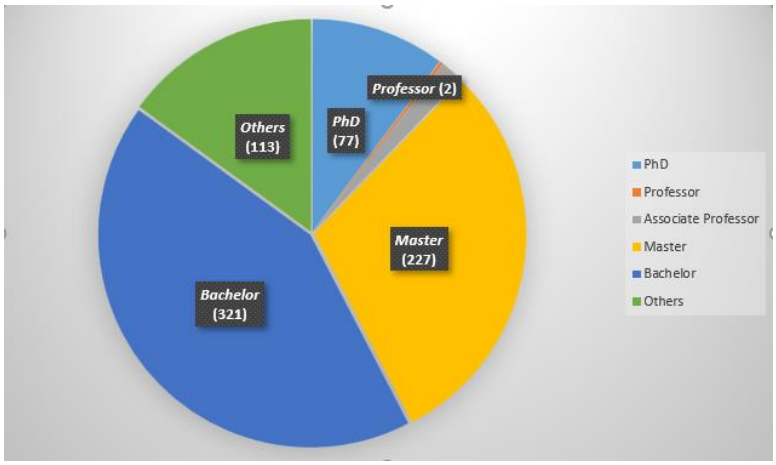
(*) One research facility of VINATOM in Da Nang has been managed, operated, and deployed by Research and Development Center for Radiation Technology since January 14, 2019.

By the end of 2023, VINATOM has **738 officials and contract staff members** (231 of whom are women, which accounts for 31.3%). According to Decision No. 901/QD-BKHCN dated May 12th, 2023, VINATOM has been assigned 685 working people.

In terms of professional qualifications, there are 77 doctorates (including 02 professors and 13 associate professors), 227 masters, 321 people with bachelor's degrees and 113 people with intermediate and elementary education degrees.

Regarding to professional tittles, VINATOM has 24 senior researchers and equivalent, 88 principal researchers and equivalent, 513 researchers, engineers and equivalent, 35 technicians and equivalent, and 78 support employees.

With regards to age, there are 130 people under the age of 30 (corresponding to 17.6 %), 501 people in the 30-50 age group (67.9%), 107 people over 55 years old (14.5%). This is shown in Figure 2.



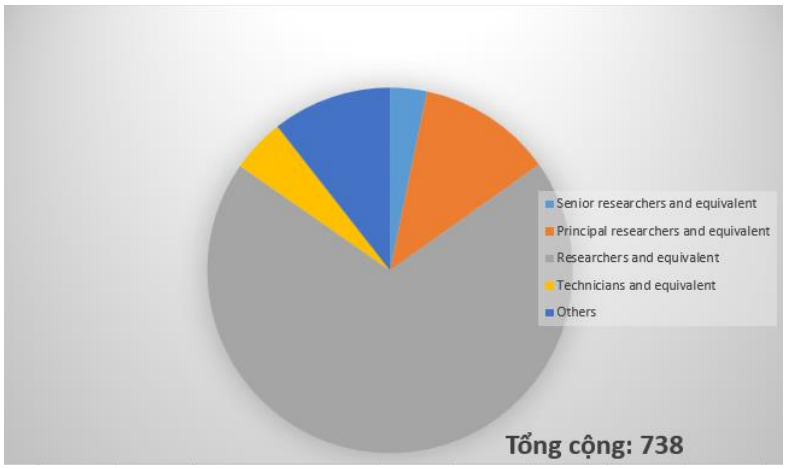


Figure 1 and Figure 2. Academic levels of VINATOM's staff

1.2. INVESTMENT RESOURCES

In 2023, the state-funded resources for implementing activities of VINATOM was **more than 160 billion VND,** of which **approximately 17 billion VND** was allocated for the implementation of science and technology projects at ministrial and institutional levels.

1.3. RESULTS OF RESEARCH, DEVELOPMENT AND APPLICATIONS

1.3.1. HIGHLIGHT OF RESEARCH ACTIVITIES AND SERVICE IMPLEMENTATION

The total number of published works by VINATOM in 2023 was 353 (articles), including: 82 papers in ISI international journals; 21 papers in SCOPUS and other international journals; 82 papers in national journals; 41 papers presented at international conferences; 123 papers presented at domestic conferences; 4 patents/useful solutions; and participation in the development of content for 4 monographs.

Nuclear Research Institute (NRI) safely operated and effectively utilized the Da Lat Reactor, completing 49 cycles with a total operating time at nominal power of 5,645 hours (the target was 30 cycles, 80-100 hours per cycle). It also enhanced the production capacity of radiopharmaceuticals to meet the demand from hospitals amid a shortage due to the inability to import these products from abroad. The production of radiopharmaceuticals in 2023 was 1,650 Ci (target: 1,000 Ci).

Institute of Nuclear Science and Technology (INST) ensured continuous operation of the Environmental Radiation Monitoring and Warning Network, which consists of 11 radiation monitoring stations for atmospheric environments located in various provinces and one central control center. It continued to expand the database of background radiation levels in critical areas that might be affected early by transboundary nuclear radiation incidents.

The Cyclotron 13 MeV at the Hanoi Irradiation Center (HIC) officially went into operation (after more than 10 years of trial operations and licensing processes) to produce Vinatom FDG radiopharmaceuticals, marking a new service sector for the center. It supplies these radiopharmaceuticals to major hospitals in Hanoi for early cancer diagnosis, with initial successes. In 2023, the HIC produced over 100,000 mCi of FDG radiopharmaceuticals, which were supplied to major hospitals in Hanoi, including K Hospital, Central Military Hospital 103, Hospital 19/8, and Hanoi Oncology Hospital, facilitating PET/CT imaging for over 5,000 patients.

The Center for Applications of Nuclear Techniques in Industry (CANTI) won 3 international contracts for the design and manufacture of industrial CT equipment, tendered by the International Atomic Energy Agency (IAEA). The center has completed 1 contract for Kuwait, while the remaining 2 contracts for the Czech Republic and Angola will be delivered in 2024.

Despite many challenges, VINATOM's application and service activities in science and technology have been relatively stable. As of the end of November 2023, the total revenue of the VAEC reached 364.367 billion VND.

1.3.2. RESULTS OF APPLICATIONS AND SERVICES

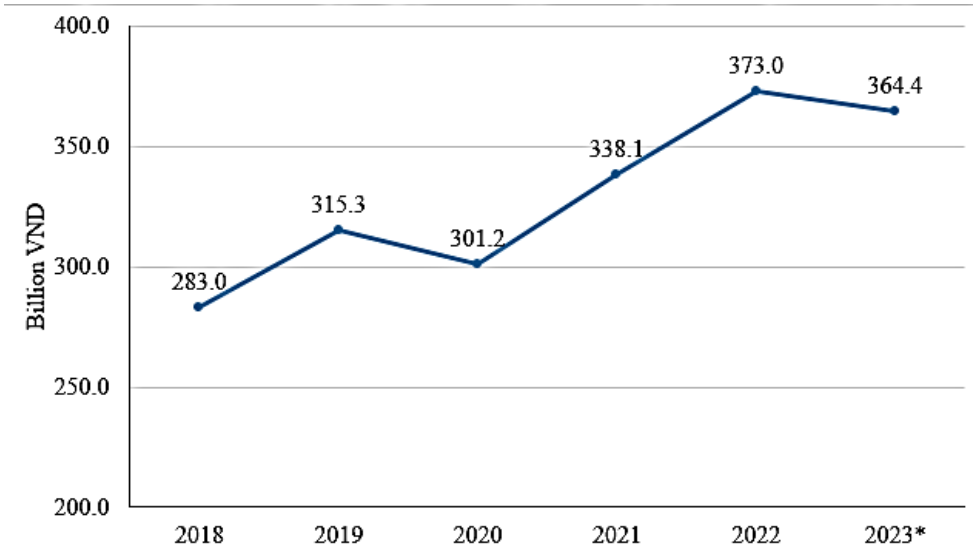


Figure 4: Total revenue from all types of services of VINATOM

Nuclear Research Institute

By the end of 2023, the total revenue was 69.5 billion VND *(around 57.9 billion VND in 2022).* The revenue of each service is specified below.

+ Preparing and supplying radiopharmaceuticals and marker kits: 54.3 billion VND

+ Personal dosimetry, calibration and testing of equipment for radiation facilities: 6.8 billion VND *(6.6 billion VND in 2022).*

+ Service of analysis for exporting agricultural products and ensuring domestic food hygiene and safety, VietGAP assessment and certification, environmental radiation monitoring, radioactive testing in food, exported food, environmental impact assessment of investment projects, etc.: 7.15 billion VND *(6.45 billion VND in 2022).*

+ Training and fostering knowledge of radiation safety: 0.63 billion VND *(1.04 billion VND in 2022).*

Institute for Nuclear Science &Technology

The total revenue from application and technical services of INST by the end of November 2023 reached 16.91 billion VND, which shows a slight increase over the same period in 2022 *(14,561 billion VND).* The total revenue includes:

+ Radiation safety service: 11.765 billion VND *(In 2022:* 10.565 *billion VND)*

+ Analysis services: 2.418 billion VND *(In 2022:* 1.695 *billion VND)*

+ Training services: 2.727 billion VND *(In 2022:* 2.180 *billion VND)*

Institute for Technology of Radioactive Waste and Rare Elements

The total revenue from production and service of ITRRE stood at 115.29 billion VND *(about* 189.930 billion *VND in 2022)*. The revenue of each service is specified below.

+ Production of zinc products: 114.00 billion VND *(In 2022: 185.00 billion VND)*

+ ZOC factory waste treatment service: 0.68 billion VND *(In 2022: 4.728 billion VND)*

+ Analysis service: 0.35 billion VND *(In 2022: VND 0.167 billion* VND*)*

+ Production of heat stabilizers: 0.26 billion VND *(In 2022: 0.252 billion VND)*

Research and Development Center for Radiation Technology

In 2023, VINAGAMMA focused on deploying irradiation services for sterilizing food products for export and sterilizing medical equipment; providing services for the production of Nano silver products, chitosan-based products, antibacterial fabrics, and superabsorbent materials; offering technical support for the Dong Nai Irradiation Center project implemented by the Dong Nai Department of Science and Technology, as well as the Can Tho irradiation facility and other related activities. The total revenue of 2023 reached 96.09 billion VND *(*66.164 *billion VND in 2022).* The revenue of each service is specified below.

+ Irradiation service: 45.74 billion VND *(In 2022:* 61.967 billion VND*)*

+ Other services: 50.35 billion VND *(In 2022: VND 4.197 billion)*

Hanoi Irradiation Center

In 2023, Hanoi Irradiation Center focused on deploying irradiation services, primarily for irradiating traditional medicine, functional foods, and quarantine of fresh fruits for export. The total volume of irradiated goods reached approximately 7,315 cubic meters, equivalent to 1,724 tons of goods, with about 5,000 hours of irradiation. The revenue from irradiation activities increased by 2.018 billion VND (a 20.1% increase compared to 2022). Specifically, the revenue from the traditional medicine irradiation service alone increased by over 1.4 billion VND, accounting for 70% of the revenue growth in the irradiation-related service sector. In addition, the center continued to maintain its support services in radiation safety training and radiation and nuclear incident response. Notably, the production of the Vinatom FDG radiopharmaceutical is a new service of the center, which has officially started producing FDG drugs supplied to major hospitals in Hanoi for early cancer diagnosis. The total revenue of 2023 reached 31.538 billion VND. The revenue of each service is specified below.

+ Irradiation service: 12.07 billion VND (9.528 billion VND in 2022)

+ Support for implementation of radiation safety and incident response: 2.5 billion VND (2.4 billion VND in 2022)

+ Production of Vinatom FDG: 16.1 billion VND

+ Other services: 0.86 billion VND

Center for Application of Nuclear Techniques in Industry

In service implementation of 2023, the center consecutively won two international bids for oil field marking, invited by the Vietsovpetro Joint Venture. At the time of report, the center was executing three contracts with Vietsovpetro simultaneously. During the year, the center also won three international bids for the design and manufacture of CT equipment for industrial use, invited by the International Atomic Energy Agency (IAEA). So far, the center has completed one contract for Kuwait, while the remaining two contracts for the Czech Republic and Angola will be delivered in 2024. Total revenue from service implementation in 2023 reached 10.4 billion VND, exceeding the planned target by 30%. Specifically:

+ Analysis and environmental services: 0.412 billion VND (1.3 billion VND in 2022)

+ Application of nuclear techniques in industry: 9.693 billion VND (5.2 billion VND in 2022)

+ Training services: 0.317 billion VND

Center for Nuclear Techniques, Ho Chi Minh City

In 2023, the Center for Nuclear Techniques continued to implement contracts and services related to radiation safety, dosimetry, and NDT services; organized training, workshops, evaluations, and certification for Level II NDT for several units in Ho Chi Minh City and neighboring provinces. In 2023, the Center's revenue reached 4.683 billion VND. *(The revenue by December 15th 2022 reached 6.231 billion VND)*

NDE Center, Ha Noi

In 2023, NDE Center continued to promote the application of research results into socio-economic production activities, such as: training, evaluation, and certification of NDT technician qualifications for more than 70 courses with over 500 participants; consulting and supporting units in setting up laboratories and operating NDT equipment; implementing major projects such as maintenance of Mong Duong Thermal Power Plant, Nghi Son Thermal Power Plant, the railway overpass on Nguyen Tat Thanh Street, the Kiss Bridge Project, Tra Linh Hydropower Plant; the project for inspecting engine body quality in collaboration with Viettel Manufacturing Corporation (VMC) under the Viettel Group, which has been implemented on a large scale at many military facilities with high technical requirements, thereby assessing the quality of weapons and equipment, contributing to extending their service life and ensuring the combat readiness of military units.

The Center's revenue in 2023 reached 19.15 billion VND (17.950 billion VND in 2022), including:

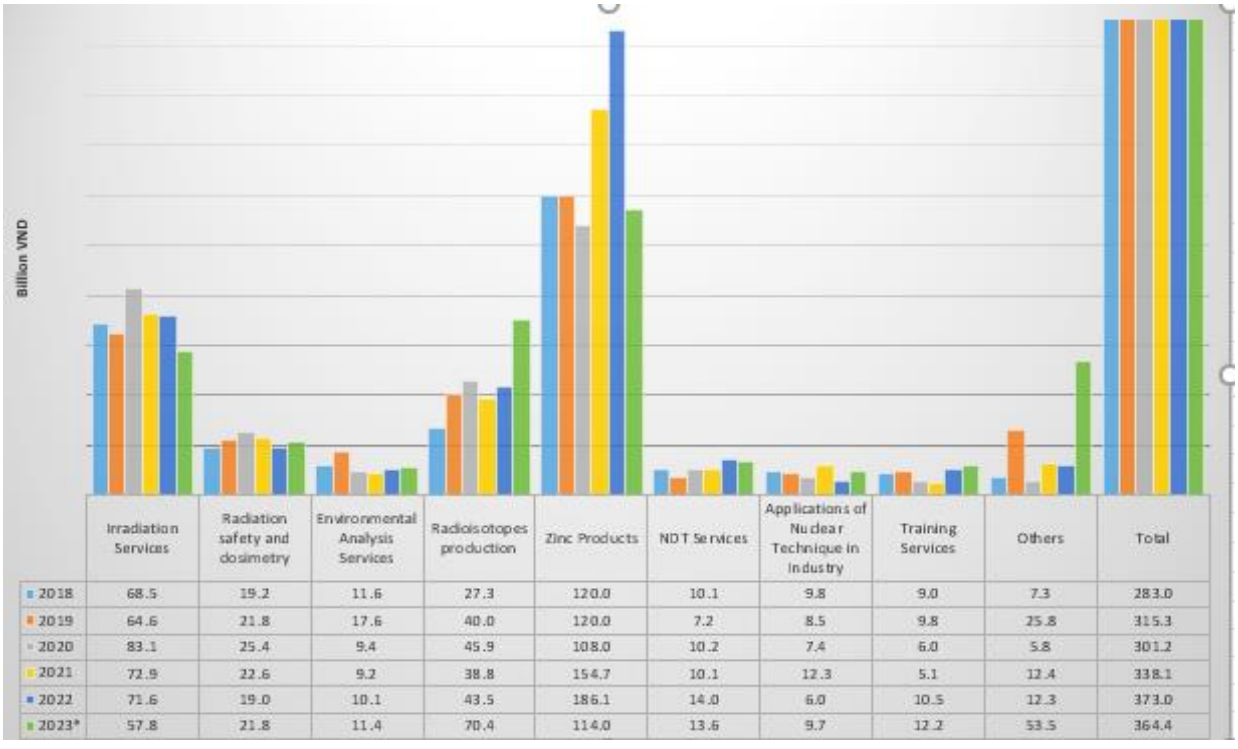
Radiation safety services (nuclear technology applications): 1.9 billion VND (1.2 billion VND in 2022)

NDT services: 13.2 billion VND (13.55 billion VND in 2022)

Training services: 4.05 billion VND (3.2 billion VND in 2022)

Table 3. VINTOM's services and corresponding revenues in 2021 and 2022

No	Services	Revenue (billion VND)	
		Year 2022	Year 2023
1	Irradiation	71.592	57.810
2	Radiation safety, dosimetry	19.008	21.765
3	Analysis services, environment	10.087	11.430
4	Radioisotope production	43.500	70.420
5	Producing zinc products	186.056	114.000
6	NDT	13.985	13.552
7	Application of nuclear techniques in industry	5.950	9.694
8	Training	10.523	12.215
9	Others	12.327	53.481
	Total	**373.028**	**364.367**



** Estimated revenue in December 2023.*

Figure 4: VINTOM's services and corresponding revenues in the period 2018-2023

1.4. SCIENTIFIC PUBLICATIONS

In 2023, scientific research activities were boosted, thereby achieving remarkable results. Compared to the previous year, the number of publications this year increased in both quantity and quality, as shown in Table 2 and Figure 3 below.

Table 2. Summary of scientific articles/publications by the members under VINATOM

Units	ISI journals (ISI)	SCOPUS and other international journals	National journals	International conferences	National conferences	International publications	Patents /utility solution	Total
INST	26	1	6	14	20			
NRI	28	5	35	14	44		2	
ITRRE	4	5	11	2	16			
CNT	11	2	5	4	10			
VINAGAMMA	5	1	5	1	10			
CANTI		2	5	1	6			
HIC		4	12	3	8			
NDE Center			2	1	3			
NTC	4	1	1	1	6		2	
Head Quarters	4							
Total	**82**	**21**	**82**	**41**	**123**	**0**	**4**	**353**

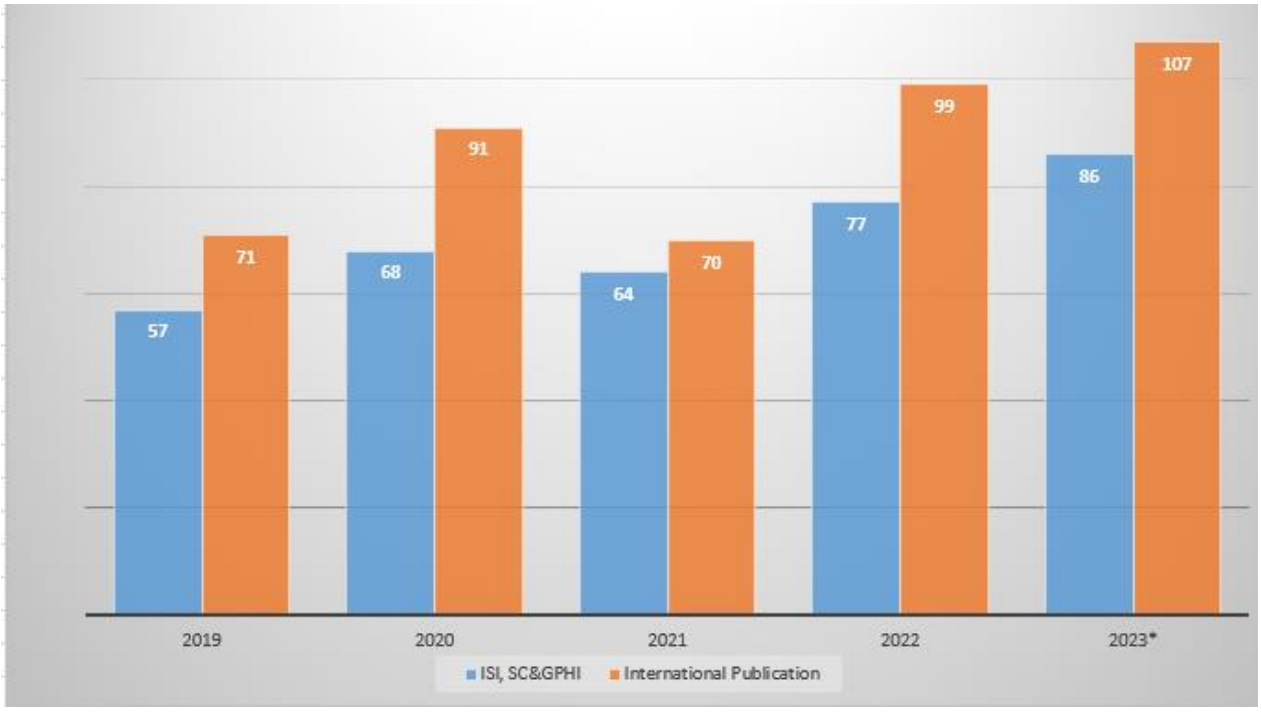


Figure 3: Overview of international publications and ISI articles between 2019 and 2023

1.5. TRAINING AND DEVELOPMENT OF HUMAN RESOURCES

1.5.1. Doctoral Training

In 2023, VINATOM delivered 4 Doctor of Philosophy (PhD) programs including: Atomic and nuclear physics; Theoretical and computational physics; Analytical chemistry; Inorganic chemistry.

The total number of PhD candidates at NTC by 2023 was 39, 29 of whom followed Atomic and Nuclear Physics, 3 of whom followed Theoretical and computational physics, 3 of whom followed Analytical chemistry and 4 followed Inorganic chemistry.

1.5.2. Human Resources Development

Besides, VINATOM organized the courses to improve skills and foster knowledge for the officials, coordinated and supported the internship programs, research skills to improve the personnel quality. The courses are specified below:

Nuclear Training Center organized a short-term training course on "Safe Operation of Reactors Using a PC-based Simulator" for staff from the Institute of Nuclear Science and Technology (INST) and students from the University of Science and Technology, Vietnam National University, Hanoi. A total of 17 participants received certificates of completion for the training course. The center also supported the organization of 4 specialized internship sessions for 178 students from universities in the field of nuclear energy at facilities and units under the Vietnam Atomic Energy Institute (VAEC).

Nuclear Research Institute (NRI) conducted lectures and guided sessions for 992 students, pupils, staff, and lecturers who participated in internships, visits, and learning about the application of nuclear technology in socio-economic development.

1.6. INTERNATIONAL COOPERATION

1.6.1. Multilateral cooperation activities

The cooperation with the IAEA is considered one of the most effective channels for collaboration in the field of nuclear energy applications and plays a particularly important role in promoting radiation applications for the socio-economic development of Vietnam.

In 2023, VINATOM continued to implement two IAEA-supported projects for Vietnam: VIE1010 on "Promoting a Safe Reactor Development Program (Phase 3: Enhancing National Capacity in Safety Analysis and Risk Assessment)" and VIE7006 on "Using Isotopes as a Tool for Comprehensive Assessment of Flow Conditions and Biogeochemistry in the Lower Red River System in Vietnam," with a total budget of 360,885 euros. Through these projects, the IAEA provided funding to VINATOM for the purchase of workstations, a high-speed digital camera for research in simulation and experimental safety analysis of reactors (VIE1010); one laser analyzer for water molecule isotopes, a set of standard sample containers, and several laboratory devices for water molecule isotope analysis (VIE7006).

VINATOM is the focal point for implementing 10 regional Non-RCA (RAS) projects and 3 interregional (INT) projects, with a total budget of 7,686,235.75 EUR for all member countries, including Vietnam. In 2023, many pieces of equipment were provided to the Institute through these projects, including a microplastic water sampling system that enabled the Institute of Nuclear Science and Technology (INST) to meet the standard for microplastic sampling (RAS7038) and 10 devices for environmental radiation survey and monitoring (RAS1026).

VINATOM continues to serve as one of the two national focal points for the Asian Nuclear Safety Network (ANSN) under the IAEA, helping to enhance nuclear safety capabilities.

At the time of this report, VINATOM was executing 05 Cost-Free Expert (CPR) contracts with the IAEA, with a total budget of 140,000 EUR.

In April 2023, VINATOM signed a Practical Arrangement with the IAEA on "*Application of Nuclear Techniques to Assess and Monitor Marine Environmental Pollution and Climate Change*" and is in discussions with the IAEA focal point to implement it. The execution of this agreement, as well as participation in the Nutech Plastic Program, enhances Vietnam's capabilities and contributes alongside the IAEA to developing nuclear techniques to address marine environmental pollution issues.

The IAEA's INPRO program provided the ASENES computational tool and training courses on methodologies to enhance the capacity for calculating energy scenarios, supporting the development of policies for future nuclear power development. Accordingly, one institutional-level project and one ministry-level project were implemented in this direction, with the participation of the Department of Atomic Energy, PECC2, PECC1, and others.

In 2023, VINATOM collaborated with the IAEA to develop and gain approval for two projects, with a total budget of nearly 400,000 EUR, namely VIE1011 on research reactors and VIE1012 on building an NDT training system, to be implemented during the 2024-2025 period.

Three-Party Cooperation Agreement between Vietnam - IAEA - Cambodia/Laos: The trilateral cooperation agreement between Vietnam, IAEA, and Cambodia/Laos was renewed in September 2022 in Vienna, Austria. In March 2023, VINATOM welcomed an IAEA expert delegation to discuss further cooperation. As part of this, VINATOM hosted: one PhD student from Laos; five staff members from the Department of Standards and Metrology of Laos for a six-week internship on NDT; three staff members from the same department to learn about NDT laboratory operations in civil construction; and two staff members each from Laos and Cambodia to explore food irradiation. The IAEA was highly impressed and appreciative of the achievements within this cooperation framework and emphasized that this is a model example of regional cooperation that the IAEA wishes to promote and replicate.

Cooperation within the framework of the RCA: As the coordinating agency for Vietnam's RCA Agreement, VINATOM was coordinating 14 IAEA/RCA (RAS) projects, with a total budget of 6,879,048.04 Euro for all member countries, including Vietnam. Among these, VINATOM directly led 9 out of the 14 RAS projects. At the 45th RCA National Coordinator Meeting held in Sydney, Australia, from May 8-12, 2023, Vietnam handed over the RCA presidency to the Australian RCA National Coordinator. The IAEA and RCA member countries highly appreciated Vietnam's efforts during its RCA presidency, which included numerous contributions to the RCA, such as organizing the first RCA Presidents' Meeting in Da Nang (February 27 – March 2, 2023) to propose an action plan to implement the RCA Ministerial Conference Declaration in Vienna in 2022; leading the preparation of a feasibility study report for the RCA Scholarship Program; proposing the establishment of National Nuclear Research Institutes (NNRIs) and a Nuclear Technology Transfer Forum within the RCA. As a responsible nation, Vietnam actively supported Australia—president of the RCA in 2023—regarding activities related to the RCA Agreement.

In September 2023, Vietnam received assistance from the IAEA in the form of a toolkit, equipment, and software to support quality assurance inspections for the RAS6101 project, as well as a calibration toolkit for the RAS6097 project, with a total value of 35,465.6 Euro.

Forum for Nuclear Cooperation in Asia (FNCA): As the national focal point, VINATOM was coordinating 7 FNCA projects, directly leading 4 FNCA projects related to the application of radiation technology, research reactor applications, radiation safety and radioactive waste management, and climate change. On behalf of the Ministry of Science and Technology leadership, VINATOM delegation participated in the 24th FNCA Ministerial Conference (MLM) and the Senior Officials Meeting (SOM) from November 27-28, 2023, in Bangkok, Thailand.

1.6.2. Bilateral Cooperation Activities

Cooperation with the Russian Federation*:* On April 7, 2023, VINATOM welcomed and worked with the delegation of the Deputy Prime Minister of the Russian Federation, Mr. D. Chernyshenko. This event reaffirmed the interest of both governments in collaborating on nuclear energy, particularly in promoting the project to establish the Nuclear Science and Technology Research Center (CNST).

With the State Atomic Energy Corporation of the Russian Federation (ROSATOM), VINATOM continues to implement cooperative activities: (i) the project to construct a new research reactor at CNST (both parties have signed a contract for site survey, assessment, and feasibility report); (ii) purchasing fuel for the Da Lat research reactor to extend its operation by an additional 10 years; (iii) signing an action plan with REP and currently in the process of discussing a Non-Disclosure Agreement (NDA) to collaborate on research supporting the consideration of implementing a nuclear power plant project in Vietnam; (iv) exchanging and signing an NDA regarding the Multi-Purpose Fast Neutron

Research Reactor (MBIR) project, which will support scientific research and applications in medicine and industry, to advise the Ministry's leadership on the possibility of joining the International Research Center (IRC) alliance based on the MBIR reactor.

Additionally, both parties also discussed issues such as: (i) ROSATOM's investment in Can Tho Irradiation Company, allowing Vietnam to access technology transfer for accelerators; (ii) deep processing of coastal mineral resources; (iii) producing new radioactive pharmaceuticals in Vietnam for cancer treatment.

VINATOM signed cooperation agreements with several partners: the Institute for Nuclear Safety under the Russian Academy of Sciences (IBRAE) on radiation safety, nuclear safety, emergency response, and environmental radiation monitoring (November 2023); and MEPhI University for research collaboration and human resource training, including doctoral training (December 2023).

VINATOM also established the partnerships with: the Nuclear Physics Institute, part of the Russian Academy of Sciences, on accelerator technology; Budker Nuclear Research Institute, Russian Academy of Sciences, regarding the ILU-14 accelerator; and the Joint Institute for Nuclear Research (JINR) in Dubna for collaboration within the CNST project.

Cooperation with Japan: VINATOM continued to play a key role in Vietnam's collaboration with nuclear energy organizations in Japan, notably with the Japan Atomic Energy Agency (JAEA) in human resource training through ITC, AITC, and MEXT courses organized and funded by JAEA. 12 staff members from both within and outside the Institute have been sent to study in Japan. The Institute has also organized three FTC training courses in Vietnam with technical support from JAEA on emergency response, nuclear technology, and environmental radiation safety, attracting 69 participants from ministries, departments, universities, and research institutes nationwide.

In collaboration with the Japan International Nuclear Energy Development Company (JINED) and Hanoi University of Science and Technology, VINATOM successfully organized the 5th Japan Course on Nuclear Power Plant Technology from November 16-17, 2023, with 34 out of 38 participants from universities, companies, and research institutes receiving completion certificates. Annually, the 13th Vietnam-Japan Forum was held in December 2023, attracting around 40 Vietnamese experts and 20 Japanese experts to exchange knowledge on accelerators, artificial intelligence, and machine learning in the field of nuclear energy.

Cooperation with the United States: Since August 2022, VINATOM has been assigned by the Ministry of Science and Technology to act as a focal point, coordinating with the U.S. Department of State to implement the FIRST program aimed at enhancing capacity in Small Modular Reactor (SMR) technology. Under this program, VINATOM organized two workshops on nuclear safety and regulation for SMRs in 2023.

At the time of this report, VINATOM was in discussions with the U.S. Nuclear Regulatory Commission (USNRC) to sign an Information Exchange Agreement, which would pave the way for signing a CAMP agreement that allows VINATOM to use the thermal-hydraulic calculation toolkit for nuclear safety.

VINATOM also hosted three delegations from the U.S. Department of Agriculture (USDA) and the U.S. Embassy to review security measures for quarantine staff, facilitating the verification and approval of the Hanoi Irradiation Center for irradiating products exported to the U.S. market.

Cooperation with South Korea: On June 22, 2023, during the state visit to Vietnam by South Korean President Yoon Suk Yeol, Korea Hydro & Nuclear Power Co., Ltd. (KHNP), part of the Korea Electric Power Corporation (KEPCO), signed a Memorandum of Understanding (MOU) with VINATOM to promote research cooperation in the field of advanced nuclear energy systems, including Small Modular Reactors (SMR). Currently, both parties are discussing a specific cooperation plan between the Korea Atomic Energy Research Institute (KAERI), KHNP, and relevant partners in Vietnam (including Hanoi University of Science and Technology and consulting firms affiliated with EVN) to enhance research capacity for Vietnamese personnel regarding SMR technology.

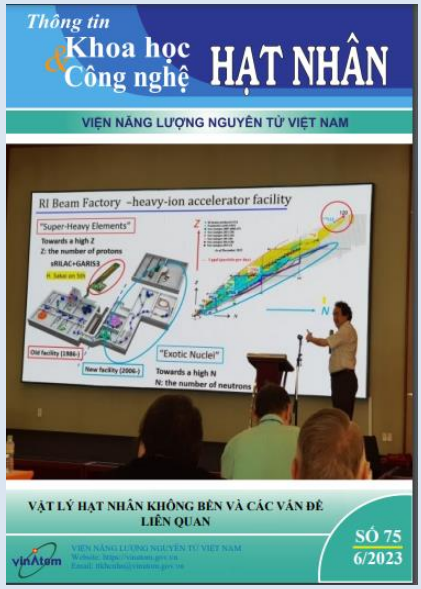
Cooperation with India: VINATOM continued cooperation programs between Vietnam and India which includes organizing the 3rd Vietnam-India Joint Committee Meeting on Atomic Energy at the VAEC headquarters from May 25-26, 2023. Ongoing discussions focus on collaboration in the exploration and processing of rare earth elements and monazite with the Indian Rare Earths Limited (IREL) under the Department of Atomic Energy (DAE). Efforts were made to supply Co-60 radioactive sources to Vietnam, and there would be a proposal to provide neutron diffraction equipment for research reactors, as well as training support for Vietnamese personnel in various technical fields, based on agreements reached at the Vietnam-India Joint Committee Meeting in May 2023.

Cooperation with China: From September 16-17, 2023, a delegation from the VINATOM participated in the 2nd China-ASEAN Forum on the Use of Nuclear Technology for Peaceful Purposes held in China at the invitation of China National Overseas Nuclear Corporation (CNOS). Two representatives from CNOS also attended the VINANST-15 conference and delivered speeches there. Additionally, through CNOS's introduction, five personnel from VINATOM and the Vietnam Electricity Corporation participated in short-term training courses in China. Currently, VINATOM and CNOS are in discussions to sign a cooperation agreement in areas such as irradiation, the production of radioactive pharmaceuticals for medical use, safety, and SMR technology.

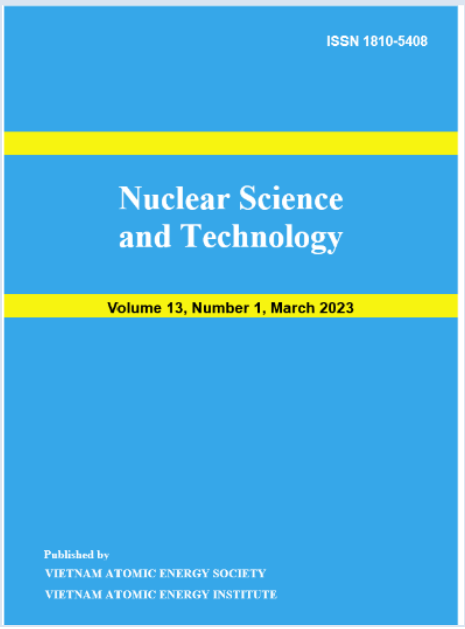
1.7. INFORMATION & COMMUNICATION, SCIENTIFIC CONFERENCES

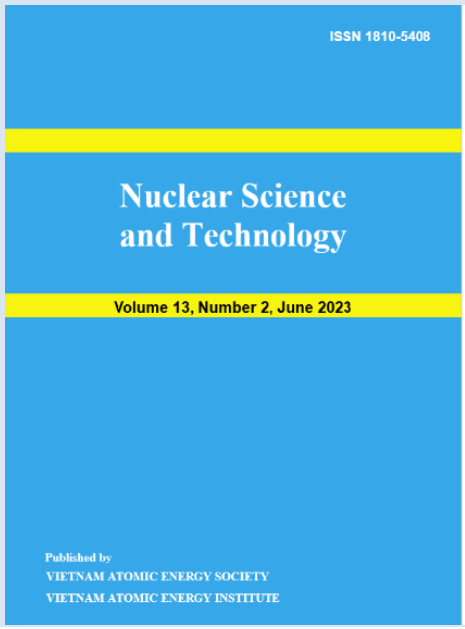
The following publications were completed by VINATOM in 2023:

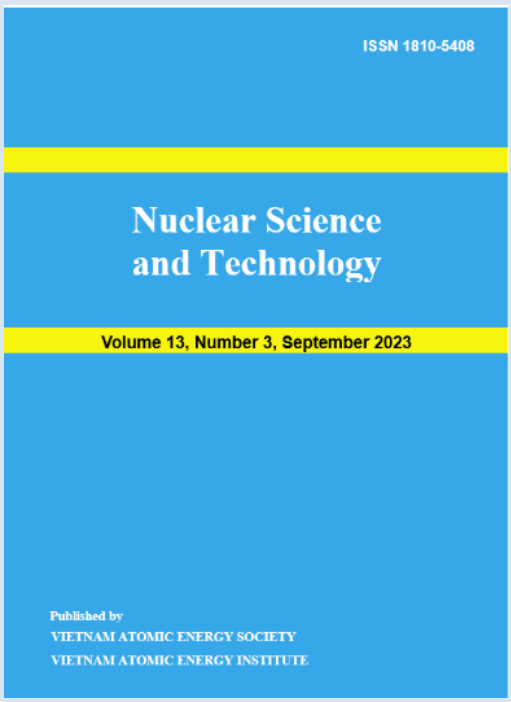
+Nuclear Science and Technology Information (online versions. Available from https://vinatom.gov.vn/an-pham-tai-lieu)

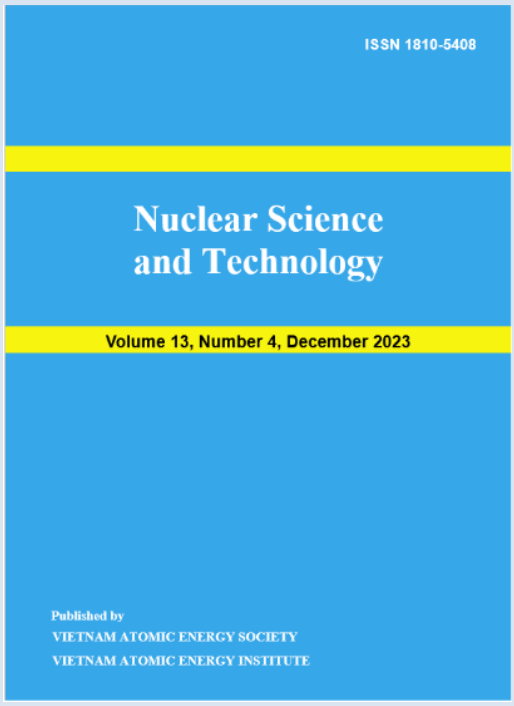


+Journal of Nuclear Science and Technology (printed and online versions. Available from http://jnst.vn/index.php/nst/index/). The online publishing system (jnst.vn) and the DOI digital identification system for the Journal were put into operation, which strongly support the online submission and review of articles and tightly connect with domestic and international scientific database systems.









+ Annual reports for 2022 (printed and electronic versions providing an insight in VINATOM's activities and scientific research projects in 2022. (online versions. Available from https://vinatom.gov.vn)

VINATOM Web Portal in Vietnamese and English versions worked properly and was frequently updated for the purpose of disseminating the information.

Domestic information on nuclear science and technology was selected, modified in the form of inputs which comply with the IAEA's standards and regularly contributed to the repository of International Nuclear Information System (INIS), IAEA.

In 2023, VINATOM successfully organized the 15th Nuclear Science and Technology Conference (VINANST-15) in Nha Trang City, Khanh Hoa Province (August

9-11, 2023), with the participation of nearly 450 scientists engaged in scientific research at research institutes and universities both domestically and internationally, as well as management officials from various ministries, sectors, and localities. The conference featured 195 presentations, including 127 oral presentations and 66 poster presentations. This was a significant scientific event for the nuclear energy research community, serving as a platform for scientists to share and publish their latest research findings. Through the conference, it ignited passion and promoted research activities among scientists in the Institute's various research fields.

The high-performance computing system (VINATOM-HPC) was efficiently deployed for scientific research.

1.8. INVESTMENT PROJECTS

VINATOM continued to implement the major projects in the field of atomic energy. The details are presented as follows.

1.8.1. RESEARCH CENTER OF NUCLEAR SCIENCE AND TECHNOLOGY

The project, invested by the Ministry of Science and Technology, received approval for investment from the Prime Minister in November 2018. It is currently in the phase of preparing for investment. After a period of adjusting the policy to change the funding source for the preparation of the Feasibility Study Report and Site Profile, the project completed the contractor selection process for the mentioned package in 2023.

On November 30, 2023, a contract signing ceremony for consulting services to prepare the Feasibility Study Report and Site Profile took place at the Ministry of Science and Technology headquarters between the Project Management Board of the Nuclear Science and Technology Research Center and the Joint Stock Company "State Specialized Design Institute (GSPI)" from the Russian Federation.

Simultaneously, the Project Management Board, primarily staffed by personnel from the VAEC, is continuing to develop the task outline and budget; organize the contractor selection for various packages: bomb and mine clearance (before conducting survey drilling); establish tasks and planning at a scale of 1:500; and organize the selection of contractors for the Environmental Impact Assessment Report, among others.

1.8.2. UPGRADING THE TECHNOLOGY SYSTEMS AND FUNCTIONAL EQUIPMENT AND SUPPLEMENTING FUEL FOR THE DA LAT NUCLEAR REACTOR TO ENSURE ITS EFFECTIVE AND SAFE OPERATION AT LEAST UNTIL 2030

The project "Upgrading the technology systems and functional equipment and supplementing fuel for the Da Lat nuclear reactor to ensure its effective and safe operation at least until 2030" is led by the Nuclear Research Institute and was approved for investment by the Ministry of Science and Technology in Decision 164/QĐ-BKHCN on February 16, 2023, with a total investment of 80.488 billion VND. The main content of the project is to purchase additional fuel for the reactor. However, due to the political

situation, sanctions, and economic measures imposed by the United States and Europe on the Russian Federation, the fuel prices have risen significantly compared to the projections, and the payment channels between Russia and Vietnam are currently facing many difficulties. The project needs to reduce several items to ensure the planned amount of fuel. As of now, the project is behind schedule.

1.8.3. INVESTMENT IN LABORATORY EQUIPMENT SYSTEMS TO SERVE THE RESEARCH OF ADVANCED MATERIALS AND THE TREATMENT OF RADIOACTIVE WASTE IN COASTAL MINERAL PROCESSING

The project "Investment in laboratory equipment systems to serve the research of advanced materials and the treatment of radioactive waste in coastal mineral processing" is led by the Center for Application of Nuclear Techniques in Industry (CANTI) and is currently in the investment preparation phase. The project was approved for investment in Decision No. 3012/QĐ-BKHCN on November 23, 2021, with CANTI as the investor and the implementation location at No. 1, DT723 Street, Ward 12, Da Lat City, Lam Dong Province. The project is based on the research development direction of the CANTI Center towards establishing a laboratory focused on titanium and ilmenite ore, leveraging its proximity to coastal mineral areas and collaboration with Ukraine in this field. However, as of now, due to the increasingly complex political context, cooperation with Ukraine in technology transfer and equipment procurement has become unfeasible, resulting in significant disadvantages for CANTI in project implementation. In light of this reality, the Nuclear Research Institute of Vietnam has reviewed the situation and assigned the task of researching the continuation of the project to the Institute of Social Sciences, which has deep expertise in titanium and zircon processing and the capacity and experience to effectively implement the project.

Until now, the project has submitted a proposal for adjustment of the investment policy and will continue to be implemented by the Institute of Social Sciences in 2024.

2- RESEARCH REPORTS 2023

Source: eagetutor.com

Source: https://1boss.vn/

2.1. RESEARCH REACTOR, NUCLEAR POWER TECHNOLOGY, NUCLEAR SAFETY, NUCLEAR POWER ECONOMY

A STUDY ON THE APPLICATION OF ARTIFICIAL NEURAL NETWORK TO PREDICT SOME PHYSICAL CHARACTERISTICS OF SMALL MODULAR REACTOR

Le Tran Chung, Nguyen Thi Dung, Nguyen Thi Mai Hương, Cao Dinh Hung

Institute for Nuclear Science & Technology, VINATOM, 179 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam

Project information:

- **Project name: A study on the application of artificial neural network to predict some physical characteristics of small modular reactor**
- **Code: CS/23/04-03**
- **Managerial Level: Institute**
- **Duration: 12 months (Jan 2023- Dec 2023)**
- **Contact email: chungletran@gmail.com**
- **Published papers related to the project:**

1. Le Tran Chung, Nguyen Thi Dung, Tran Viet Phu, Nguyen Thi Mai Hương, Cao Dinh Hung. A study on the application of artificial neural network to predict some physical characteristics of small modular reactor. 15th Vietnam Conference on Nuclear Science and Technology (VINANST-15), August 2023, Khanh Hoa, Viet Nam

Machine learning (ML) using artificial neural network (ANN) methods is being applied to predict required parameters for nuclear reactor research based on learning from big data sets. The ML models usually give faster calculation speed while the accuracy is good. This study applies a multi-layer perceptron (MLP) neuron network to predict k-eff and the peaking factor for the small modular PWR. The dataset used to train the model is generated by the SRAC2006 code. MLP neural network structure is built and trained to achieve high accuracy when compared with simulation results. Studying the necessary features to train the model as well as reduce the size of the dataset while ensuring the accuracy of the model is also performed.

The small modular PWR considered in the current work is a 200 MW thermal reactor with a simplified core containing 37 shortened PWR fuel assemblies and light water as a reflector. Each assembly consists of 289 rods with 264 fuel rods, 24 control rod guide tubes, and 1 central instrument tube arranged on a 17x17 grid. The fuel pellets made of UO_2 with three different U-235 enrichments (2.35 wt%, 3.40 wt%, and 4.45 wt%) are loaded into three types of assemblies named F235, F340, and F445, respectively. The core contains 37 fuel assemblies arranged with quadrant symmetry. Thus, at each position of a quarter-core, one of three fuel assembly types is randomly placed to create different LPs. To make the training dataset for the ML model in this study, 20000 LPs were calculated. The calculated parameters include the effective multiplication factor (k-eff) and the power peaking factor at the beginning of cycle. In the

following sections, the dataset is divided into 3 parts including a test set (1000 LPs ~ 0.5 % of dataset), a validation set (3800 LPs ~ 20 % rest of the dataset), and a training set (15200 LPs).

The MLP is a type of ANN consisting of multiple layers of interconnected artificial neurons or nodes. It is a feedforward neural network, meaning that information flows in one direction, from the input layer through the hidden layers to the output layer. The MLP is widely used in various fields for tasks such as classification, regression, and pattern recognition. The architecture of MLP consists of an input layer, one or more hidden layers, and an output layer. Each layer is characterized by its nodes, where each node performs a weighted computation on input signals received from the previous layer. Introducing activation functions within these nodes allows non-linear data transformations, enabling the MLP to model intricate relationships beyond the limitations of linear classifiers. A perceptron was inspired by structure of neurons, that is illustrated in Figure 1.

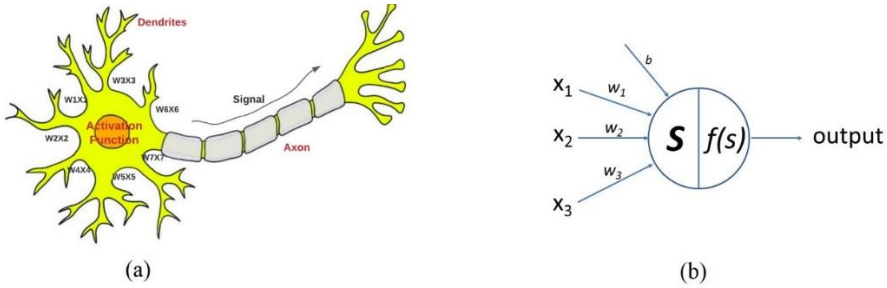


Figure 1. Neuron (a) and perceptron (b) illustration

The training process and prediction results of the two best models including the k-eff prediction model and the peaking factor prediction model were given. The input features include k-inf and enrichment of assemblies. The two best models were used to predict k-eff and peaking factor of 1000 test LPs (the LPs were not used in training and validating processes). The results of the comparison with SRAC2006 code are presented in Figure 2. It can be seen that the deviations of k-eff are mostly between -50 pcm to 50 pcm and the deviations of peaking factor are mostly between -0.4 % to 0.4 %. The maximum deviation of k-eff and peaking factor are 268 pcm and 1.764 %, respectively. These results show good agreement between the MLP models and SRAC2006 code. In addition, MLP models only needed about 5 seconds to compute for 1000 LPs, while the time required for SRAC2006 was about 1 hour. Therefore, it can be seen that when there was enough data for training, MLP models were able to predict k-eff and peaking factor of nuclear reactor accurately and at high speed.

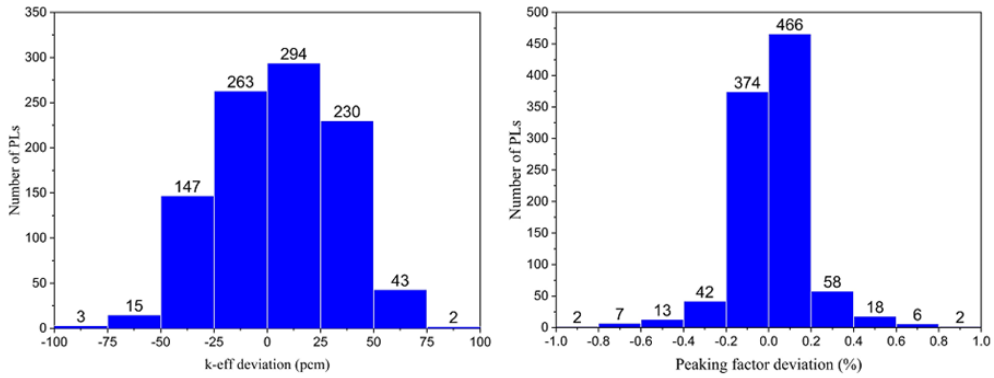


Figure 2. Deviation distribution of k-eff prediction (a) and peaking factor prediction (b) predicted by the best models

This study has built an MLP network structure to predict k-eff and peaking factor of the small modular PWR core. The MLP network consists of more than 500000 parameters with 1 input layer, 4 hidden layers and 1 output layer with 1 output. A dataset of 20000 LPs and necessary features has been calculated by SRAC2006 code to train the MLP network. As above-mentioned, the dataset was divided into the test set (1000 LPs), the validation set (3800 LPs), and the training set (15200 LPs). The trained model was used to predict the k-eff and peaking factor of the test set and compared with the results of SRAC2006 to evaluate the accuracy of the models. The survey results show that it takes about 6000 LPs to train MLP models with acceptable accuracy. When there is enough training data, the models can use only 1 or more features of the fuel assembly to train the model while maintaining accuracy. The best MLP models show a good agreement with SRAC2006 code. The calculations for 1000 test LPs show that the average and maximum deviations of k-eff were 24 pcm and 268 pcm, respectively, and the average and maximum deviations of peaking factor were0.135 % and 1.764 %, respectively. These show great promise for applying machine learning models to nuclear reactor research, design, and operation.

RESEARCH ON USING ASENES TOOLS IN ANALYSIS OF NUCLEAR POWER DEPLOYMENT SCENARIOS AND APPLICATION TO VIET NAM

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[1]Institute for Nuclear Science and Technology, 179 Hoang Quoc Viet, Cau Giay, Ha Noi

[2]Power Engineering Consulting Joint Stock Company 2, 32 Ngo Thoi Nhiem, Vo Thi Sau, District 3, Ho Chi Minh

Project information:

- **Project name: Research on using ASENES tools in analysis of nuclear power deployment scenarios and application to Viet Nam**
- **Code: CS/23/04-04**
- **Managerial Level: Institute**
- **Duration: 12 months (Jan 2023- Dec 2023)**
- **Contact email: vohuong1705@gmail.com**
- **Published papers related to the project:**

1. Vo Thi Huong, Nguyen Thi Thanh Thuy, Le Tran Chung, Pham Nhu Viet Ha. Study on economic assessment of nuclear energy system using NEST tool. 15th Vietnam Conference on Nuclear Science and Technology (VINANST-15), August 2023, Khanh Hoa, Viet Nam

At the global climate change conference COP26 in Glasgow, Viet Nam has committed to reach net-zero carbon emission targets by 2050, to phase-out coal power in the 2040s. Nuclear power can play an important role to achieve these goals. Therefore, although Vietnam's nuclear power plant project has been postponed, the building capacity to analyze and evaluate nuclear power deployment scenarios, to support decision making and to systematically assess the sustainability of the nuclear system is very important and necessary. INPRO has developed the ASENES tools including NEST, MESSAGE-NES, KIND-ET and ROADMAPS-ET that can comprehensively evaluate nuclear energy systems and scenarios. In this work, research on using the ASENES tools was performed to learn how to use these tools in analyzing, evaluating, comparing and ranking the nuclear energy systems and constructing a roadmap for the deployment of nuclear scenarios. Then, the application of ASENES tools to analyze a hypothetical nuclear power scenario deployed in Viet Nam was also carried out.

It is shown that NEST's results provided very good support for the evaluation and ranking of NES using KIND-ET. MESSAGE-NES was used to perform nuclear scenario and material flow analyses. However, its calculation mainly focused on the issues related to the fuel cycle. We recognized that NEST had better support for KIND-ET calculation.

Therefore, when the ASENES tools were applied to analyze a hypothetical nuclear power scenario deployed in Viet Nam, only three tools including NEST, KIND-ET and ROADMAPS-ET were used to perform the economic assessment and energy planning. Two types of nuclear power technology VVER1200 and APR1400 operating with an open fuel cycle and one advanced coal power technology with a total capacity of 1200 MWe were considered in this calculation. Thermal efficiency of coal power plant is up to 42%.

NEST was used to calculate the levelized unit energy cost (LUEC), internal rate of return (IRR), Return on Investment (ROI) and Net present value (NPV) values for all three types of technologies. The effect of real discount rate and overnight construction (OC) costs on the economic competitiveness of nuclear power technologies with coal power was also investigated. The discount rate was from 3% to 15%. The OC costs of VVER1200 and APR1400 were [2271-7000] $/kWe and [2157-6000] $/kWe, respectively. The OC costs of coal power plant 1200 MWe were about 739 $/kWe. The results show that if the real discount rate were less than 5%, even the OC cost of nuclear power were about 7000 $/kWe, the competitiveness of both nuclear power technologies would be still higher than coal power. If the real discount rate were [6%-10%] and the OC cost of nuclear power technologies were around [3800-6660] $/kWe, the competitiveness of both nuclear power technologies would be higher than coal power plant when. If the discount rate were 11%-15% and OC cost of nuclear power technologies were around [2660-3500] $/kWe, the competitiveness of two nuclear power technologies would be higher than coal power technologies. However, Vietnam is a country that has no experience in building nuclear power, so it is not feasible to achieve OC cost in the range of [2660-3500] $/kWe. It means that the discount rate of 11%-15% is not suitable when Vietnam intends to build VVER1200 and APR1400 reactors.

The NEST's results also show that with the average retail electricity price of 81.4 mills/kWh in 2019, the nuclear power projects are profitable and feasible to deploy and still competitive with coal power when the discount rate is 7% and the OC cost is 5400$/kWe for the VVER-1200 project and 5340$/kWe for the APR-1400 project. With the average retail electricity price of 83.4 mills/kWh in 2023, the nuclear power projects are profitable and feasible to deploy and still competitive with coal power when the discount rate is 7%, the OC cost is 5650$/kWe for the VVER-1200 project, 5530$/kWe for the APR-1400 project.

KIND-ET tool was used to perform a comparative evaluation and ranking of three technologies VVER1200, APR1400, and 1200 MWe coal power, according to the economic criteria, performance, and acceptability criteria. The economic criteria include 5 indicators: levelized cost of electricity, total investment, R&D, construction time, external costs. The performance includes 7 indicators: CO_2 emissions, specific RAW inventory, emergency planning zone radius, flexibility for non-electric services and energy products, load following, security of fuel supply and availability of human resources. The acceptability includes 3 indicators: grid integration, the need to create a

special infrastructure, and public perception. Four cases with different assumptions on the weight of economic criteria, performance, and acceptability criteria are analyzed to investigate the feasibility of a nuclear power project.

The results show that coal power was dominant when the proportion of economic factor, performance, and acceptability were equal or the proportion of performance is greater than economic factor. However, if economics factor is a priority goal or economic and performance are considered with the same weight, nuclear power technology is dominant.

A hypothetical roadmap to deploy two nuclear power technologies VVER1200 and APR1400 in Viet Nam from 2035 to 2120 is proposed using the ROADMAPS-ET tool. It is assumed to operate the first 3 units of VVER1200 in 2035 to gradually replace 10 coal power units with a capacity from 110 MWe to 440 MWe. The total capacity of these coal power units is about 2730 MWe. The next 3 units of VVER1200 are assumed to operate in 2040, 2045, and 2050 to replace at least 6 coal power units with a total capacity of 3600 MWe. Four units of APR1400 are expected to operate in 2060, 2075, 2100, and 2105 to gradually replace coal power plants with a capacity of 1000 MWe-1200 MWe that will phase out after 2060. Total electricity production provided by nuclear reactors in 2035 would be about 3240 MWe/year and would increase to 4320 MWe/year in 2040. From 2045-2120, the electricity production would be above 5000 MWe/year. With this annual capacity, nuclear power plants can gradually replace about 16 small and medium-sized coal power plants with a capacity of 110-600 MWe from 2035-2050.

RESEARCH ON ESTABLISHING A METHOD FOR NEUTRON ELASTIC SCATTERING CROSS-SECTION MEASUREMENT OF ^{181}TA NUCLEUS ON THE NO.4 CHANNEL OF THE DALAT NUCLEAR REACTOR

Trinh Van Cuong, Pham Ngoc Son, Phan Bao Quoc Hieu, Tran Tuan Anh, Nguyen Bich Thuy

Dalat Nuclear Research Institute, 01 Nguyen Tu Luc str, Dalat City, Lamdong Province, Vietnam

Project information:

- **Project name: Research on establishing a method for neutron elastic scattering cross-section measurement of 181Ta nucleus at the No.4 channel of the Dalat Nuclear Reactor.**
- **Code: CS/23/01-02**
- **Managerial Level: Institute**
- **Duration: 12 months (Jan 2023- Dec 2023)**
- **Contact email: cuongtv@dnri.vn**
- **Published papers related to the project:**

1. Trinh Van Cuong, Pham Ngoc Son and et al, "An improved 148 keV neutron beam for neutron scattering measurement at the Dalat Nuclear Reactor", The Poster of the 15th Vietnam Conference on Nuclear Science and Technology (VINANST 15), Nha Trang City, Vietnam, 2023, p. 93-94

This research focuses on addressing the issue of improving the quality of the 148 keV neutron beam at the No. 4 channel of the Dalat Nuclear Research Reactor to figure out the solution of "establishing a method for measuring the elastic neutron scattering cross-section at E_n=148 keV for the ^{181}Ta sample". The research method employed was MCNP simulation to identify the most suitable configuration, which was followed by experimental setup based on the configuration derived from the simulation. The optimized 148 keV filter configuration for this experiment consisted of 98 cm Si + 2.63 cm Ti + 0.1 cm Cd + 0.22 g/cm² ^{10}B, the obtained flux of 4.9E+06 n/cm²s with the purity of 95.87%. The experimental device was a neutron detection system using ^{3}He tubes.

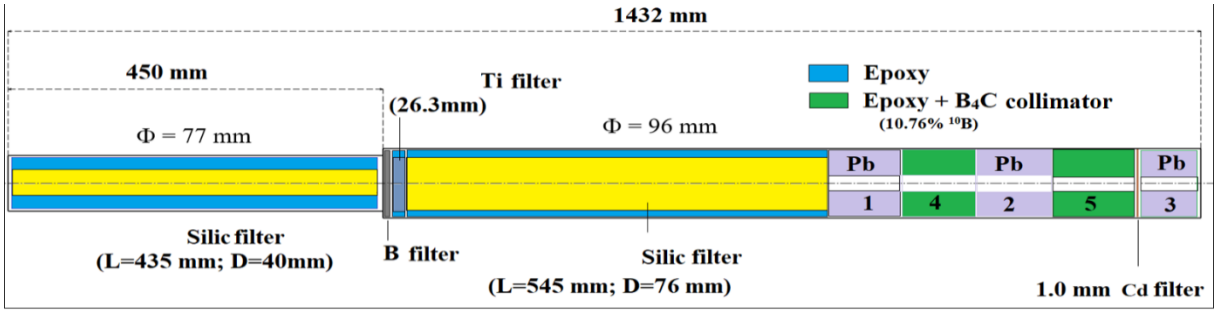


Figure 1. Configuration of the 148 keV neutron filter at the No.4 channel of Dalat Nuclear Reactor

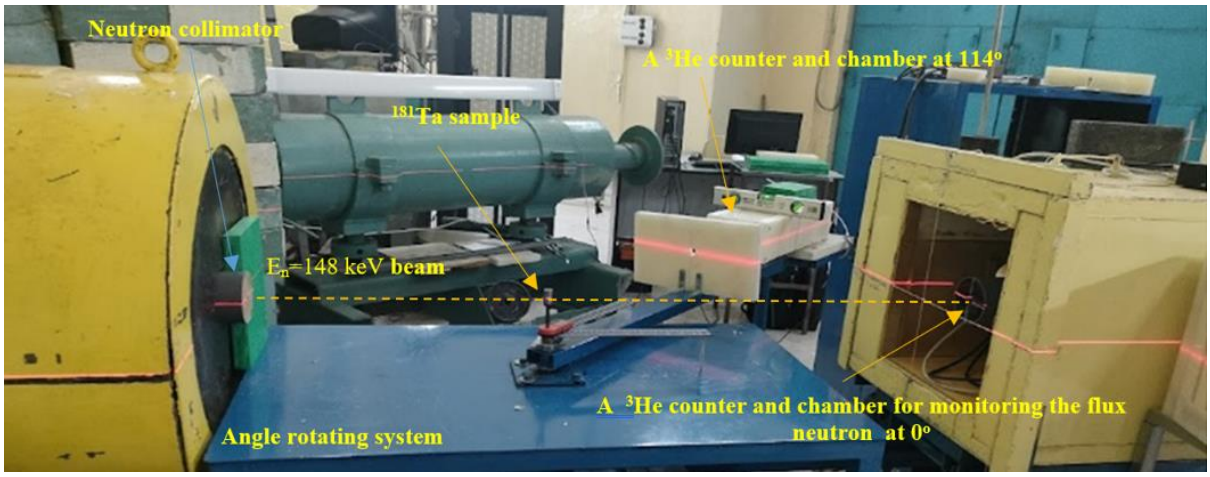


Figure 2. The neutron elastic scattering measurement system at the No.4 neutron channel of the Dalat Nulear Reactor

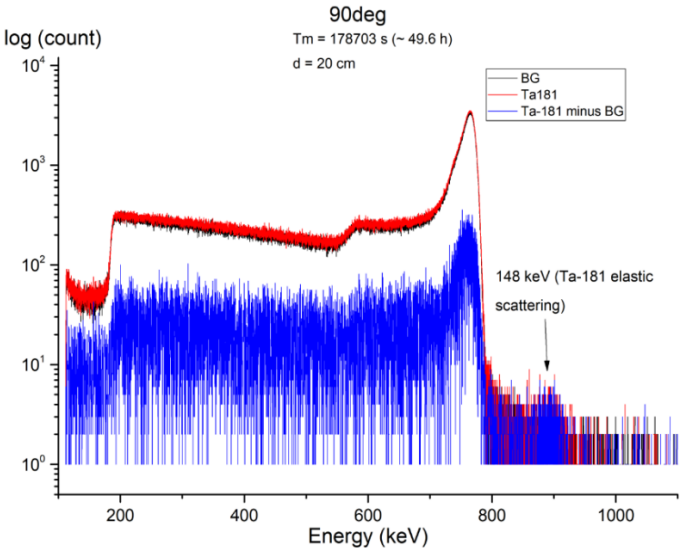
In previous studies, to collimate the No.4 neutron channel, an approach to reduce neutron and gamma background was conducted outside the irradiation channel (outside the reactor wall). This approach involved using large quantities of paraffin and B_4C-mixed concrete materials to create shielding blocks; the achieved effectiveness of background reduction was not high. The approach in this research was to directly collimate the beam from inside the neutron guide tube (completely within the concrete wall of the reactor). With this approach, the mass and volume of materials used for neutron collimation were reduced, while better efficiency for background reduction was achieved. The neutron background at channel number 4 was reduced by up to 80%. The next step following the reducion of the neutron background was to arrange the experiment. The experimental configuration consisted of one ^{3}He detector for scattering measurement which was placed at a distance of 20 cm, mounted on a manually turn-table angle system and an another ^{3}He detector which was positioned at 0° angle to monitor the 148 keV flux passing through the sample over time. The survey results indicate that the measurement modes with and without the ^{181}Ta sample should be conducted with a measurement time of 100 hours per angle and a sample-detector distance of 20 cm to achieve good statistics for the 148 keV elastic scattering peak.

Table 1. The angular differential cross-section of the elastic neutron scattering of ^{181}Ta at En=148 keV

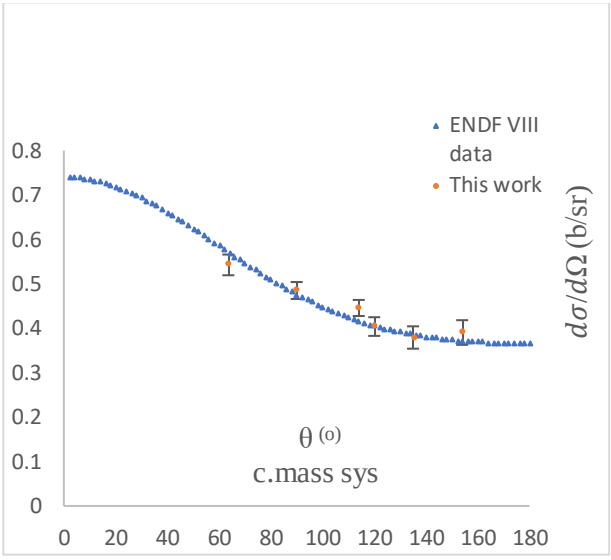
Angle (°)	ENDF VIII (barn)	This work (barn)	Difference (%)
154	0.370	0.390 ± 0.028	5.45%
135	0.383	0.379 ± 0.035	-0.99%
120 *	0.404	0.404 ± 0.021	-

90	0.475	0.485 ± 0.048	2.19%
63.6	0.567	0.580 ± 0.048	2.30%

(*) 120° is the standardization angle with ENDF VIII data



a)



b)

Figure 3. (a) The elastic neutron scattering spectrum and (b) The correlation between the experiment results and the ENDF data

The measurements were meticulously conducted at six angles of 154°,135°,120°, 114°, 90°, and 63.6°. The calculated results in Table 1 indicate that the measured cross-sections of elastic neutron scattering at 6 angles were in good agreement with the ENDF VIII data with the maximum difference of 7.52% at the angle of 114°. Figure 3 (a) depicts the experimental scattered spectrum measured at an angle of 90° and Figure 3 (b) depicts the correlation between this work and ENDF data. Our study has established a complete method for measuring neutron scattering at E_n=148 keV for the ^{181}Ta nucleus. The measurements at the other angles will be implemented in the near future.

SIMULATION OF NATURAL CONVECTION FLOW FOR VERTICAL HEATED ROD BY USING ANSYS/FLUENT

Thanh Tung Duong, Tan Hung Hoang, Hoang Tuan Truong, Chi Thanh Tran, Hiroshige Kikura

Nuclear Training Center, 140 Nguyen Tuan Street, Thanh Xuan District, Hanoi, Vietnam

Project information:

- Project name: Study on natural convection using CFD code

- Code: CS/23/10-01

- Managerial Level: Institute

- Duration: 12 months (Jan. 2022- Dec. 2023)

- Contact email: duongttung@gmail.com

- Published papers related to the project:

1. 1. Thanh Tung Duong, Tan Hung Hoang, Hoang Tuan Truong, Chi Thanh Tran, Hiroshige Kikura "Simulation Of Natural Convection Flow For Vertical Heated Rod Using ANSYS/FLUENT", Journal of Nuclear Science and Technology, Nucl. Sci. and Tech., Vol.13, 2023.

2. Thanh Tung Duong, Tan Hung Hoang, Hoang Tuan Truong, Chi Thanh Tran, Hiroshige Kikura "Simulation Of Natural Convection Flow For Vertical Heated Rod Using ANSYS/FLUENT", Vietnam Conference on Nuclear Science and Technology, VINANST-15, Nha Trang, Vietnam, August 2023.

The decay heat removal by natural convection is very important in case of Station blackout (SBO) of a nuclear reactor. The computational fluid dynamic (CFD) is helpful to simulate the flow and temperature field. However, the CFD simulation models need to be validated by the experimental data. Thus, in this report, the Ansys/Fluent was applied to simulate the natural convection induced by a single heater rod. Regarding the experimental method, the optical method such as Particle Image Velocimetry (PIV) was applied for 2-dimensional velocity distribution. The k-type thermocouple was used to measure the pointwise temperature history. Accordingly, the simulation results of natural convection were confirmed with experimental data.

The main test section was the vertical heated rod with a diameter of 12 mm and the length of 22.5 mm. The wild rod was immersed at the center of a vertical pipe made of transparent acrylic with an inner diameter of 150 mm and a height of 500 mm. The transparent acrylic had a thickness of 3 mm for illumination and image acquisition. The working fluid was water; the initial temperature (Tin) was kept at room temperature (27 ^{o}C). The power set to the heater rod was 100 W, corresponding to a heat flux of 11864 W/m^2. Nylon powder (d=80 μm; ρ = 1020 kg/m^3) was dispersed in working fluid as reflector particles for PIV (Particle Image Velocimetry) measurements (Figure 1). A camera with 60 fps was used to record the movement of particles illuminated by a laser

sheet. This data allows one to analyze the 2-dimensional velocity distribution by using the PIV method.

The flow behavior and temperature history were selected to compare the simulation results and the turbulence model. The pointwise temperature at (x*=-72, y*=7.5, z*=0) (T4) was measured by using k-type couple. Besides, the PIV method was applied to visualize the measured 2-dimensional flow field inside the container.

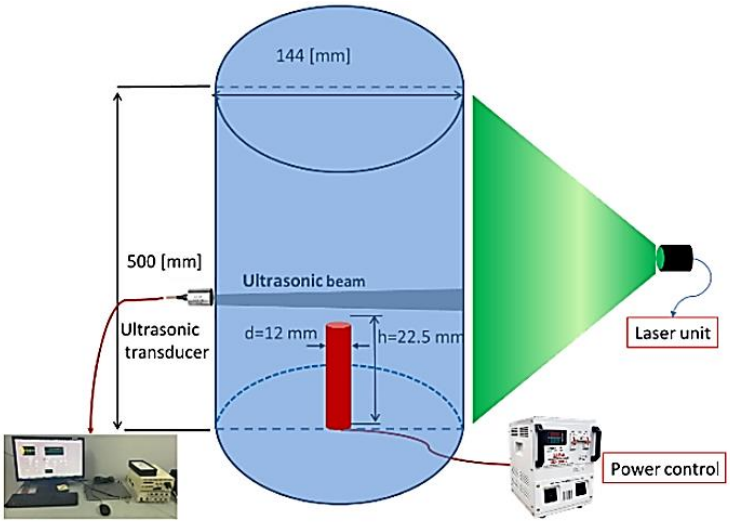


Figure 1. Sketch of experimental apparatus

In order to simulate the natural convection flow induced by a heated rod, the 3-dimensional geometry was created like the experimental apparatus. The k-ε turbulence model was applied to simulate natural convection. The Coupled scheme algorithm was selected instead of the Segregated Scheme in Fluent Solver. The simulation for natural convection in the vertical heated rods was performed by ANSYS/Fluent 17.2.

In natural convection, the temperature changes in the physical properties below were modeled as a function of temperature as follows:

$$\mu = \frac{-0.00018576T^3+0.197172T^2-70.15T+8401.04}{100000} \quad (1)$$

$$C_p = 0.0092T^2 - 5.6859T + 5058.24 \quad (2)$$

$$k = -0.00000905T^2 + 0.007048T - 0.6893 \quad (3)$$

$$\beta = -0.000000029783(T-273.15)^2 + 0.0000103247(T-273.15) + 0.00000755683 \quad (4)$$

Where, β is the thermal coefficient of expansion k is the thermal conductivity, μ is the dynamic viscosity and Cp is the specific heat.

Since the Ansys/Fluent Bousinesq density model does not allow thermal expansion β as a function of temperature T, it is necessary to derive a new density model with temperature as an independent variable. The custom density model was governed by Bousinesq approximation.

$$\rho = \rho_{ref}(1 - \beta(T - T_{ref})$$

(5)

As a result, the flow exhibited an upward motion at the center near the rod. The velocity which was farther from the rod was lower compared to the flow which was closer to the heater rod, as depicted in Fig. 2 and Fig. 3. Fig. 4 and Fig. 5 demonstrated a notable agreement between the simulation and experimental data when employing 2 k-epsilon turbulence models (standard and RNG). The water density near the heater rod notably decreased due to the rod's high surface temperature, prompting movement towards the colder regions driven by buoyancy forces. This behavior represents the typical natural flow pattern. Upon reaching the upper wall, the water descended. Consequently, in the upper region of the heater rod and the container's upper part, the interplay between upward and downward flows created a complex flow behavior. Both the simulation results and experimental data unequivocally indicated that the plume primarily concentrated in the region proximate to the heater rod.

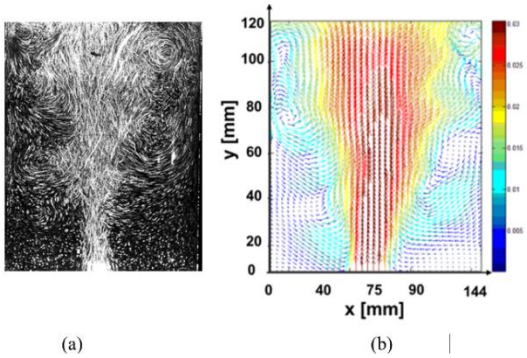


Figure 2. Experimental data of natural convection using PIV method: (a) visualization using image processing, (b) the velocity distribution using PIV at 300 s

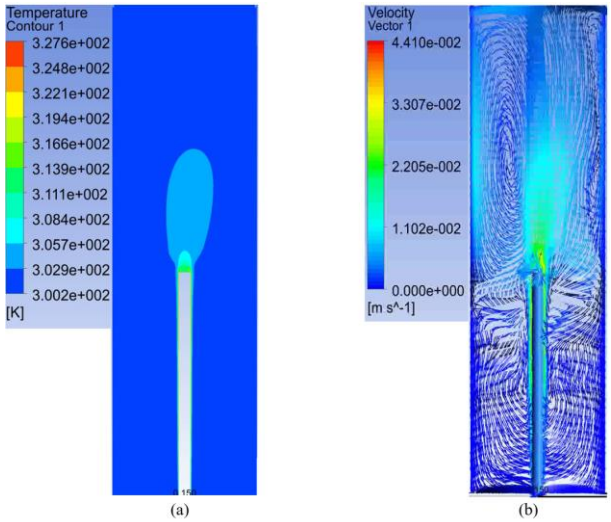
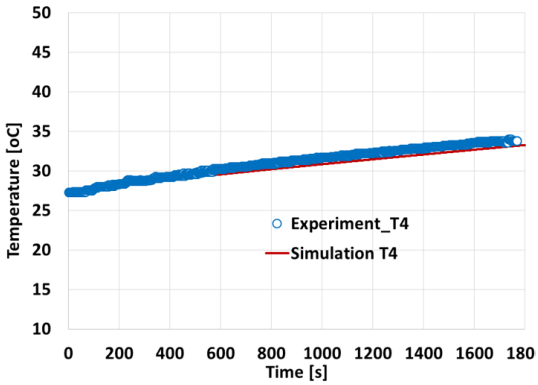
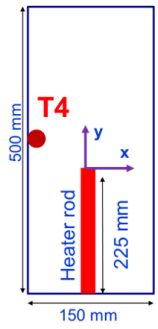


Figure 3. Simulation results of velocity and temperature distribution at 500 s

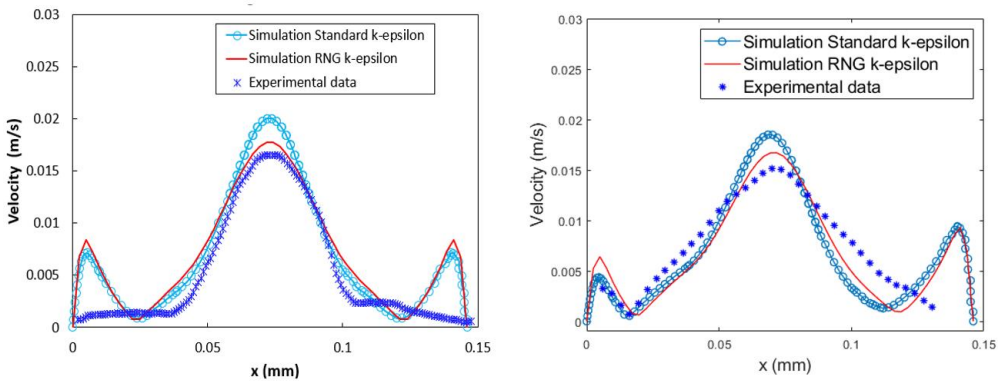




T4:

(x*=-72,y*=7.5)

Figure 4. The comparison of the history of temperature at T4 location



(a) at 100 s (b) at 500s

Figure 5. Comparison of the velocity profile at 100 s, 500 s between CFD and PIV method at 5 cm above the heater rod

In this project, the characteristic of convective flow induced by a single heater rod was investigated numerically and experimentally. The adequate model using Ansys/Fluent was applied for convective flow simulation in which a coupled scheme algorithm and temperature -dependent of physical properties was confirmed with experimental data. Accordingly, the comparison between simulation and experiment showed a good agreement.

2.2. INSTRUMENTATION, NUCLEAR ELECTRONICS

AUTOMATIC PROCESS OF THE WATER SAMPLE CHANGER FOR HIC-KOTRON13 BASED ON PLC AND MEASURING GAUGE TO DETERMINE THE POSITION OF THE PROTON BEAM TO THE TARGET

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Project information:

- Project name: Automatic process of the water sample changer for HIC-KOTRON13 based on PLC and measuring gauge to determine the position of the proton beam to the target

- Code: ĐTCB.01/22/TTCX

- Managerial Level: Ministry

- Duration: 24 months (Jan 2022- Dec 2023)

- Contact email: tuananhbk112@gmail.com

- Published papers related to the project:

1. Nguyen Tuan Anh, Nguyen Tien Dung, Pham Minh Duc, Nguyen Xuan Truong; "The design, construction of measuring block for proton current and calibrated current on accelerator HIC-KOTRON13", Journal of Science & Technology – Hanoi University of Industry, Vol.59, Number 4, 8/2023. (in Vietnamese)

The cyclotron HIC-KOTRON13 was installed and operated in the Hanoi Irradiation Center to produce radio-isotope ^{18}F. This accelerator is the R/D product supported by the Korea Institute of Radiological and Medical Sciences (KIRAMS). It needs to upgrade with the functions of the commercial PET Cyclotron. With PET-Cyclotron, the beam current is measured at the target, with 4 collimators around the target. With HIC-KOTRON13, the only beam current gauge on target was installed. The water sample changer operates manually through the switch ON/OFF. There are many times to switch ON/OFF to transfer water from the sample pot to the target and from the target to the hot cell.

This report presents two main parts. The first part is about the automatic sample water changer which was carried out based on PLC Siemens S7 1200 with LED HMI Wintek (Block diagram of this system is shown in Fig.1). The second part shows the design, construction, and testing operation of beam current proton gauge of HIC-KOTRON13.

The program control water sample changer which is written in LADER language with PLC S7-1200. Software TIA PORTAL V.14 is used for this program. The display LED is HMI Wintek with the software EasyBuilderPro.

The automatic water sample changer was installed and examined to work within the following technical parameters: (1) Water pipe operates stably with helium gas with presser 2 atmosphere; (2) The transmission time for radio-isotope ^{18}F from target to hot cell is about 4 minutes; (3) The errors of volume water in target for water loading from syringe are small after 3 times of water load. This fact is checked by changing the transparent window for the target. The operation of the water sample changer was carried out with LED HMI Wintek.

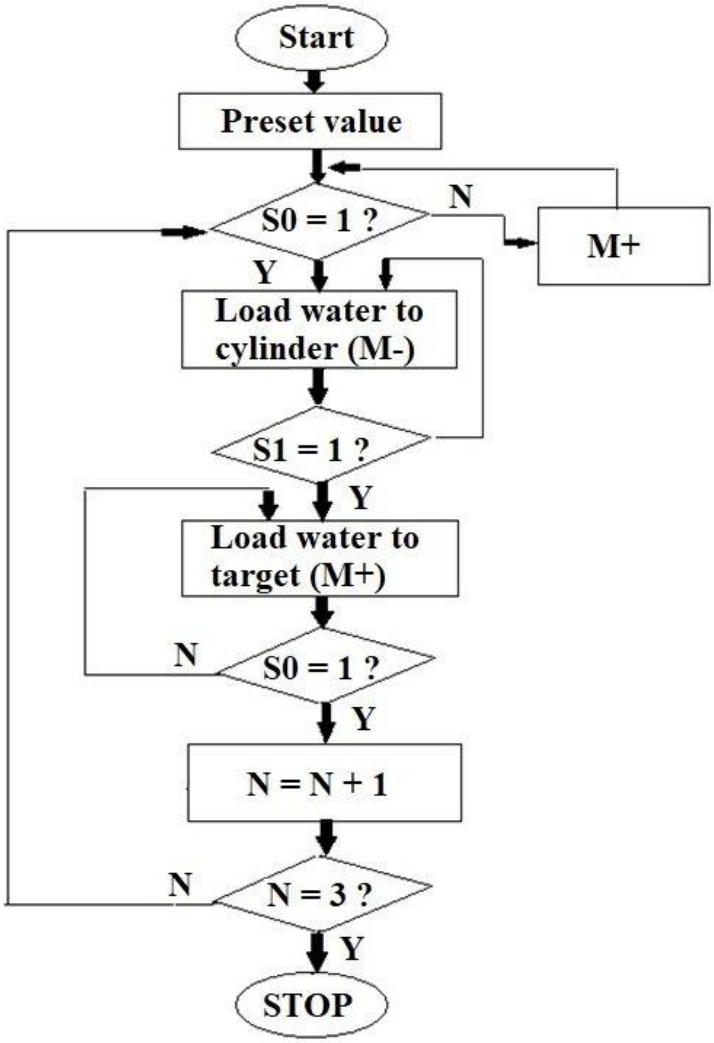

Figure 1. Block diagram of water sample changer.

The system's operation is described in details as follows. Firstly, after the process is started, the original values for water changer system are reset. Next, S0=1? Is checked. S0 is the switch position of the syringe's upper limit. If S0 = 0, the program control motor follows clockwise direction (M+) until S0 = 1. When S0 = 1, water is loaded from the water pot to the syringe. Regarding loading water to the syringe (M-), the program control motor follows anti-clockwise direction by setting value of PLC output (Q0= "1"; Q1 = "0"; Q4 = "1"). After that, S1 = 1? Is checked to check the position of lower limit switch. When S1 = 1, the syringe is full of water. Then, the water is loading for target (M+). The syringe moves from lower limit switch to upper limit switch. N = N +1, in

which N increases by one unit to count how many times the water are pumped from the cylinder into the target. If N ≤ 3, the process of pumping water into target continues. If N > 3, the process of pumping water into target finishes.

The beam current gauge that is installed on HIC-KOTRON13 is operated based on the Plane FARADAY detector. The target and four collimators around the target are detectors. The electric gauge will determine the beam current stored in the detectors

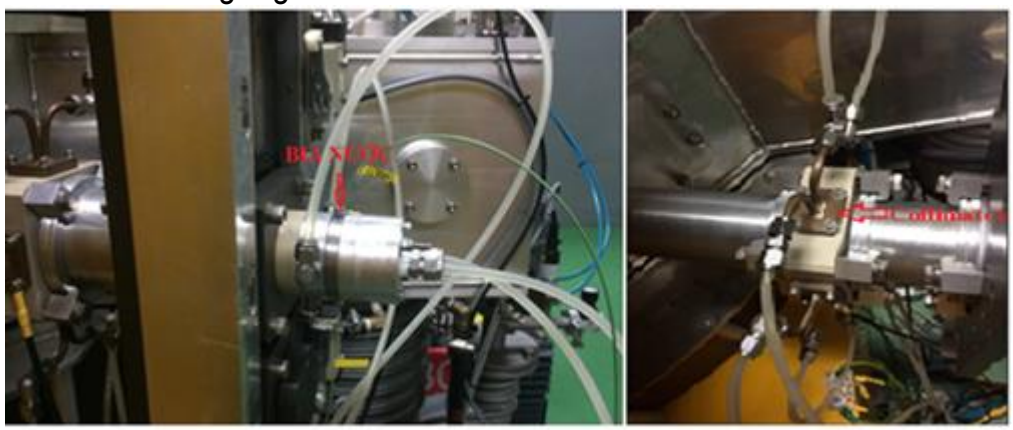

Figure 2. Photos of target and 4 collimators around target.

With the structure of the beam current gauge in Fig.3, a proton beam on target and four collimators are determined. Based on the value of beam current on four collimators, the deviation of the beam with a central point of the target can be estimated: Deviation up, down, right, and left position. This deviation is used to adjust the position of the ion source, carbon foil, etc. The general structure of the beam current gauge is as follows:

- Detector: Target and four collimator are plane FARADAY probe.
- I-V converter: Conversion current to voltage
- Voltage Amplifier: To amplify voltage to appropriate value with ADC converter.
- ADC, Display board: To display value of beam current on target and four collimators around target

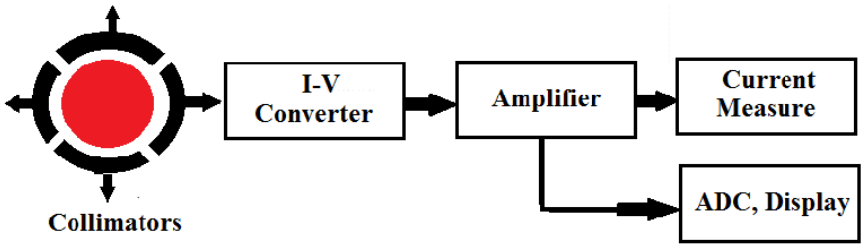

Figure 3. The structure of beam current gauge and the result of checking beam current gauge with the current generator

The Experimental result is shown in Table 1. The range of the current went up to 50 μA. The parameters of beam current gauge were as follows: Output voltage for amplifier, digital out of ADC. Conversion factor for beam current is calculated from output current generator and digital ADC out.

Table 1. Conversion factor of beam current gauge.

Current generator (μA)	Voltage output of amplifier (V)	Digital out of ADC	Conversion factor for current display
10	1.6	206	20.60
15	2.4	306	20.40
20	3.2	412	20.60
25	4.0	513	20.52
30	4.8	616	20.53
35	5.6	718	20.51
40	6.4	820	20.50
45	7.2	925	20.56
50	8.0	1022	20.44

For example, if the value of ADC output is 500, the current display on LED is shown as such: 500/20.5 = 24.4 (μA).

The new beam current gauge is installed in HIC-KOTRON13. The two options of beam current measurement are made from KOREA and HIC-KOTRON13. The conditions for the operation of HIC-KOTRON13 are the same.

With the same conditions and parameters set up for HIC-KOTRON13, the maximum deviation of beam current measured in the KOREA gauge and HIC-KOTRON13 gauge is 1.2 μA which is acceptable for PET-Cyclotron.

The project "The automatic process of water sample changer for HIC-KOTRON13 based on PLC and measuring gauge to determine the position of proton beam to target" is carried out with two mainly registered contents, including research and application of PLC in automatic operation of water sample changer and design, construction of proton beam current gauge, which is used to observe beam position from plane FARADAY probe. The products of this project comprise of mechanic block of automatic water sample changer, electronic gauge for water sample changer and electronic gauge to determine beam position for beam proton current. After the completion of the project, the research team will continue to carry out the standard and regulatory compliance procedures for the products so that they can be used for the KOTRON13 cyclotron accelerator.

STUDY ON THE APPLICATION OF SIPM AND SIPD TO MANUFACTURE AN INTEGRATED MULTI-CHANNEL GAMMA SPECTROSCOPY SYSTEM WITH SURFACE CONTAMINATION DETECTOR AND NEUTRON WARNING

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Project information:

- Project name: Study on the application of SiPM and SiPD to manufacture an integrated multi-channel gamma spectroscopy system with surface contamination detector and neutron warning

- Code: ĐTCB.04/21/TTCX

- Managerial Level: Ministry

- Duration: 33 months (Jan 2021- Sept 2023)

- Contact email: vansybn@gmail.com

- Published papers related to the project:

1. Nguyen Van Sy, Dang Quang Thieu, Nguyen Thanh Hung. Design and manufacture of scintillation detector using CsI(Tl) crystal coupled with silicon photomultipliers SiPM. Vietnam Journal of Science, Technology and Engineering, Vol B, No. 65(1)1.2023 (in Vietnamese).

2. Nguyen Van Sy. Development of scintillation detector using CsI(Tl) crystal coupled with silicon photomultipliers SiPM. Vietnam Journal of Science, Technology and Engineering, Vol A, No. 4.2023 (in Vietnamese).

3. Nguyen Van Sy, Dang Quang Thieu, Nguyen Thanh Hung. Research using PIN photodiode to measure alpha and beta radiation. Report at the 14th Vietnam Conference on Nuclear Science and Technology. Lam Dong, 09-10/12/2021 (in Vietnamese).

4. Nguyen Van Sy, Dang Quang Thieu, Nguyen Thanh Hung, Dang Cung Kiem. Correction for temperature dependence of SiPM scintillation detector. Report at the 15th Vietnam Conference on Nuclear Science and Technology. Khanh Hoa, 09-11/08/2023 (in Vietnamese).

5. Nguyen Thanh Hung, Nguyen Van Sy, Dang Cung Kiem. Design of gamma and thermal neutron detector using CLYC crystal coupled with SiPM. Report at the 7th Conference on Nuclear Science and Technology for Young Scientists. Ha Noi, 06-07/10/2022 (in Vietnamese).

According to traditional radiation measurement methods, people often use types of detectors such as scintillation detectors using a photomultiplier tube (PMT), proportional counter tube, Geiger Muller Counter tube, ionization chamber…Nowadays, with the development of semiconductor technology, Silicon Photomultipliers (SiPM) have been created that can replace the function of a PMT with the advantages of low operating voltage, immunity to magnetic fields, very compact size, and generate signals with pulse amplitude and resolution similar to PMT. In addition, Silicon Photodiodes (SiPD) have also been developed to replace counter tubes in radiation measurement with the advantages of compact size, low power, low energy consumption, and suitable price. To master these technologies, the task of the project is to use SiPM and SiPD to manufacture multi-function handheld devices to measure and control radiation.

The device is designed according to the block diagram shown in Figure 1, with functional blocks such as: (1) Gamma energy spectrometer detector block, using rectangular CsI(Tl) scintillation crystal with dimensions of 25x25x50mm, paired with Onsemi's 26x26mm SiPM ARRAYJ-30035-64P-PCB module. In this probe block, there is an LM94021 temperature sensor to correct the temperature dependence of the detector through Hamamatsu's SiPM power supply module; (2) The detector block used to measure gamma dose rate and detect neutron radiation is made of CLYC (Cs_2LiYCl_6) scintillation crystal paired with SiPM S13360-6075 with dimensions of 10x10mm from Hamamatsu. This scintillator crystal contains the ^6Li isotope that enables thermal neutron recording through the $^6Li(n,\alpha)^3T$ reaction and produces a gamma equivalent energy of about 3,2 MeV. The pulse height discrimination method is used to determine gamma and neutron radiation; (3) The alpha and beta detector block uses 3 10x10mm SiPDs from Hamamatsu: S3590-09 measures cps(α) alpha radiation, S3590-08 measures cps(β+γ) beta and gamma radiation, and one S3590- 08 has a shielded window for measuring cps(γ) gamma radiation only. The beta radiation counting rate is determined by the difference cps(β) = cps(β+γ) - cps(γ); (4) The multi-channel spectrometer uses the Flash ADC AD7472 analog-digital converter integrated with a GAL20V8 programmable logic controller and ARM STM32F407VET6 microcontroller. Spectral data is sent to the central processing unit via SPI protocol for storage, indication, and radioisotope identification; (5) The central processing unit uses the 32-bit ARM Cortex M4 microcontroller STM32F407VGT6 from STMicroelectronics, with the tasks of controlling, retrieving data, storing, instructing, and transmitting data; (6) The power supply block for the device uses a 12V battery as input and converts it into suitable DC sources to provide power for all functional blocks in the device. It is capable of maintaining device operation for 45 hours continuously.

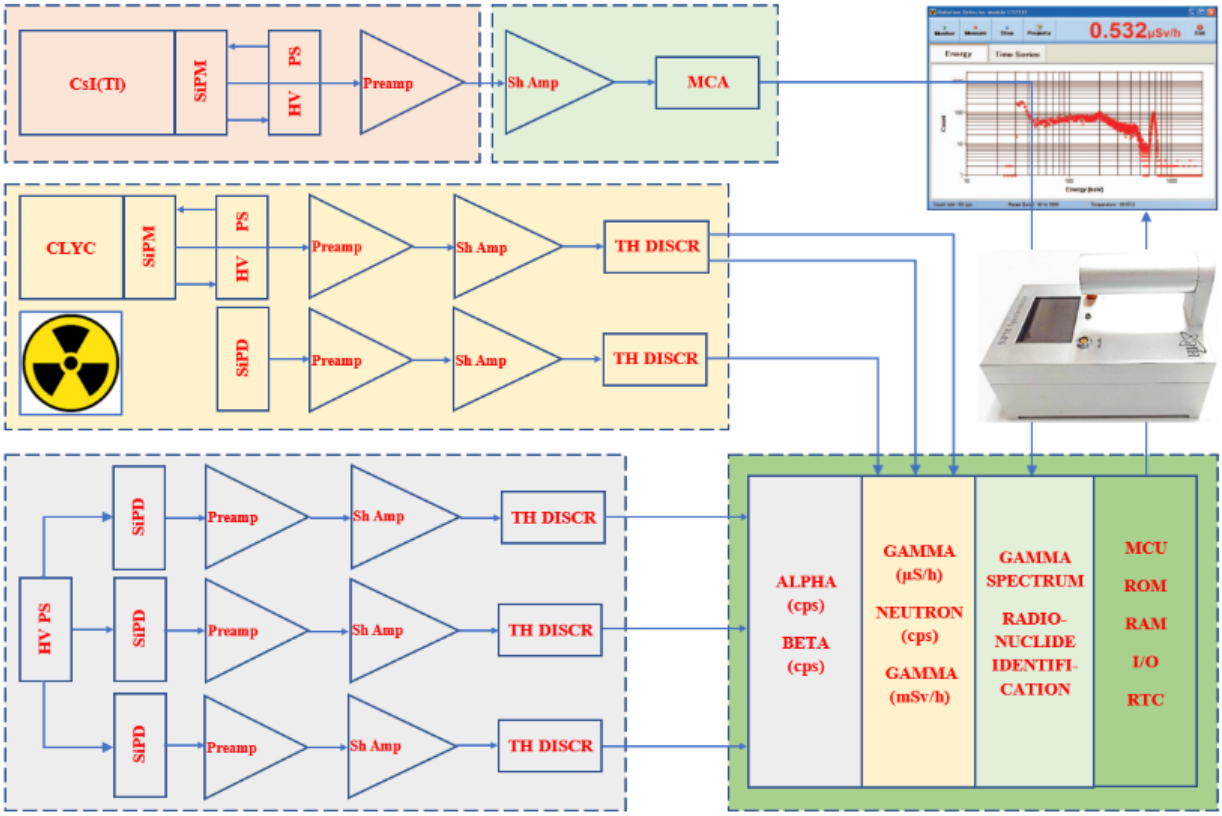

Figure 1: Block diagram of the multi-function radiation measuring device

The device can record the gamma energy spectrum with an energy resolution of 8,8% at the 662 keV peak of the ^{137}C source. The energy resolution of this detector is equivalent to the Canberra detector using a 3"x3" NaI(Tl) scintillator crystal, and the device is capable of identifying several isotopes built in the library: ^{22}Na, ^{60}Co, ^{137}Cs, ^{133}Ba, ^{226}Ra, ^{40}K. The device has been calibrated at the Secondary Standards Dosimetry Laboratory (SSDL) of the Institute of Nuclear Science and Technology in the gamma dose rate range from 8 µSv/h to 40 mSv/h with an error of less than ±10%. By extrapolation from the dose rate standard curve, the device is capable of measuring in the dose rate range from 0,01 µSv/h to 40 mSv/h with an error of less than ±15%.

The evaluation of the radiation source discrimination of the surface contamination detector shows that the alpha and beta measurement channels are completely independent, with no mistaken recording of one radiation into another radiation measurement channel. The efficiency of the alpha and beta detector was determined to be 6,9% and 33,5%, respectively. With the CLYC-SiPM detector, the device can measure and distinguish between gamma and neutron radiation to calculate the gamma dose rate and determine the counting rate of neutron radiation.

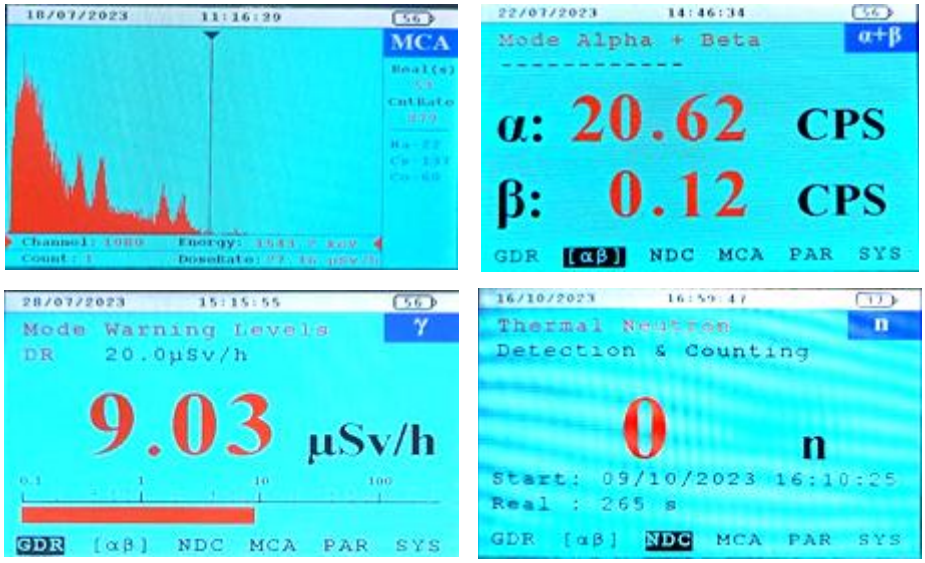

Figure 2. Figure of the device's operating mode interface

With the results achieved in the project, it is confirmed that the research team has mastered the technology by using SiPM and SiPD to manufacture radiation detectors and has been proactive in manufacturing multi-purpose radiation measuring devices with the functions such as: (1) Recording gamma energy spectrum and identifying radioactive isotopes; (2) Measuring gamma dose rate and determining the counting rate of alpha, beta, and neutron radiation. The device has been measured and tested in the accelerator and radiopharmaceutical production area at the Hanoi Irradiation Center. The results show that the measuring parameters of the device have very well supported the purpose of controlling radiation in this area during the operation and maintenance of the device.

Figure 3: Figure of the SiPM-Spectrometer multi-function radiometer

BUILDING A QUALITY ASSURANCE PROGRAM FOR CALIBRATION OF GAMMA AND X-RAY DOSIMETERS, MEETING THE REQUIREMENTS OF ISO/IEC 17025: 2017

Tran Van Trung, Nguyen Ngoc Quynh, Duong Thi Nhung, Bui Duc Ky, Dang Thi My Linh, Pham Bao Ngoc, Nguyen Dang Nguyen

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Project information:

- Project name: Building a quality assurance program for calibration of gamma and X-ray dosimeters, meeting the requirements of ISO/IEC 17025: 2017

- Code: CS/23/04-01

- Managerial Level: Institute

- Duration: 12 months (Jan 2023- Dec 2023)

- Contact email: tranvan_trung551987@yahoo.com

- Published papers related to the project:

1. Tran Van Trung, Nguyen Ngoc Quynh, Duong Thi Nhung, Bui Duc Ky, Dang Thi My Linh, Pham Bao Ngoc, Nguyen Dang Nguyen. "Building a quality assurance program for calibration of gamma and X-ray dosimeters, meeting the requirements of ISO/IEC 17025: 2017". 15th Vietnam Conference on Nuclear Science and Technology (VINANST-15), Khanh Hoa, Viet Nam.

The Ionized Radiation Standardization Laboratory at the Institute of Nuclear Science and Technology (INST) has been operated in Vietnam for many years. Since 2017, the laboratory has been certified according to ISO/IEC 17025:2005. After the standard equipment system was upgraded, some steps are being carried out for the laboratory to meet ISO/IEC 17025:2017 certification. ISO/IEC 17025:2017 has many technical and management requirements such as objectivity requirements, structural requirements, resource requirements, and management system requirements. The procedures to ensure the quality of the standard radiation field and the calibration of the equipment have been established.

The gamma radiation standard laboratory includes Hopwell's multi-source gamma system (model GC-60-10-A) and an auxiliary rail system. The multi-source gamma system includes 03 ^{137}Cs (10 mCi, 100 mCi and 1 Ci) and 03 ^{60}Co sources with varying levels of activity of 10 mC, 100mCi and 5 Ci. In addition, a new X-ray system with the maximum voltage and the current of 160 kV and 30 mA respectively, the filter film discs are used for narrow spectrum according to ISO 4037. The used equipment is the standard ionization chamber Exradin A4 with the serial number XP193013 and the electrometer SUPERMAX. The A4 ionization chamber is calibrated by the Dutch

Metrology Institute (VSL) and is considered the main standard ionization chamber of the laboratory.

The quality assurance program of standard field and calibration of equipment, is devoloped based on the criteria, process and management system requirements of ISO/IEC 17025:2017

For standard gamma field, dose rate/dose air kerma of sources of ^{137}Cs and sources of ^{60}Co was measured at a distance of 1m. The meter records the charge readings on the charge meter and makes temperature and pressure adjustments at each measurement. After the calibration, the air kerma value was calculated, the initial value and the measured value were standardized at the time of 01/01/2023. Uncertainty of measurements was calculated with the contribution of charge readings, standard coefficients of the measuring system, temperature and pressure, distance and other factors. For the standard dose rate/dose air kerma of the X-ray field, test for the narrow ray range from N40 to N150 was performed at a distance of 2 meters.

Table 1: Results of $\dot{K}_{air}$ after 1 year of operation of the gamma system for sources ^{137}Cs and ^{60}Co

Sources	Activity	$\dot{K}_{air}$ of initial value is normalized to date 01/01/2023 (µGy/h)	$\dot{K}_{air}$ of measured values are normalized to date 01/01/2023 (µGy/h)	Expanded uncertainty U_c and coverage factors k = 2, Confidence Invertal-CI 95% of $\dot{K}_{air}$	Difference (%)
^{137}Cs	10mCi	29,26	28,77	3,6 %	-1,896%
	100mCi	248,61	244,11	3,6 %	-1,812%
	1Ci	1158,11	1158,87	3,6 %	0,065%
^{60}Co	10mCi	76,04	75,16	3,6%	-1,160%
	100mCi	704,38	701,38	3,6%	-0,427%
	5Ci	18088,17	18126,83	3,6 %	0,214%

Thus the difference between the average value of $\dot{K}_{air}$ measured after standardization and the original $\dot{K}_{air}$ after standardisation does was not more than 2%.

Table 2: $\dot{K}_{air}$ test results after 1 year of operation of X-ray system for narrow spectrum N40, N60, N80, N100, N120, N150

Radiation quality	$\dot{K}_{air}$ from 5/2022 $(\frac{\mu Gy}{h.mA})$	$\dot{K}_{air}$ from 3/2023 $(\frac{\mu Gy}{h.mA})$	Expanded uncertainty U_c and coverage factors k = 2, Confidence Invertal-CI 95% of $\dot{K}_{air}$	Difference (%)
N40	1081,9	1085,0	4,4%	0,29%
N60	1635,3	1637,3	4,4%	0,12%
N80	861,1	865,0	4,4%	0,45%

N100	421,8	423,6	4,4%	0,43%
N120	458,9	461,1	4,4%	0,48%
N150	3389,6	3415,4	4,4%	0,76%

Thus, the difference between the median value of the measured $\dot{K}_{air}$ and the original $\dot{K}_{air}$ did not exceed 1%.

Gamma and X-ray Calibration Device Management Software (as name “QLCM”) has been designed to manage gamma and X-ray dose measuring devices at the Protection Radiation Centre. The software has been developed with a full set of information about a calibrated device such as: unit details, calibration device details, condition of calibrations, standard system, standard date, standard staff, results and assessments of measurement insecurity as well as the reliability of the standard results for each device. All of this information is in compliance with ISO/IEC 17025:2017 on the test report template. In addition, the software integrates calibration certificate issuance, keeps the results recorded year by year, which facilitates the retrieval of records based on information about the device usage unit and the standardized device details. The software enables to export the results to the word file, making it easier to retrieve the results.

Thus, the obtained processes and software in this project makes a good contribution to the completion process for Ionized Radiation Standardization Laboratory towards accreditation in accordance with ISO IEC 17025:2017.

DESIGNING AND FABRICATING A STATIONARY MAGNETIC PARTICLE TESTING SYSTEM MEETS THE REQUIREMENTS OF THE AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) STANDARDS

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[2]Nuclear training center - 140 Nguyen Tuan, Thanh Xuan, Hanoi

Project information:

- Project name: Designing and fabricating a stationary magnetic particle testing system meets the requirements of the American Society for Testing and Materials (ASTM) standards

- Code: ĐTCB.02/22/TTNDE

- Managerial Level: Ministry

- Duration: 24 months (January 2022 to December 2023)

- Contact email: thinhlvt@gmail.com

- Published papers related to the project:

1. 1. Le Duc Thinh, Nguyen Duc Huyen, Nguyen Xuan Thao, Phạm Thanh Tung, Nguyen Minh Duc, Duong Thanh Tung, Ngo Thi Kieu Oanh. "Design and manufacture Magnetic particle testing system (Bench unit) application in Non-Destructive Testing (NDT)". Proceedings of the 15th Vietnam Conference on Nuclear Science and Technology, Nhatrang, Vietnam, 2023 (in Vietnamese)

2. Le Duc Thinh, Nguyen Duc Huyen, Nguyen Xuan Thao, Phạm Thanh Tung, Nguyen Minh Duc, Duong Thanh Tung, Ngo Thi Kieu Oanh, "Design and manufacture a magnetic particle testing system (Bench unit) for Non-destructive testing (NDT)", Journal of Nuclear Science and Technology - Vietnam Atomic Energy Institute, Vol. 13, 2023 (in English)

Magnetic Particle Testing (MT) is a common nondestructive testing (NDT) method used to inspect objects made of ferromagnetic materials in order to detect surface and near-surface discontinuities. To achieve the highest sensitivity during the testing process, the orientation of the magnetic field must be perpendicular to the discontinuities. In practice, the orientation of these discontinuities is random and depends on the shape, manufacturing process, and usage of the product. Therefore, to detect a maximum number of discontinuities most standards and testing procedures require magnetization in at least two directions, with the second magnetization direction perpendicular to the first one. Various magnetization techniques and equipment can be applied for each magnetization. Common equipment used in magnetic particle testing include yokes, prods, coils, and stationary magnetic particle systems (bench unit). The

bench unit, comprising both a head shot and a coil, can generate both longitudinal and circular magnetic fields on test objects such as aircraft engine components, automobiles, and railway vehicles, both during the initial manufacturing phase and periodic maintenance.

Currently in Vietnam, only a few companies in the precision mechanical manufacturing industry use this system, and most of them import it from abroad at extremely high prices. Furthermore, they face difficulties in repairing, maintaining, and calibrating the equipment. Therefore, the authors conducted research to design and fabrication a magnetic particle testing system that complies with ASTM E709 and ASTM E1444 standards. The primary goal of this endeavor is to enhance self-sufficiency in Vietnam and reduce dependence on foreign suppliers.

Through an extensive survey of the requirements for magnetic particle systems at various organizations in Vietnam, with a particular focus on the aviation industry and precision machinery manufacturing units, the authors have undertaken comprehensive research and synthesized relevant documents encompassing fundamental principles in the fields of electrical engineering, electronics, mechanics, and applicable standards. This effort has enabled the development of the most suitable designs. Throughout the fabricating process, the system is continually assessed for suitability, and design parameters are optimized to ensure the production of a high-quality product that complies with standards.

Each part has been successfully designed, fabricated, and assembled into the complete system by the research team. This system is evaluated for accuracy, stability and overall system performance according to ASTM E709 and E1444 standards. The specifications of the bench unit are as follows:

Power supply voltage: 200 V - 240 V Maximum output current: 1500A, AC & HWDC Frequency: 50 – 60 Hz Duty cycle: 10% at maximum current output Timed current energies: 0.5s and 4s Ammeter: Digital Overall dimensions of the system (length x width x height): 150 x 70 x 154 (cm) Central conductor: Copper, OD x L: 2,5 x 100 (cm)	Maximum test part length: 100 cm Maximum test part diameter: 125 mm for the head shot and 60 mm for the coil magnetization Maximum part weight: 100 kg Magnetic coil with 4 turns, diameter 300 mm The wet magnetic particle irrigation equipment includes an 18-liter tank with an automatic stirring unit The UV lamp with of 365 nm wavelength and an intensity least 1000 µW/cm^2 on test surface

Figure 1. The stationary magnetic particle testing system

The accuracy and stability of the ammeter in the bench unit are evaluated. This assessment includes the measurement of the system's output current by connecting a shunt resistor meter in series with the headshot and coil, respectively. Subsequently, the current flow is measured and compared to the current value displayed on the shunt resistor meter. In accordance with the ASTM E709 and E1444 standards, the deviation between these current values must not exceed 10% or 50A, whichever is greater. This evaluation criterion is applicable to both alternating current (AC) and half-wave rectified direct current (HWDC) equipment systems. The evaluation is performed with randomly selected current flow values evenly distributed in the range from 0 to 1500 A of the bench unit. To ensure stability, assessments are performed multiple times a day and over multiple days. As a result, the current values displayed on the system and on the shunt resistor meter are within the allowable range of the ASTM standards.

To ensure the system operates safely without electric leakage, checking for internal short circuit before use is necessary. The test is carried out by applying a maximum current flow of 1500 A to the clamping head assembly without any conductors between. The current meter must be at 0 A. If the meter displays any current value, it is a sign of an internal short circuit and the system must be repaired before use. Test results of the bench unit show that when no conductor is placed between the two clamps and generates the maximum current of 1500 A, the current meter shows 0 A. Thus, the system operates well with no signs of internal short circuit.

The system underwent an evaluation for both overall performance and sensitivity utilizing the Ketos AS 5282 ring. The evaluation employed the circular magnetization technique through the central conductor with a current of 500 A using HWDC, and utilized visible and fluorescent wet magnetic particle that conform to ASTM E709 and E1444 standards. The results of the equipment system's assessment demonstrate that the magnetic particle indications for three drill holes at a current level of 500 A meet the standard requirements.

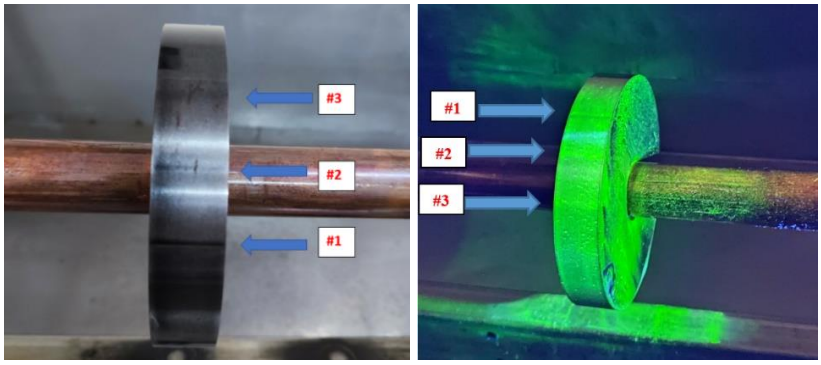
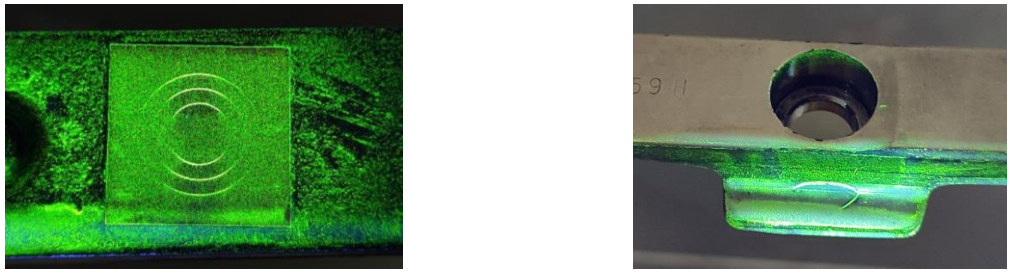


Figure 2. Indications when tested on Ketos AS5282 ring

After undergoing assessments for stability and accuracy, the system is employed to inspect various cast and wrought machine parts. To thoroughly examine the entire component for both longitudinal and transverse discontinuities, it becomes essential to utilize both circular (head shot) and longitudinal (coil) magnetization techniques. Depending on the dimensions of the test object, the magnetizing current can range from 500A to 1000A. Before each test, the adequacy of the magnetizing current strength is confirmed using a shim magnetic field indicator. The following image displays indication of cracks detected on a test object:



a) Indication on Shim's surface b) Crack indication

Figure 3. Test results using the circular magnetization technique

The Bench unit has been successfully designed, fabricated, evaluated and applicated on some products, yielding promising initial results. Grounded in mastery of the techniques, the testing procedures related to the equipment align with international standards. The outcomes of this research are expected to be widely applicable to various entities with diverse needs, ranging from direct fabricating applications to accompanying services such as maintenance, repair, calibration, and training for NDT personnel.

However, this system represents its initial version, meeting the basic testing specifications outlined in ASTM standards. Future iterations must undergo further improvements and upgrades to cater to actual user requirements, enhancing convenience. These enhancements may include:

- Enhancing the current parameter display unit to retain the maximum magnetizing current value.

- Implementing a control button-based switching mechanism between AC and HWDC currents, eliminating the need for manual conversion.

- Developing specialized pre-programmed software or AI tools to automate the testing process, as well as the analysis and evaluation of results.

The bench unit has been fully designed and fabricated with a maximum magnetizing current of 1500A. This includes components such as the primary transformer, secondary transformer, current control, time settings, coil, and head shot. The Bench unit undergoes calibration for the following aspects: ammeter accuracy, timer accuracy, internal short circuit check, overall performance, and sensitivity, all in accordance with the requirements specified in ASTM E709 and E1444 standards. This calibration process aids us in mastering the technology, preparing for technology transfer for practical applications, facilitating localization of features, and reducing reliance on foreign factors. As a result, it leads to reduced product costs and enhanced competitiveness in the market.

2.3. INDUSTRIAL APPLICATIONS

STUDY ON THE TRACER CHARACTERISTICS OF SOME PERFLUOROCARBON COMPOUNDS (PFC) APPLIED TO GAS INJECTION SURVEILLANCE IN OIL FIELDS

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Project information:

- **Project name: Study on the tracer characteristics of some Perfluorocarbon compounds (PFC) applied to gas injection surveillance in oil fields**
- **Code: ĐTCB.17/21/TTUDKTHN**
- **Managerial Level: Ministry**
- **Duration: 24 months (Jun 2021- May 2023)**
- **Contact email: tamltt@canti.vn**
- **Published papers related to the project:**

1. Le Van Son, Nguyen Huu Quang, Huynh Thi Thu Huong, Tran Trong Hieu, Dang Nguyen The Duy, Le Thi Thanh Tam, Measurements of PFCs partition coefficients under reservoir conditions using chromatographic method, Conference on Nuclear Science and Technology, Dalat, 2021 (in Vietnamese);

2. Le Thi Thanh Tam, Nguyen Thi Kim Anh, Phan Van Phuc, Study on establishing the procedure for determination of some perfluorocarbon (PFC) tracers in gas samples from the oil reservoir with thermal desorption method combined with gas chromatography–mass spectrometry, Conference on Nuclear Science and Technology for Young Scientists, Hanoi, 2022 (in Vietnamese);

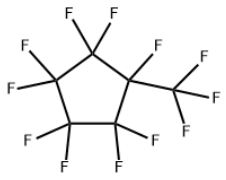
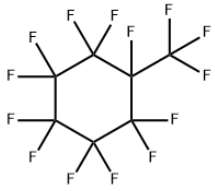
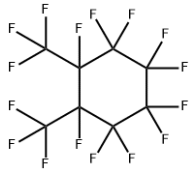
3. Le Thi Thanh Tam, Nguyen Thi Kim Anh, Phan Van Phuc, Study on establishing the procedure for determination of some perfluorocarbon (PFC) tracers in gas samples from the oil reservoir with thermal desorption method combined with gas chromatography-mass spectrometry (in Vietnamese); Vietnam Analytical Sciences Society (accepted)

Around the world, injecting gas tracers in oil fields has been carried out since the 1950s using radioisotope gases such as Kr-85, Methane with H-3 or C-14, CO_2 with C-14…Due to the need to use multiple tracers at the same time in the injection well, reduce the cost of tracers and limit the injection of radioactive material into the environment, Perfluorocarbons (PFCs) was proposed as chemical tracers in oil fields by the Brookhaven National Laboratory in the 1990s.

PFCs are cycloalkanes in which all the hydrogen atoms are replaced by fluorine atoms. The chemical inertness of PFCs assists in their separation from other interfering compounds during chromatographic analysis. Besides their inertness, the PFCs are potential tracers because of their high affinity for reaction with electrons. In most cases, a gas chromatograph equipped with an electron capture detector (GC/ECD) or negative chemical ionization mass spectrometer (NCI-MS) (GC/MS) is used for analysis. PFCs are nontoxic and require less environmental treatment than radioactive tracers (Dietz et al, 1983). In comparison with freons and other hydrocarbons when catalyzed combustion, PFCs are stable and unchanged if the temperature is not too high. The stability of the PFCs prevents their loss in the reservoir by degradation through chemical reactions. PFCs have kinetic properties similar to methane, ethane. In the oil and gas field, PFCs, the popular non-radioactive chemical tracers, are very popular and widely used for the investigation of gas injection processes in oil fields because of their chemical, thermal and microbial stability, high detectability (10^{-12} L/L) that can be analyzed by gas chromatography combined mass spectrometry (GC/MS). In the tracer technique, a quantity of PFC gas is injected with injection gas such as associated gas, CO_2 or nitrogen into the injection wells. During the transportation in the field, the tracer gas follows the pumped gas to the production wells with three typical processes: advection, dispersion and partitioning into gas, oil and water phases. These processes depended on hydrocarbon composition, reservoir pressure and temperature.

This project is conducted to improve the analytical capacity, means, techniques and technology for PFC tracers in gas samples with hydrocarbon-rich composition in order to supply the demands of oil and gas companies in production enhancement for oil recovery in the current period. The specific objective of this project is to establish a procedure to analyze 06 compounds of perfluorocarbons (Fig. 1) on the TD/GC-MS system and study on the characteristics of PFCs in gas tracer technology in the oil and gas field (distribution coefficient K_d of PFCs in oil/gas/water phases, movement of PFCs in oil-saturated porous environment).

To determine the accuracy of the PFC analysis method in oilfield gas samples by TD-NICI-GC/MS, parameters such as detection limit, precision and repeatability were determined according to the guidance of method validation for chemical and microbiological analysis. The matrix gas used in this research was from Su Tu Trang gas well in block 15-1, belonging to the Cuu Long basin. The gas sample from the Cuu Long oil reservoir is taken into a 500mL cylinder at the production wellhead after passing through the oil separator and transported to the laboratory. The parameter settings on the TD and GC/MS system were shown in Table 1.

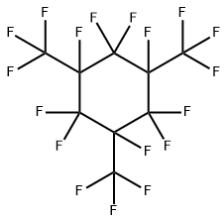
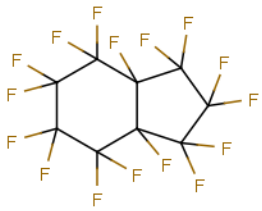
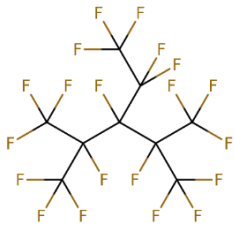
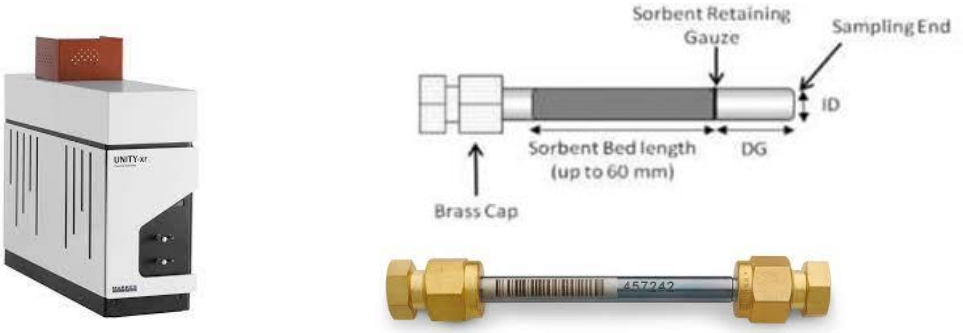
Perfluoromethylcyclopentane (PMCP)	Perfluoromethylcyclohexane (PMCH)	1,2-Perfluorodimethylcyclohexane (1,2-PDMCH)
		
1,3,5-Perfluorotrimethylcyclohexan (1,3,5-PTMCH)	Perfluoroperhydroindane	Perfluoro-2,4-dimethyl-3-ethylpentane

Figure 1. PFC compounds in gas tracers

Table 1. The parameters on the TD-GC/MS

TD	**Standby flow**	**10mL/min**
	Prepurge time	**1 min**
	Trap in line, trap flow	**50mL/min**
	Tube desorb	**350°C in 5 min**
	Trap desorb	**Purge time: 1 min, flow: 50mL/min, heating rate: max, temperature 350°C in 10 min.**
GC/MS	Temperature program ..	50°C, hold 0.75 min, ramp rate 20°C/min to 200°C, hold 20 min
	Total run time	28.25 min
	Carrier gas flow rate	1 mL/min
	Mode	Constant flow
	Ionization mode	CI
	Ion source temperature	150°C
	Quadruple temperature	150°C
	Mode	SIM (300, 350, 400, 412, 450, 488 *m/z*)



(a) **(b)**

Figure 2. Thermal desorption device (a) and adsorbent tube (b)

During the thermal desorption process, the PFC compounds trapped on the solid adsorbent (Carboxen 569) were desorbed by heating the adsorbent tube in the presence of an inert gas stream (helium), the PFCs were flushed into the cold trap of the TD device and instantly heated up to 350 °C. The newly desorbed PFCs were transferred into the injection port of the GC/MS instrument by carrier gas.

An analytical method for the simultaneous determination of 6 ultratrace PFCs in petroleum reservoirs by thermal desorption combined with gas chromatography-mass spectrometry using a chemical ionization source (TD-NICI-GC/MS) has been developed and validated. The procedure has a detection limit of 2-9 fL/L (10^{-15} L/L) with RSD repeatability <11% and good recovery efficiency (80-106%), high stability and reliability as shown in Table 2.

Table 2. Results of the analytical method validation for PFC using TC-GC/MS

No.	Compound	IDL pL/L	MDL pL/L	MQL pL/L	Working range, pL/L	RSD_R %	H %
1	PMCP	0.005	0.008	0.027	0.04-5	11	84-103
2	PMCH	0.005	0.006	0.021	0.04-5	8	93-102
3	1,2-PDMCH	0.005	0.004	0.014	0.02-5	7	95-101
4	PFIND	0.002	0.002	0.007	0.005-5	5	89-100
5	PTCH	0.005	0.003	0.008	0.02-5	5	80-106
6	PDMEP	0.01	0.009	0.032	0.04-5	6	97-104

A packed slim-tube was used to carry out the experiments for the partition coefficients determination of PFC in oil/gas/water phases and for the evaluation of PFC dynamic movement in the oil-saturated porous medium (Fig. 3) at 90°C, under the pressure from 1000 to2500 psi.

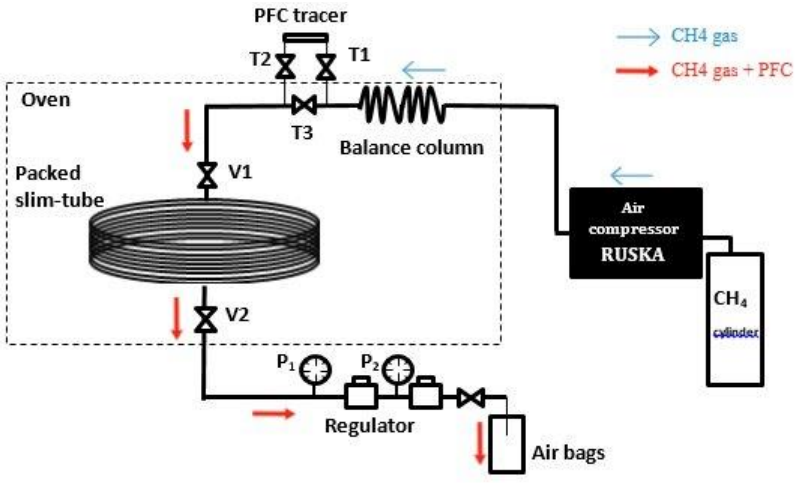


Figure 3. Schematic of the laboratory experimental system

Experiments with the crushed reservoir rock (100-120 mesh) were conducted using a 6-m long, 0.46-cm inside-diameter stainless steel tube filled with the liquid phase

(including water and/or oil) as a stationary phase and CH_4 gas () as a mobile phase. The experimental system pressure was achieved using a high-pressure air compressor and a pressure regulator. The carrier gas stream (CH_4) containing the PFC tracers was pumped through the packed column. During the process of moving with the injected gas, the tracer continuously diffused into the liquid phase (including water and/or oil) creating a chromatographic delay effect. During phases contact, gas samples were collected over time through the valve and analyzed for PFC tracer concentrations. The partition coefficient of PFC ($K_{d(LG)}$) in liquid/gas phase is the ratio of PFC concentration in the liquid phase and in the gas phase under equilibrium conditions.

Diffusion transport equation of gas tracer in porous medium containing oil (*o*), water (*w*) and gas (*g*) fluids is given as following:

$$\frac{\partial}{\partial t}\left(\sum_{i=o,w,g}\phi S_i C_i\right)=\nabla.\left(\sum_{i=o,w,g}\phi S_i D_i^{*}\nabla C_i\right)-\nabla.\left(\sum_{i=o,w,g}\phi S_i v_i^{*} C_i\right)$$

Based on the water/oil ratio in the column and the retardation factor of the PFC compound, the partition coefficient in the liquid/gas and water/gas phases of the PFCs are determined. Tracer concentration curves as a function of time or pore volume is used as experimental data to match the analytic solution of the diffusion transport equation to simultaneously determine the average retention time, liquid-gas partition coefficient, retardation factor, and dispersion coefficient of the tracer.

Experimental results showed that in the presence of oil and gas phase, the transport of PFC tracers in the porous medium was controlled by three characteristic processes including convection, dispersion and distribution between the two phases. The ratio of the average retention time of PFC to the gas travel time, or delay coefficient R, was in the range (2.1 - 2.7) with Kd ~ (3 - 4, 4), in the range (1.6 – 1.9) with Kd ~ (2 – 3), and in the range (1.6 – 1.9) with Kd below 2. The dispersion coefficient and partition coefficient values of PFC tracers gradually decreased with increasing pressure. Besides, at high pressure conditions (such as 2500 psi), the dispersion ability of PMCP and PMCH, PDMCH and PTCH did not show much difference.

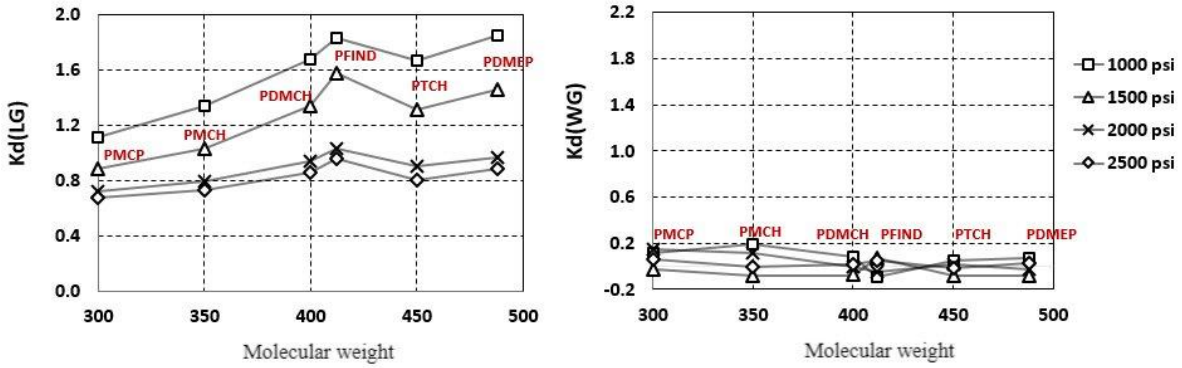


Figure. 4. Relationship between $K_{d(LG)}$ and $K_{d(WG)}$ of PFCs with molecular mass at different pressures.

Partition coefficients of PFC tracers in oil/gas/water phases from the dynamic movement experiments showed that PFC compound was extremely low soluble in water with $K_{d(WG)}$ < 0.2 (Fig. 4). Six PFC compounds at 90°C under pressure 1000 - 2500 psi had liquid/gas partition coefficients $K_{d(LG)}$ in the range of 0.68 - 1.85 and gradually decreased with increasing pressure (Fig. 5). The PFC compounds have larger molecular weight, their distribution will be better into the liquid phase (large $K_{d(LG)}$). The PFC with two rings structure (such as PFIND, M = 412 g/mol) tends to distribute more into the oil phase than others with one ring (PTCH) or branch chains at equivalent molecular weight (PDMEP).

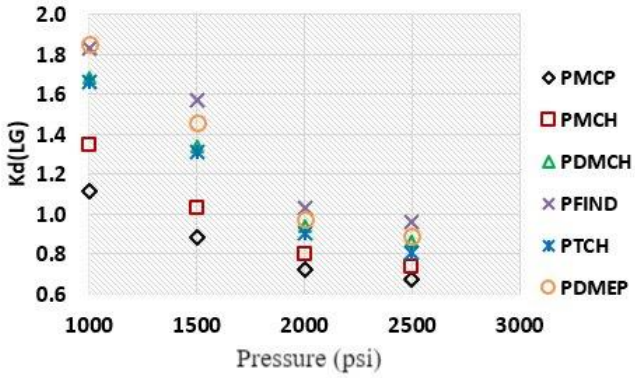


Figure 5. $K_{d(LG)}$ of PFCs decreases with increasing pressure

Six of investigated PFC compounds including PMCP, PMCH, 1,2-PDMCH, PFIND, PTCH and PDMEP have properties such as being able to dissolve into the oil and gas phases, not diffusing into the water phase, having negligible adsorption on the rock surface, being stable in reservoir conditions that make them suitable as the ideal gas tracers to the reservoir sweep performance evaluation programs in water-alternative-gas injection and oil recovery processes and having distribution coefficient $Kd_{(LG)}$ in the range of 0.68 - 1.85 at 90°C under pressure 1000 - 2500 psi. The selection of appropriate PFC compound depends on the facts of distance between injection wells and production wells, the number of injection wells, reservoir temperature and pressure conditions, as well as the financial capacity. However, among these compounds PMCP, PMCH and 1,2-PDMCH should be preferred because the liquid/gas partition coefficient $Kd_{(LG)}$ ranges from 0.68 - 1.85 and the retardation factor ranges from 2.3 - 3.5 at 90°C under pressure 1000 - 2500 psi.

DETERMINATION OF CHARACTERISTIC PARAMETERS OF SOME NEW TRACER COMPOUNDS INCLUDE BENZYL ALCOHOL AND PYRAZINE GROUP TO EVALUATE THE USABILITY IN PARTITIONING INTER-WELL TRACER TEST FOR DETERMINATION OF RESIDUAL OIL SATURATION

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Project information:

- Project name: Determination of characteristic parameters of some new tracer compounds include benzyl alcohol and pyrazine group to evaluate the usability in partitioning inter-well tracer test for determination of residual oil saturation

- Code: CS/17/01-01

- Managerial Level: Institute

- Duration: 18 months (Jan 2023- Jun 2024)

- Contact email: anhntk@canti.vn

- Published papers related to the project:

1. Nguyen Thi Kim Anh, Duong Thi Bich Chi, Le Thi Thanh Tran, Validation of analysis method of benzyl alcohol compounds in oil production water samples using gas chromatography-mass spectrometry (in Vietnamese); Vietnam Analytical Sciences Society (accepted).

The Partitioning Interwell Tracer Test (PITT) for determination of residual oil saturation S_{or} is the only current tool that allows identifying remaining oil in the interwell zone that can be further exploited by enhanced recovery EOR technology. The PITT technique uses a partitioning tracer with oil-water distribution properties to inject into the field along with non-partitioning tracer to determine Sor through the delay in travel time of the partitioning tracer from the injection well to the production well. The traditional interwell partitioning tracers are the straight chain alcohols that have quite poor analytical sensitivity (about 10^{-6}), are unstable under high temperature conditions and making them unsuitable for large-sized reservoirs. Therefore, recent researches have focused on finding new partitioning tracer compounds that have low analytical sensitivity and are stable in reservoir conditions in order to improve the capabilities of the tracer method. The potential partitioning tracers such as benzyl alcohol and pyrazine often have substituents attached to the aromatic ring that increase the stability and thermal strength of the molecule, limit their loss under field conditions.

In 2020, Mario Silva and et al. developed an analytical method for the simultaneous determination of new tracers including 4-chlorobenzyl alcohol; 2,6-dichlorobenzyl alcohol; 4-methoxybenzyl alcohol; 3,4-dimethoxybenzyl alcohol; pyridine

and 2,3-dimethylpyrazine by sample enrichment followed by gas-phase chromatography and tandem mass spectrometry (GC-MS/MS). With the advantage of good sensitivity (μg/L), the tracer amount injected into the oilfield is much less than that of the conventional tracer. By 2021, the authors continued to investigate the stability and K_d distribution coefficient of those compounds. Experimental results show that pyridine; 2,3-dimethylpyrazine; 4-chlorobenzyl alcohol and 2,6-dichlorobenzyl alcohol are stable at 150°C for 3 months. They do not interact with the common formation materials and are not affected by pH conditions (5,5 ÷ 8,0); the K_d values at 25°C are also in the optimal range from 1,3 to 1,9. The field tests have shown that those compounds have the ability to be the partitioning tracers in the interwell tracer technology.

This research project was carried out to strengthen the CANTI Center's capacity in the field of interwell tracer to determine residual oil saturation in large fields with thicknesses of tens of meters and distances between wells of up to thousands of meters at a depth of 3000 to 4000 m below the sea level to meet the needs of oil and gas industries in implementing enhanced oil recovery in the current period.

The specific goal of the project is to establish the procedure for analyzing pyridine, 2,6-dichlorobenzyl alcohol and 2,3-dimethylpyrazine in produced waters by gas chromatography-mass spectrometry with low detection limit (about 10 μg/L); determine the characteristic parameters of three compounds related to the interwell test (including the partitioning coefficient K_d in the temperature range from 60°C to 90°C, thermal stability over time in Miocene reservoir conditions) in order to evaluate the usability of those tracers in PITT for determination of residual oil saturation.

The research team conducted the assessment of the analysis procedure of pyridine; 2,6-dichlorobenzyl alcohol and 2,3-dimethylpyrazine in oilfield produced water samples by solid phase extraction (SPE) combined with gas chromatography-mass spectrometry (GC/MS) on the samples of produced water in the Miocene reservoir, Bach Ho field. The results of the study consisted of a detection limit of 5 – 9 (μg/L) with RSD repeatability < 7 %, good recovery efficiency in the range (81 – 113%), high stability and reliability as shown in Table 1.

Table 1. Results of determined parameters for pyridine; 2,6-dichlorobenzyl alcohol and 2,3-dimethylpyrazine in analysis method by GC/MS.

No.	Compound	IDL μg/L	MDL μg/L	MQL μg/L	Working range, μg/L	RSD_R %	H %
1	pyridine	2,5	5	14	15 – 500	7	81 – 102
2	2,3-dimethylpyrazine	2,5	5	15	15 – 500	6	86 –

							103
3	2,6-dichlorobenzyl alcohol	5	9	28	30 – 500	5	95 – 113

The experiments of partition coefficient K_d of pyridine 2,6-dichlorobenzyl alcohol and 2,3-dimethylpyrazine in oil/water phases were conducted on the oil-saturated packed column at 60°C, 80°C and 90°C. Experimental results show that the concentration distributions of pyridine and 2,3-dimethylpyrazine have a Gauss-shape with the retardation factor about 20 – 40% compared to water. Under the same experimental conditions, the partition coefficient K_d of all substances increases with temperature, the partition coefficient K_d of pyridine is the lowest (0,40 ÷ 0,48); the K_d of 2,3-dimethylpyrazine is in the range of (0,63 ÷ 0,83) and the K_d of 2,6-dichlorobenzyl alcohol is the highest (4,87 ÷ 5,07).

Thermal stability study of pyridine; 2,6-dichlorobenzyl alcohol and 2,3-dimethylpyrazine were performed at 90°C over time. Experimental results showed that the ratio of the remaining concentration of the tracers in solution over time compared to the initial concentration is 0,83 for pyridine; 0,94 for 2,6-dichlorobenzyl alcohol and 2,3-dimethylpyrazine after 90 days of heat exposure at 90°C. Based on thermal kinetic modeling, the potential loss due to heat of pyridine; 2,6-dichlorobenzyl alcohol and 2,3-dimethylpyrazine was 40%, 25% and 20%, respectively during a monitoring period of 12 months. The results show those tracers are relatively stable at temperatures of 90°C in produced water from the Miocene reservoir, Bach Ho field.

In conclusion, with characteristics such as solubility in oil / water phase, stablilty in reservoir conditions and suitable partition coefficient K_d, pyridine, 2,6-dichlorobenzyl alcohol and 2,3-dimethylpyrazine can be used as partitioning tracers in PITT for determination of residual oil saturation. Depending on the actual situation of the fields in terms of distance between injection wells and production wells, number of injection wells, temperature conditions as well as financial capacity, it is possible to choose one of three suitable substances. Among them, 2,3-dimethylpyrazine should be preferred because this compound has high thermal stability and fairly low partition coefficient K_d in the range of 0,63 – 0,83 at temperatures of 60°C – 90°C.

The results of this study are a premise for the application of the partitioning tracers which belongs to the group of benzyl alcohol and pyrazine in PITT for determination of residual oil saturation. Also, the results of the project contribute to improve the Center's competitiveness when the Center participates in domestic and foreign tracer projects.

2.4. APPLICATIONS IN ECOLOGY, ENVIRONMENT AND GEOLOGY

INVESTIGATING THE POSSIBILITY OF APPLYING URANIUM ISOTOPES TO DETERMINE THE AGE OF GROUNDWATER IN THE NAMBO PLAIN

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Project information:

- Project name: Investigating the possibility of applying uranium isotopes to determine the age of groundwater in the Nambo Plain

- Code: CS/23/02-02

- Managerial Level: Institute

- Implementation time: 12 months (Jan 2023 – Dec 2023)

- Contact email: nptuongminh1002@gmail.com

- Published papers related to the project:

1. Nguyen Pham Tuong Minh et al, *Studying to determine activity ratio $^{234}U/^{238}U$ in the groundwater in Nambo Plain by ion exchange method – using cation C100*, Vietnam Conference on Nuclear Science and Technology, Nha Trang, 09th – 11th August 2023, Poster.

2. Nguyen Pham Tuong Minh et al,, *Studying to determine the correlation between ^{14}C activity and uranium activity in the groundwater in Nambo Plain*, Ho Chi Minh University of Education Journal of Science.

Understanding the age of groundwater is a crucial aspect of hydrogeology. Along with the commonly used ^{14}C dating technique, uranium isotopes with a long half-life (10^5-10^9 years) and solubility are also used to determine groundwater age. This study aimed to determine the uranium activity in groundwater by extracting samples using radiochemical methods, and also determine the age of groundwater samples in the Nambo Plain using the ^{14}C method, thereby, evaluating the feasibility of using the activity ratio $^{234}U/^{238}U$ in future studies. The Nambo Plain has eight groundwater aquifers, namely: qh, qp_3, qp_{2-3}, qp_1, n_2^2, n_2^1, n_1^3, and Mz. For this study, samples were collected from six of these aquifers (excluding qh and Mz) at the same monitoring station, which provided that the water samples had an electrical conductivity (EC) below 2000 μS/cm. The six wells chosen for this study belong to six different aquifers and are located at station Q602.

After cleaning the wells based on the sampling pump procedure, the groundwater samples were acidified to a pH of 2, labeled, and transported to the laboratory. The separation of uranium in groundwater samples was carried out according to TCVN 12028:2018 by using the C100 ion exchange method:

(1). 500 mL of samples were evaporated. Then, samples were added to 5 mL of a HNO_3 solution with a pH of 2.

(2). Two grams of dry C100 cation exchange resin were weighed, and then the resin column was cleaned with 8 mL of 2M HCl and 8 mL of 1M HNO_3, respectively. Then, 8 mL of HNO_3 solution with a pH of 2 was run through the column to create the same environment as (1).

(3). The prepared samples were added through the cation column, and the flow rate was controlled to 1 mL/min. The beaker was changed before performing the elution.

(4). The column was eluted with 30 mL of 2M HNO_3 to recover the amount of uranium adsorbed on the C100 surface.

(5). The solution after eluting was collected and electrolysis steps were carried out.

(6). The electrolysis solution included 1 mL of 10% HNO_3 and 10 mL of $(NH_4)_2SO_4$ 0.23M. The electrolysis was conducted under the following conditions: U = 12 V, I = 0.5 A, and t = 60 minutes.

(7). After the electrolysis process was completed, any remaining impurities were removed from the stainless-steel disc surface by using distilled water. Finally, the activity was measured by using an alpha spectrometer system.

Uranium activity in the measured sample was calculated according to formula (1) and error according to formula (2):

$$\boldsymbol{A = \frac{S}{t.\varepsilon.H_{dp}.H_{rg}.V}} \quad (1)$$

$$\sigma_A = A.\sqrt{\left(\frac{\sigma_S}{S}\right)^2 + \left(\frac{\sigma_\varepsilon}{\varepsilon}\right)^2 + \left(\frac{\sigma_{H_{dp}}}{H_{dp}}\right)^2 + \left(\frac{\sigma_{H_{rg}}}{H_{rg}}\right)^2 + \left(\frac{\sigma_V}{V}\right)^2} \quad (2)$$

In which: *A is the specific activity of the sample (Bq/mL); S is the spectral peak area measured by the alpha spectrometer system (count); t is the sample measurement time (s); ε is the efficiency of the detector (%); H_{dp} is the efficiency of the electrolysis process (%); H_{rg} is the efficiency of the uranium elution process (%); V is the volume of the sample (mL).*

At the same time, the ^{14}C age of groundwater samples was determined. The results were presented in Table 1.

Table 1. Results of ^{14}C age, ^{238}U, ^{234}U activity and $^{234}U/^{238}U$ activity ratio of groundwater samples

	Sample	Aquifer	Depth (m)	Age (year)	^{238}U (mBq/L)	u^{238}U (mBq/L)	^{234}U (mBq/L)	u^{234}U (mBq/L)	papa
1	Q602020	qp_3	75	14,300	0.984	0.237	1.208	0.264	1.2
2	Q602030	qp_{2-3}	130	16,400	1.640	0.530	1.804	0.557	1.1
3	Q602040	qp_1	188	20,400	6.771	0.818	13.461	1.222	2.0
4	Q602050	n_2^2	220	18,700	3.499	0.567	7.807	0.882	2.2
5	Q602060	n_2^1	344	20,300	2.185	0.362	3.331	0.457	1.5
6	Q602070	n_1^3	444	28,300	0.970	0.236	1.250	0.269	1.3

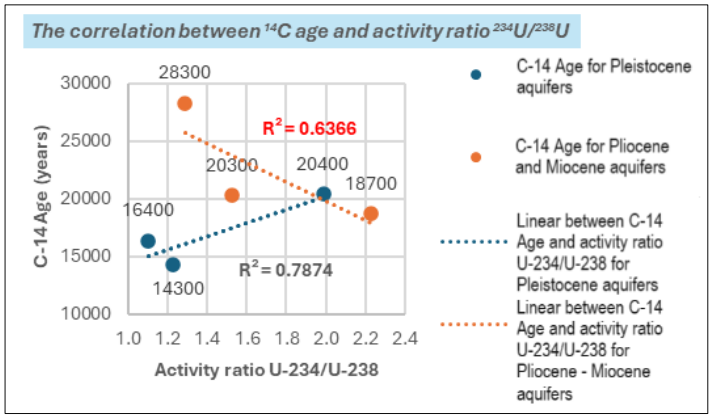

Figure 1. The correlation between ^{14}C age and activity ratio $^{234}U/^{238}U$

The results indicate that the specific activity of ^{238}U varied from 0.970±0.236 mBq/L to 6.771±0.818 mBq/L, while the specific activity of ^{234}U ranged from 1.250±0.269 mBq/L to 13.461±1.222 mBq/L. It was observed that the uranium activity gradually increased from top to bottom of the geological structure for the Pleistocene aquifers, and it reached the highest level at Q602040. This suggested that uranium was most dissolved in qp_1 aquifers in the Nambo Plain. On the other hand, in the Pliocene and Miocene aquifers, uranium activity decreased.

The age of groundwater in aquifers could be determined by studying the correlation between the sampling depth of the aquifers and the ^{14}C age. As the depth of geological structure increased, the age of groundwater also got older. The activity ratio $^{234}U/^{238}U$ was divided into two trends. For the Pliocene and Miocene aquifers, it was negative, while for the Pleistocene aquifers, it was positive. Figure 1 shows that there was a negative correlation between ^{14}C age and the activity ratio $^{234}U/^{238}U$ for the Pliocene - Upper Miocene aquifers, while there was a positive correlation for the Pleistocene aquifer. The Pleistocene aquifers could be recharged with "new" uranium sources. The stability of uranium activity in the upper Pliocene and Miocene aquifers confirmed that uranium could be used to study the age of groundwater and determine the age of water in the aquifer.

RESEARCH AND IMPROVEMENT OF THE ANALYSIS PROCESS TO DETERMINE THE ACTIVITY OF ARTIFICIAL RADIOACTIVE NUCLEAR ($^{239+240}$Pu, ^{90}Sr) IN SOIL SAMPLE

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Project information:

- **Project name: Research and improvement of the analysis process to determine the activity of artificial radioactive nuclear ($^{239+240}$Pu, ^{90}Sr) in a soil sample**
- **Code: CS/23/04-02**
- **Managerial Level: Institute**

  Implementation time: 18 months (Jan 2023- June 2024)
- **Contact email:** nguyenvankhanh.hus88@gmail.com
- **Published papers related to the project:**

1. Nguyen Van Khanh et al., "Survey of background radiation levels of $^{239+240}$Pu, ^{90}Sr and ^{137}Cs in the soil in some provinces in northern Vietnam". The 15th Conference on Nuclear Science and Technology in Atomic Energy Industry, Nha Trang, 2023 (in Vietnamese).

2. Nguyen Van Khanh et al., "The investigation of $^{239+240}$Pu, ^{90}Sr, and ^{137}Cs background radiation levels in soil samples in some provinces in the north of Vietnam". Nuclear Science and Technology.

The Center for Environmental Radiation Monitoring and Impact Assessment - INST has the function of monitoring radiation, assessing environmental impacts, and being ready to warn and support response to radiation and nuclear incidents. Improving analytical capacity and quality is always a requirement for the institute's laboratory. The INST used the precipitation method to separate strontium from other elements one by one. This method uses fuming nitric acid, which affects the health of the technician directly handling it. Furthermore, actual analysis of soil samples shows low and unstable recovery efficiency. Therefore, it is necessary to conduct research and improve existing processes to increase and improve the stability of recovery efficiency. The process of analyzing the activity concentration of $^{239+240}$Pu followed a new method in the world, the ion exchange method, but the recovery efficiency still fluctuated within a wide range. Therefore, the research team proposed the topic: "Research and improve the analytical process to determine the activity of artificial radionuclides ($^{239+240}$Pu, ^{90}Sr) in soil samples".

Research and improve the process of analyzing the activity concentration of $^{239+240}$Pu in soil samples:

In this study, the research team conducted a more detailed analysis of the processing steps to improve the analysis process. The process of analyzing the activity concentration of $^{239+240}$Pu in soil samples includes the following steps: (1) sample digestion to release Pu

from the sample matrix, (2) steps such as co-precipitation, running chromatography column to separate Pu from impurities; (3) create a source to determine the activity concentration of Pu by alpha spectrometry or mass spectrometry.

We have conducted research and improvements in steps (1) and (3), specifically:

- Determine sample ashing time and sample digestion time.
- Add strong oxidant $NaNO_2$ to the sample before running the ion exchange column.
- Investigate the effect of NH_3 on the surface of metal discs during the electrolysis process.
- Survey the optimal electrolysis time.
- Reduce sample volume to be processed.

The survey results were as follows:

- Increase sample ashing time from 4 hours to 6 hours and sample digestion time from 2 hours to 6 hours.
- Add HF solution to the digestion step.
- Add strong oxidant $NaNO_2$.
- Add a few drops of NH_3 to the sample before removing the electrolysis tank.
- Reduce electrolysis time to 1.5 hours instead of 2 hours.
- The mass of soil samples that need to be treated is reduced to 30 grams, thereby reducing the use of chemicals, helping to save costs, and reducing the amount of waste released into the environment.

Research and improve the process of analyzing the activity concentration of ^{90}Sr in soil samples:

To separate ^{90}Sr from the sample matrix and process the results of counting its ^{90}Y daughter isotope, we need to go through the following main steps:

- Digest the sample, and release Sr^{2+} from the sample matrix.
- Carbonate precipitation to remove group I metals.
- Oxalate precipitation to enrich Ca, Sr.
- Use the ion exchange column to separate and collect Sr^{2+}.
- Remove Y by co-precipitation with Fe^{3+}/OH^-, creating $SrCO_3$ precipitation to calculate the chemical recovery efficiency of Sr according to the gravimetric method and the radiometric method measuring the ^{85}Sr tracer using a gamma spectrometer.
- Create an equilibrium between ^{90}Sr and ^{90}Y after 02 weeks, separate Yttrium from the sample, process, and count beta from Yttrium oxalate precipitate.

Based on the reference to the Japanese process, combined with the existing internal process, the research team used an additional ^{85}Sr tracer to check the recovery efficiency through each step, thereby overcoming and optimizing several steps in the above process. Testing the new process on different types of soil in Vietnam, thereby obtaining the most complete process suitable to the situation and conditions of the laboratory. Improvement research steps include:

- Check and compare the digestion process with HCl and HNO_3.
- Check the efficiency of carbonate precipitation to remove group I metals.
- Check oxalate precipitation efficiency.
- Survey the amount of eluent (B: ammonium acetate 2M)

Survey results achieved compared to the old process:

- The sample weight is reduced from 500 grams to 100 grams, so the amount of chemicals used for the new method will be more economical.

- Reduce Oxalate precipitation from 3 times to 2 times. Reduce sample processing time.

Some changes compared to Japan's ^{90}Sr analysis process:

- Digesting samples with HCl was better than using HNO_3 and digesting 2 times instead of 1 time to completely release Sr.

- Precipitate oxalate twice to recover all Sr^{2+}.

- The volume of ammonium acetate to elute Sr^{2+} increases (following the calcium content in the sample).

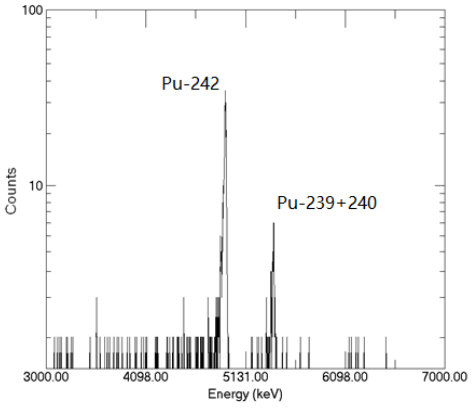

Figure 1: Alpha spectrum of isotope $^{239+240}Pu$ and tracer ^{242}Pu

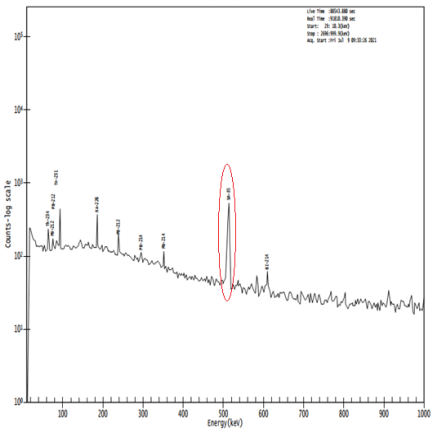

Figure 2: Gamma spectrum of tracer isotope ^{85}Sr

The recovery efficiency results of both analytical processes are higher and more stable than the previous process. After studying and improving the analytical processes, we proceed to confirm the validity of the two methods, including determining the repeatability, reproducibility, accuracy, detection limit, and uncertainty. Experimental results show that the repeatability and laboratory reproducibility of the test are completely consistent with the requirements (AOAC), and the precision of the measurement is consistent with the requirements of the method. By calculating the recovery of the test and the bias compared to the standard sample, it can be concluded that the accuracy of the measurement meets the requirements of the method. The analytical limits of activity concentrations of $^{239+240}Pu$ and ^{90}Sr in soil samples are 0.004 and 0.012 Bq/kg dry soil, respectively. The uncertainty of the analysis results of the activity concentration of ^{90}Sr in soil samples is ≤ 20% and ≤ 30% for $^{239+240}Pu$, meeting the requirements of the explanation. The research team classified three types of soil according to soil composition, including sandy soil, clayey soil, and silty soil, and determined the activity concentrations of $^{239+240}Pu$ and ^{90}Sr in these classified soil samples

STUDY ON CHARACTERISTICS AND SOURCES OF FINE AEROSOL POLLUTION IN HANOI DURING 2021-2023

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Institute for Nuclear Science and Technology, 179 Hoang Quoc Viet, Cau Giay, Hanoi

Project information

- Project name: **Study on characteristics and sources of fine aerosol pollution in Hanoi during 2021-2023**

- **Code: ĐTCB.14/21/VKHKTHN**

- **Managerial Level: Ministry**

- **Duration: 36 months (Jan. 2021 - Dec. 2023)**

- **Contact email: vtbac@yahoo.com and vtbac@vinatom.gov.vn**

- **Published papers related to the project**:

1. Quang Tran Vuong, Vuong Thu Bac, Phan Quang Thang, Min-Kyu Park, Sung-Deuk Choi (2023). Trace element characterization and source identification of particulate matter of different sizes in Hanoi, Vietnam. *Urban Climate,* Volume 48, March 2023, 101408. https://doi.org/10.1016/j.uclim.2023.101408. (ISI, IF=6.663, 2023).

2. Pham Duy Hien, Vuong Thu Bac*, Nguyen Thi Hong Thinh, Ha Lan Anh, Duong Duc Thang, Nguyen The Nghia (2021). A Comparison Study of Chemical Compositions and Sources of $PM_{1.0}$ and $PM_{2.5}$ in Hanoi. *Aerosol and Air Quality Research*. Volume 21, Issue 10, October 2021. https://doi.org/10.4209/aaqr.210056. (ISI, IF=3.063, 2021).

3. Pham Duy Hien, Vuong Thu Bac*, Ha Lan Anh, Quang Tran Vuong. Impacts of the East Asia Monsoon on the $PM_{2.5}$ Acidity in Hanoi (*The manuscript has been submitted to an international journal and is being reviewed*).

4. Vuong Thu Bac, Ha Lan Anh, Mai Dinh Kien, Nguyen Huyen Trang et al. (2023). Characteristics of fine dust pollution $PM_{2.5}$ in Hanoi in 2021. JNST No…. 2024.

5. Vuong Thu Bac, Ha Lan Anh, Mai Dinh Kien, Nguyen Huyen Trang et al. (2023). Characteristics and distribution of $PM_{2.5}$ fine dust pollution sources in Hanoi in 2021. *Proceedings of Vietnam Conference on Nuclear Science and Technology VINANST-15.* p194-203_8-2023 (in Vietnamese).

6. Nguyen Huyen Trang, Vuong Thu Bac, Nguyen Van Khanh, Duong Duc Thang. X-ray fluorescence (XRF) analysis method analyzes some key elements in air dust samples (2021). *Proceedings of Vietnam Conference on Nuclear Science and Technology VINANST-14. Lam Dong* 12-2021 (in Vietnamese).

Currently, air dust pollution in general in densely populated cities is one of the most complicated and difficult problems that many scientists and managers are concerned about,

because it is one of the leading causes of air pollution directly affecting human health and the ecosystem, especially $PM_{2.5}$ fine aerosols. Vietnam suffers economic losses of 10.8-13.2 billion USD each year due to air pollution, equivalent to about 5% of the country's GDP. Some recent studies show that fine aerosol pollution in Hanoi is reflected in many days exceeding the standard (nearly 149 days/year) and there are often periods of severe pollution for many days. In 2021, 100% of districts in Hanoi will exceed QCVN 05:2013/BTNMT standards and WHO recommendations in 2021.

The project is set with two following goals: 1) Determination of the characteristics and levels of fine aerosol pollution in Hanoi in the period 2021-2022; 2) Identification of the sources of pollution, their contribution and potential areas of contribution to $PM_{2.5}$ aerosol pollution.

To achieve these two goals, the project has set out the three following main contents:

(i) Overview of some results of air pollution research using nuclear analysis techniques and related analysis techniques. Technical overview of positive matrix factorization (PMF) model, HYSPLIT-4 backward trajectory model, potential source contribution function (PSCF) applied in aerosol pollution research.

(ii) Design and implementation of a program to collect fine aerosol samples, determine $PM_{2.5}$ concentration, analyze samples to determine the content of major chemical elements (K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Sr, Se, Br, Pb…), content of dissolved ions (F^-, Cl^-, NO_3^-, PO_4^{3-}, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}) and the content of major carbon compounds (BC, OC) in the $PM_{2.5}$ fine aerosol sample. Collect and process major meteorological parameters (WD, WS, RF, T, RH, radiation intensity) during sample collection.

(iii) Research on characterizing, identifying the sources and contribution of various types of fine aerosol pollution sources in 2021, 2022 and during typical periods of severe pollution; Research on identifying potential areas contributing to $PM_{2.5}$ fine aerosol pollution.

To carry out the project, the following research methods and sample analysis and data processing techniques were applied:

(i) Overview of documents, research results on fine aerosols and techniques for collecting and analyzing fine aerosol samples from advanced countries in the world.

(ii) Making use of the GENT and TWIN DUST sample collection equipment to collect $PM_{2.5}$ samples with an average frequency of two days and nights per week according to 24-hour standards and to seasons at the INST. Utilization of the system of specific equipment for meteorological parameters of interest at the Institute of Natural Science and Technology.

(iii) Applying nuclear analytical techniques (ED-XRF and PIXE) to analyze and determine the content of chemical elements, and related analytical techniques (IC, ICP-MS, LR-reflection technique light, OC/EC analysis techniques) to analyze and determine the content of dissolved ions, toxic heavy metals and carbon compounds in $PM_{2.5}$ fine aerosol samples.

(iv) Applying advanced statistical and long-range transportation models such as PMF, PSCF, HYSPLIT-4 to process data, studying the characteristics and sources of fine aerosol pollution, and the contribution of pollution sources components and areas that have the potential to contribute to $PM_{2.5}$ fine aerosol pollution.

After the implementation period, the project was fully completed and exceeded the registered content. The main scientific research products were detailed out below.

Firstly, the data set which was established including more than 34 parameters on $PM_{2.5}$ concentration, content of main chemical elements (K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn , As, Sr, Se, Br, Pb...), content of major dissolved ions (F^-, Cl^-, NO_3^-, PO_4^{3-}, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}), content Main carbon components (BC, OC, EC) in 212 $PM_{2.5}$ fine aerosol samples.

Secondly, the project has identified the typical characteristics of fine aerosols, the main sources of pollutants and their contribution to the air in Hanoi in 2 years 2021, 2022 and during typical periods of severe pollution.

The winter of the year 2021 (from October 2021 to March 2022) had a 24-hour average $PM_{2.5}$ fine aerosol concentration of (121.334 ± 77.589) µg/m^3 which was 2.533 times greater than $PM_{2.5}$ in the summer of the same year (from April to September 2021) (51.970 ± 16.404) µg/m^3, 2.247 times larger than QCVN-2023 (50 µg/m3) and 8.089 times larger than AQG (2021: 15 µg/m^3).

The winter of the year 2022 (from October 2022 to March 2023) had a 24-hour average $PM_{2.5}$ fine aerosol concentration of (99.531 ± 48.264) µg/m^3 which was 1.611 times greater than $PM_{2.5}$ in the summer of the same year (from April to September 2022) (61.779 ± 27.541) µg/m^3, 1.991 times larger than QCVN-2023 (50 µg/m^3) and 6.635 times larger than AQG (2021: 15 µg/m^3).

Based on the built data set, applying the PMF statistical model, six sources of $PM_{2.5}$ fine aerosol pollution and the contribution of component pollution sources in the duration from 5/2021 to 3/2023 were identified. These sources are specified as such: Pollution sources due to biomass burning account for (33.8 ± 6.0)%, secondary aerosols containing a lot of Amonium and Sulfate account for (17.3 ± 3.0)%, industrial activities (12.5 ± 2.2)%, soil/construction dust (10.0 ± 1.8)%, vehicle emissions (8.4 ± 1.5)%, sea aerosols (3.0 ± 0.5)% and unknown source composition accounts for (15.0 ± 2.7)%. The average $PM_{2.5}$ fine aerosol concentration during this period was (80.742 ± 48.791) µg/m3 (Figures 1 and 2).

The most typical period of severe pollution is the dry season of 2021 (from October 2021 - March 2022) and 2022 (from October 2022 - March 2023). Six sources of $PM_{2.5}$ fine aerosol pollution and the contribution of component pollution sources during this period were also identified. These sources are specified as such: Pollution sources due to biomass burning accounted for (33.4 ± 3, 0)%, secondary aerosols containing a lot of Amonium and Sulfate account for (24.6 ± 2.2)%, industrial activities (11.5 ± 1.0)%, soil/construction dust (9.9 ± 0.9)%, vehicle emissions (8.5 ± 0.8)%, sea aerosols (3.9 ± 0.4)% and unknown source components (8.3 ± 0.8)%. The average $PM_{2.5}$ concentration during periods of severe pollution was about 1.3 times higher than the average $PM_{2.5}$ in both 2021 and 2022. All six pollution sources were 1.2 to 1.8 times larger. Among these, sea aerosol source and secondary aerosol saw the highest rise of 1.6 and 1.8 times, respectively.

Thirdly, by applying advanced models HYSPLIT-4, PSCF, TrajStat and ArcGIS, a map of potential pollution areas contributing to $PM_{2.5}$ fine aerosol pollution during the research period was created (Figures 3 and 4).

The results of the project and the findings related to $PM_{2.5}$ fine aerosol pollution were published in several international journals such as "*Urban Climate*" in 2023, "*Aerosol and Air Quality Research*" magazine in 2021, domestic specialized scientific journal (NST) in 2024. Additionally, the outcomes of this study was presented at two Vietnam Conferences on Nuclear Science and Technology in December 2021 and August 2023, and was reported in one master's thesis in Physics.

Figure 1. Timeseries of observed $PM_{2.5}$ (blue) and $PM_{2.5}$ predicted by the PMF model (red)

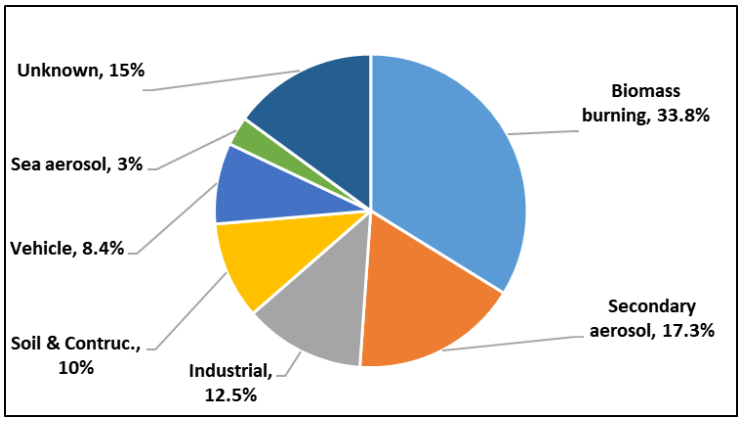
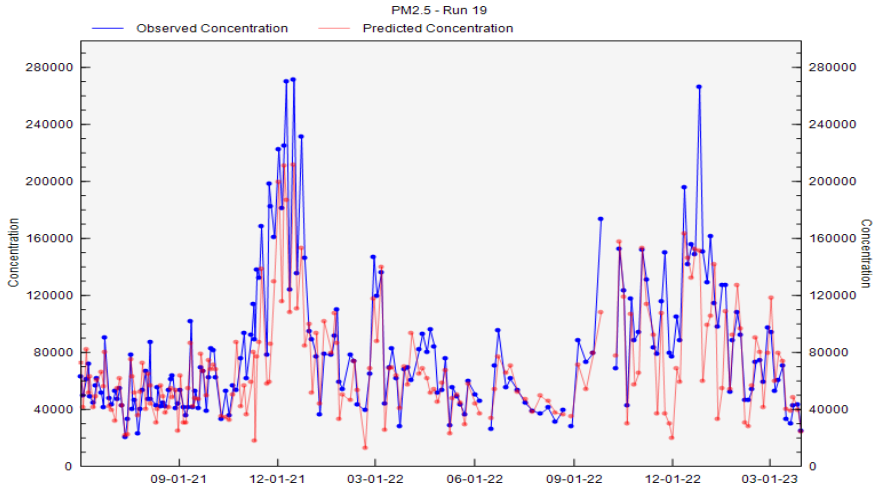


Figure 2. Contribution of component pollution sources to $PM_{2.5}$ fine aerosol in duration from 5/2021 to 3/2023

Currently, the manuscript titled "*Impacts of the East Asia Monsoon on the $PM_{2.5}$ Acidity in Hanoi*" has been submitted for publication in an international journal and is being reviewed. The project is still processing the obtained data and plans to write and submit more articles to international journals.



The project has completed well and exceeded the research content, meeting the set goals of ensuring quality and reliability. The results obtained from the project on the chemical composition data set, the composition of fine aerosol sources, the contribution of composition sources and the map of potential pollution areas have highly scientific and practical significance, contributing to the scientific basis for managers to plan control and management policies to reduce the current $PM_{2.5}$ fine dust pollution in Hanoi.

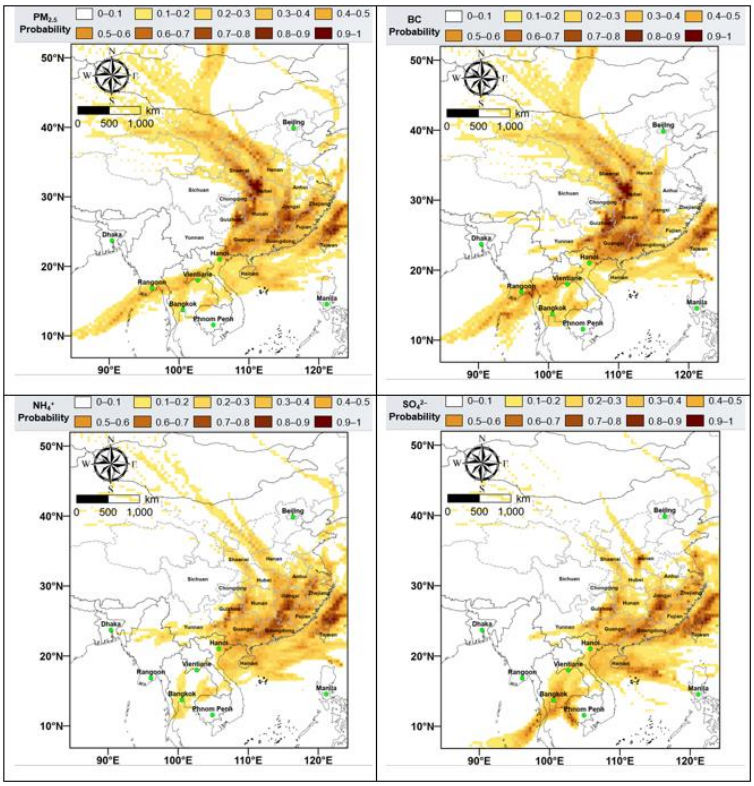


Figure 3. Map of potential areas contributing to $PM_{2.5}$ fine dust pollution in Hanoi 2021 (May 2021-March 2022)

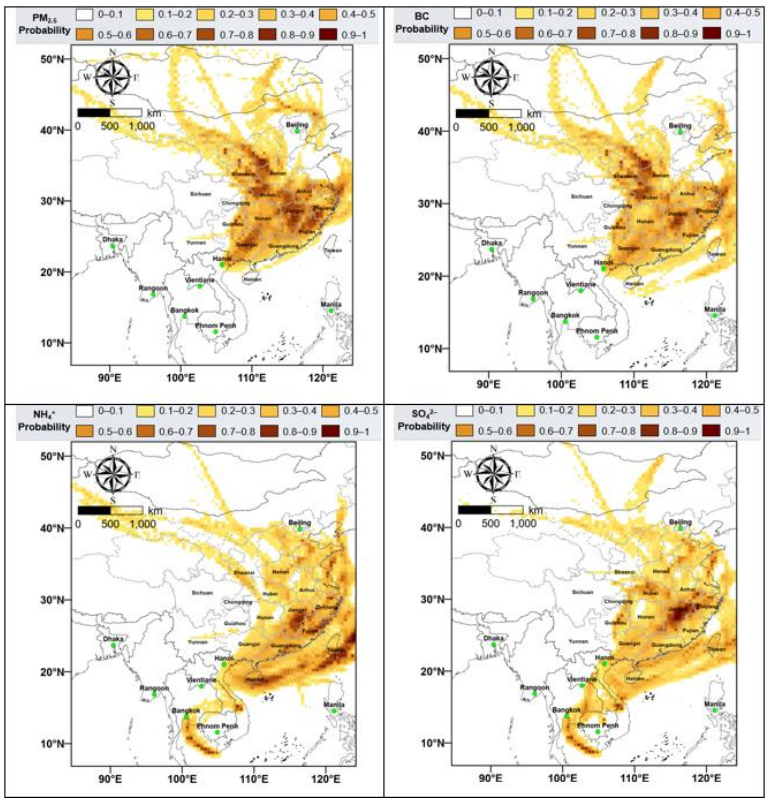


Figure 4. Map of potential areas contributing to $PM_{2.5}$ fine dust pollution in Hanoi in 2022 (April 2022 - March 2023)

2.5. APPLICATIONS IN BIOLOGY, AGRICULTURE AND MEDICINE

STUDY ON THE SYNTHESIS AND EVALUATION OF THE EFFECT OF RARE EARTH ASCORBATE COMPLEX PRODUCT ON DISEASE-RESISTANCE AND GROWTH ABILITIES OF STRIPED CATFISH (*PANGASIANODON HYPOPHTHALMUS*)

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Project information:

- **Project name: Study on the synthesis and evaluation of the effect of rare earth ascorbate complex *product* on disease-resistance and growth abilities of striped catfish (*Pangasianodon hypophthalmus*)**
- **Code: ĐTCB.18/21/TTHN**
- **Managerial Level: Ministry**
- **Duration: 24 months (June 2021- May 2023), extended to 30th Nov 2023.**
- **Contact email: Ngoctrinhhathi@gmail.com**
- **Published papers related to the project:**

1. Ha Thi Ngoc Trinh, Pham Quang Minh, Phung Vu Phong, Vuong Huu Anh, Ngo Van Tuyen, Cao Đinh Thanh, Nguyen Huu Phuc, Duong Dinh Tho, Tran Van Khanh, Pham Duy Hai, Le Thi Lam, Nguyen Thanh Tam, "*Research on the synthesis process of rare earth (La, Ce) ascorbate complex from (La, Ce)Cl_3 solution and evaluation of the effect of complex on the growth ability of striped catfish* (*Pangasianodon hypophthalmus*)", Vietnam Conference on Nuclear Science and Technology 15th (VINANST 15), Nha Trang, 2023.

2. Ha Thi Ngoc Trinh, Pham Quang Minh, Phung Vu Phong, Vuong Huu Anh, Ngo Van Tuyen, Cao Đinh Thanh, Nguyen Huu Phuc, Duong Dinh Tho, Tran Van Khanh, Pham Duy Hai, Le Thi Lam, Nguyen Thanh Tam, "Research on the synthesis *process* of rare earth ascorbate complex from rare earth carbonate and *evaluation of the effect of complex on disease-resistance and growth abilities of striped catfish (Pangasianodon hypophthalmus)*, Accepted for publication in Journal of Chemistry and Application, Vol 2 (69)/6-2024 (in Vietnamese).

Over the last decades, many studies have been conducted on the effectiveness of rare earth elements (REEs) in feed additives for livestock. The results indicate that supplementing rare earths in the diet ration at a certain dosage can show positive results not only in terms of weight gain but also in improving the quality of meat, milk, and eggs in both livestock and poultry. In addition, the use of organic-based rare earth complexes is more effective than inorganic rare earth ones. However, there have been few studies on the process of synthesizing rare earth complexes with Ascorbic acid as well as applying this complex to the fisheries sector in Vietnam and around the world. Based on practical needs, the project "**Study on the synthesis and evaluation of the effect of rare earth ascorbate complex product on disease-resistance and growth abilities of striped catfish (*Pangasianodon hypophthalmus*)**" was set out.

In this study, the process of synthesizing the rare earth Ascorbate complex (RE-AA) was established, and then, the RE-AA complex was supplemented in the striped catfish feed with the different rates of 0, 100, 150, and 200 mg/kg ($\sum RE_2O_3$) to evaluate the effect of the complex on disease resistance and growth abilities of striped catfish.

The synthesis reaction of rare earth ascorbate complex is based on the reactivity of activated (nascent) rare earth hydroxide with ascorbic acid. From the raw material which was the total rare earth carbonate obtained from the preparation process of Dong Pao rare earth ore (**(**La_2O_3 18.35%; CeO_2 29.12%, Nd_2O_3 6.93%; Pr_2O_3 3.53%; Y_2O_3 1,82%), the synthesis process of complex was carried out according to three steps (**Figure 1.A**):

1. Dissolution of rare earth carbonate
   The reaction equation: $RE_2(CO_3)_3H_2O + 6HCl \rightarrow 2RECl_3 + 3CO_2 + 3H_2O$
2. Precipitation of the activated rare earth hydroxides $RE(OH)_3$
   The reaction equation: $RECl_3 + 3NH_4OH \rightarrow RE(OH)_3 + 3NH_4Cl$
3. Synthesis of rare earth ascorbate complex
   The reaction equation: $RE(OH)_3 + 3C_6H_8O_6 + xH_2O \rightarrow RE(C_6H_7O_6)_3.xH_2O + H^+$

The process for synthesizing the RE-AA complex on scale of 5 kg/batch was carried out with the following technological parameters: temperature of 80^oC; reaction time of 6 hours, at pH 3.5 of the medium; and the molar ratio ascorbic acid/RE^{3+} of 3.2/1 for the efficiency of over 95%. The infrared spectrum of complex showed that the absorption in the 1035.82 cm^{-1} was related to the deformation of the lactone ring confirm the presence of ascorbic acid in the complex. Both, stretching of carbonyl in free acid changing to lower frequencies and splitting off two components indicated that aggregation of the complexes occurred via C= O bridges (**Figure 1.B**). By using ICP-MS analysis, the RE-AA complex was determined to have total rare earth element content of 18.58 ± 0.30%, which was equivalent to the total oxide content of about 21.79 ± 0.36%. This result was consistent with the analysis result by thermal analysis method, which was at 21.6%. The RE-AA complex was determined to have the general molecular formula $RE(C_6H_7O_6)_3$.

The procedure for synthesizing rare earth organic compounds containing $\sum RE_2O_3$ concentrations of approximately 96.1 g/kg for use as striped catfish feed additives was thus

established in this study. The product safety criteria met the requirements of QCVN 01-190: 2020/BNNPTNT.

In this project four types of striped catfish food supplemented with RE-AA micronutrients were produced. These experimental feeds, which were developed to supply the nutritional demands of pangasius, were produced on a floating fish feed pellet manufacturing line by the Aquatic Feed Experimental Manufacturing Workshop in Tien Giang. The products had the same nutritional composition but varying quantities of RE-AA complex: T0 (0 mg/kg - control), T1 (100 mg/kg), T2 (150 mg/kg), and T3 (200 mg/kg).

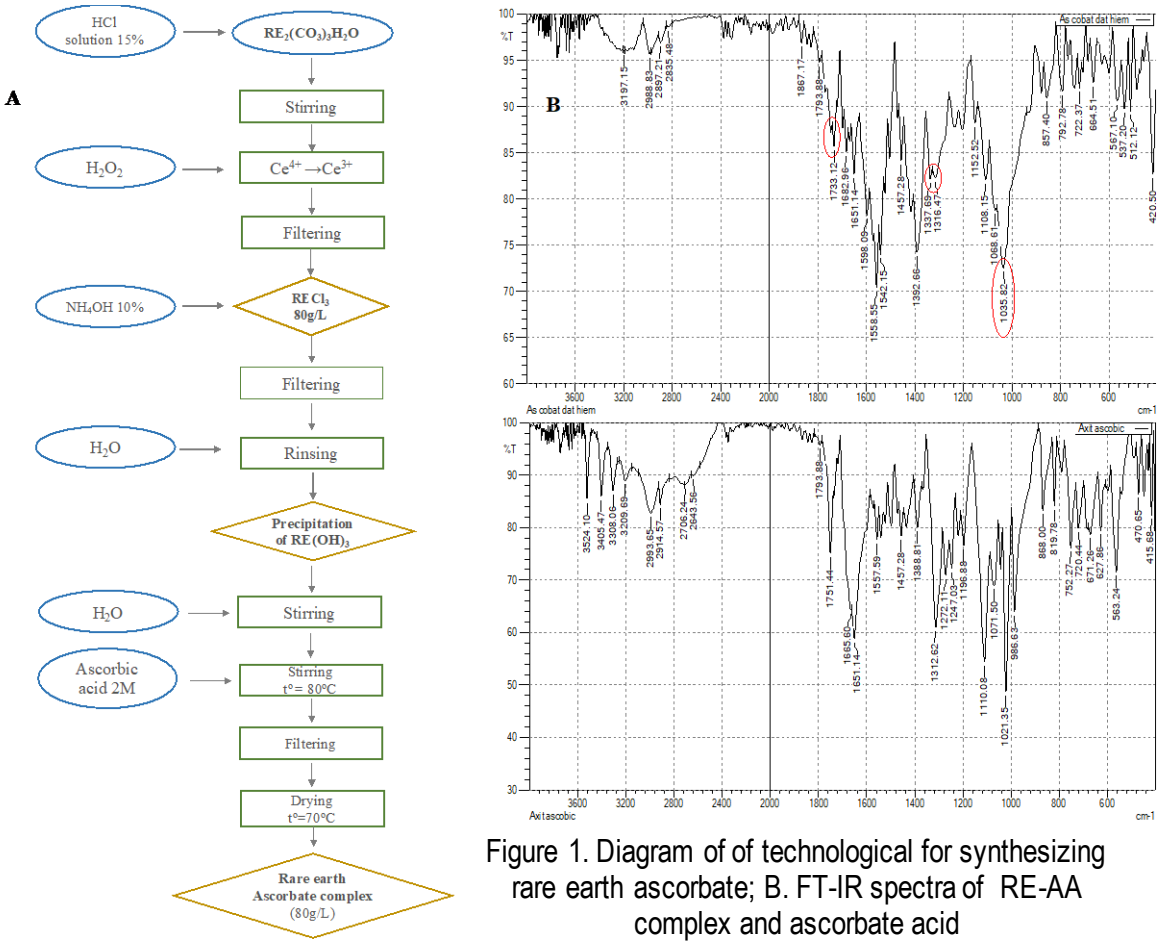

Figure 1. Diagram of of technological for synthesizing rare earth ascorbate; B. FT-IR spectra of RE-AA complex and ascorbate acid

The experiments to evaluate the effect of RE-AA complex on the growth of striped catfish were conducted on the 360 pangasius fingerlings. Fish were randomly divided into 12 of 500L composite tanks, at a density of 30 fish/tank, corresponding to 4 feed treatments and 3 replicates for each treatment. Fish were fed with experimental feed twice a day (at 8am and 4pm) with a diet of 5-6% of the fish's body weight. After 30 minutes of feeding, any leftover feed (if any) was checked and collected to determine the feed conversion ratio (FCR); The weight growth (WG) was measured by periodically weighing the fish at 56 and 84 days of culture.

$$\textbf{FCR} = I/(W_f + W_d - W_i) \quad \textbf{(1)}$$

$$\textbf{WG} = FBW - IBW \quad \textbf{(2)}$$

In which: I: the total amount of food used by fish (g/tank); W_i: the total weight of fish at the start of the experiment (g/tank); W_f: the total weight of fish at the end of the experiment (g/tank); W_d: the total weight of dead fish (g/tank); FBW: the average weight of fish at the end of the experiment (g/fish); IBW: the average weight of fish at the start of the experiment (g/fish).

Table 1. Weight growth and FCR of striped catfish after 56, 84 days of feeding with 4 diets

Growth parameters	Experiments			
	T0 (0 mg/kg)	T1 (100 mg/kg)	T2 (150 mg/kg)	T3 (200 mg/kg)
Initial weight (g)	$26.88^{a} \pm 0,53$	$27.28^{a} \pm 0.43$	$27.12^{a} \pm 0.67$	$26.64^{a} \pm 0.48$
WG after 56 days (g)	$43.59^{a} \pm 1.15$	$45.59^{ab} \pm 0.94$	$46.29^{bc} \pm 1.81$	$48.82^{c} \pm 0.91$
WG after 84 days (g)	$65.82^{a} \pm 4.03$	$66.35^{a} \pm 4.90$	$69.32^{a} \pm 4.35$	$71.58^{a} \pm 4.03$
FCR after 56 days	$1.64^{b} \pm 0,01$	$1.57^{ab} \pm 0.04$	$1.55^{ab} \pm 0.07$	$1.51^{a} \pm 0.06$
FCR after 84 days	$1.81^{a} \pm 0,06$	$1.76^{a} \pm 0.13$	$1.72^{a} \pm 0.11$	$1.69^{a} \pm 0.03$

Different letters within a row indicate statistically significant differences with $p < 0.05$

The results showed that supplementing RE-AA complex at 200 mg/kg improved the weight gain by nearly 12% ($p<0.05$), and decreased the feed conversion ratio (FCR) by 7.9% ($p<0.05$) in the comparison with the control batch after 56 days of culturing. After 84 days of farming, the fish had grown quite significantly, all experimental fish reached 93 g or more. The growth of pangasius reached its highest value at T3 (200 mg/kg) with an increase of nearly 72 g after 3 months of farming, an increase of about 8.75% compared to the control T0. However, there was no statistically significant difference ($p>0.05$) at this stage (**Table 1**). This might be due to the different effect of the complex on each growth period of the striped catfish.

In order to evaluate the effects of the complex on the disease resistance ability of pangasius by *Edwardsiella ictaluri* (*E. ictaluri*) bacteria, the experiments were conducted similarly to the growth assessment experiments. After 56 days of culturing, 20 fish in each tank were transferred to the corresponding glass tank to be infected with *E. ictalurid* bacteria at the dose of $LD_{50}=6.92x10^{5}$ CFU/mL by immersion method. The fish were inspected daily for activity and clinical symptoms, as well as their mortality rate for 15 days. The Kaplan-Meier Estimator Method in SPSS 20 software was used for collecting and displaying these data.

The research results demonstrated that diseased striped catfish exhibited pathological signs such as stop feeding, lethargic swimming, internal organs that were swollen, bruised, and hemorrhagic, with necrotic areas (appearance of round white spots with a diameter of 0.5 to

2 mm), and the presence of fluid in the abdominal cavity (**Figure 2**). Fish in the groups of T0, and T1 began to die after 72 hours. The mortality rate gradually increased on day 5 and day 6 and stopped dying after 10 days of infection. At the supplementation of 150 mg/kg, fish death appeared later after the day 4. At the supplementation of 200 mg/kg, the time when fish died delayed to day 5 and finished on day 9. After infection examinations, it proved that *E. ictaluri* was the primary cause of mortality in catfish based on observations of clinical symptoms and signals inside the internal sinuses as well as bacterial isolation from fish kidney samples.

The bacteria *E. ictaluri* was the principal cause of necrotic enteritis in striped catfish and basa fish. If they were not diagnosed and treated promptly, mortality rates could reach up to 50% in the grow-out stage and up to 90% in the fingerling stage. Supplementing 150 and 200 mg/kg of rare earth complex extended catfish resistance to the disease *E. ictaluri* by two days and raised the survival rate by approximately 7% compared to the control group (**Figure 3**). This makes it possible for afflicted fish farms to have more time for timely control in the event of unfortunate disease outbreaks.

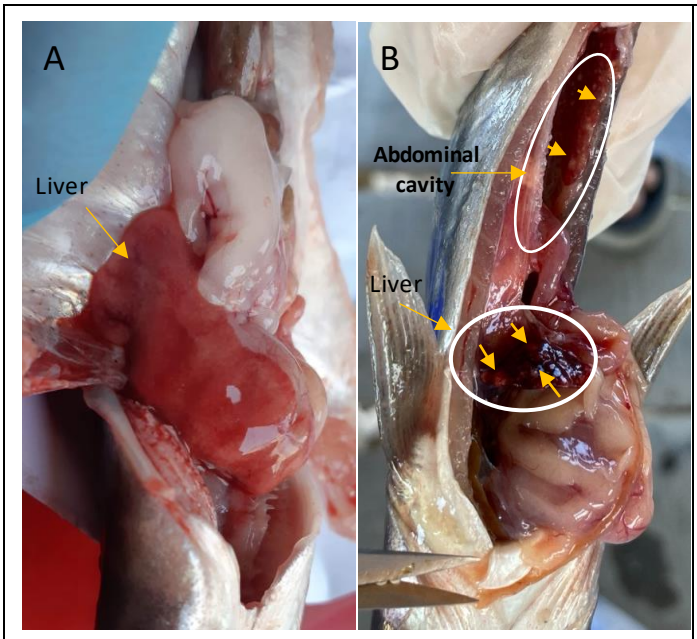

Figure 2. (A). Healthy fish internal organs with exhibited bright coloration, (B). Ddiseased fish internal organs with hemorrhagic liver, appearance of round white spots in the liver, the abdominal cavity

Diets	Survival rate(%)
T0	48.3
T1	50.0
T2	51.7
T3	51.7

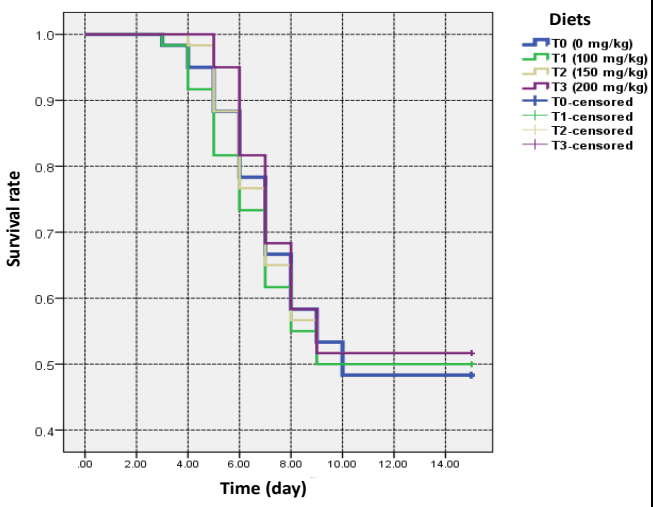

Figure 3. Evolution of survival rate of striped catfish in an experiment to evaluate disease resistance

These positive effects of the RE-AA complex on the growth and disease resistance of striped catfish might be due to the impact of the rare earth elements contained in the complex on the physiological processes of fish such as stimulating the secretion of digestive enzymes in the intestine and helping regulate nutrient (protein or lipid) metabolism and cell proliferation. Rare earth elements also showed anti-inflammatory and antioxidant effects as well as immune stimulation to kill bacteria, thereby improving weight gain, FCR, and disease resistance.

In short, the RE-AA complex can be potentially utilized as immune-stimulants and growth promoter for aquaculture. In the next studies, several trials will be carried out some experiments on food containing a higher RE-AA complex content of over 200 mg/kg (250, 300 and 350 mg/kg) to identify the optimal content for the growth of pangasius with a weight of 20-200 g. Besides, more supplemental tests to evaluate the effectiveness of the rare earth RE-AA complex on different growth stages of pangasius as well as on a variety of pathogenic bacteria also need to be studied.

STUDY ON PREPARATION OF THE BIOLOGICAL PRODUCTS HAVING GROWTH - PROMOTING AND DISEASE-RESISTANT EFFECTS ON TEA PLANTS BASED ON IRRADIATED XANTHAN AND ALGINATE

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- Project name: Study on preparation of the biological products having growth - promoting and disease-resistant effects on tea plants based on irradiated xanthan and alginate.

- Code: ĐTCB.03/21/TTCX

- Managerial Level: Ministry

- Implementation time: 33 months with extension (Jan 2021 – Sept 2023)

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- Published papers related to the project:

1. Nguyen Van Binh, Hoang Dang Sang, Tran Bang Diep, Tran Xuan An, Hoang Phuong Thao, Tran Minh Quynh. Effects of radiation dose and dose rate on alginate and the use of radiation degraded alginate for peanut. International Journal of Biological Macromolecules. Volume 266, Part 1, May 2024, 131038.
https://doi.org/10.1016/j.ijbiomac.2024.131038
2. Nguyen Van Binh, Tran Minh Quynh, Tran Xuan An, Hoang Phuong Thao, Tran Bang Diep. Effects of EB irradiation on the properties of xanthan in solid state for utilization as adjuvant to improve foliar applications. Vietnam Journal of Chemistry, 2024 (In production).
3. Van Binh Nguyen*, Xuan An Tran, Xuan Tung Nguyen, Dang Sang Hoang, Bang Diep Tran, Huyen Thanh Tran, Phuong Thao Hoang, Minh Quynh Tran. Effect of EB irradiation on some characteristics of xanthan with emphasis on application in foliar fertilizer production. Vietnam Journal of Science and Technology B, 2024 (accepted).
4. NV. Binh, NT. Thom, HD. Sang, TB. Diep, TX.An, HP. Thao, TM. Quynh. Effects of dose rate, absorbed dose and H2O2 concentration on molecular weight of alginate degraded by gamma ray Co-60 irradiation. Conference on Nuclear Science and Techniques, Da Lat, 9th-10th December 2021.
1. 5. Van Binh Nguyen, Xuan An Tran, Xuan Tung Nguyen, Dang Sang Hoang, Bang Diep Tran, Huyen Thanh Tran, Phuong Thao Hoang, Minh Quynh Tran. The effects of EB irradiation to the prooerties of xanthan at dry. Conference on Nuclear Science and Techniques, Nha Trang, 9th-11th August 2023.

Recently, natural polysaccharides such as chitosan, alginate, carrageenan, and xanthan have been extensively studied and widely used in agriculture production as plant growth promoters (PGP), elicitors, or main components of biological fertilizers due to their biological degradabilities and potential bio-activities. Among those, alginate is well-known as a popular PGP with its growth promotion and disease-resistant effects, and xanthan is a very high molecular weight polysaccharide that can be utilized as a wettable or bio-adhesive agent in agriculture. However, their high viscous properties have limited their application on a large scale. Some methods have been studied and applied to degrade these polysaccharides into smaller molecular weights or even oligomers, which can be easier for the uptake of plants.

Recently, radiation-induced depolymerization has been recognized as an effective technique for producing low molecular weight polysaccharides and oligomers such as oligochitosan, oligo-β-glucan, and oligoalginate. Radiation processing has also been shown to enhance the biological activity of polysaccharides, including antibacterial properties, growth stimulation, and disease resistance. Mixing radiation-depolymerized alginate and xanthan can enhance the effectiveness of both substances for tea plants, promoting growth and resistance to diseases. These bio-activities can improve tea production in major tea-growing regions such as Thai Nguyen provine and also be widely applied to various crops.

In this study, sodium alginate in powder form with weight-average molecular weight (Mw) of about 2,500 kDa was purchased from Kishida Chemical Company, Japan, and xanthan (from China) with Mw of about 1,700 kDa was supplied by Ba Dinh Technology Company, Hanoi, Vietnam. The effects of irradiation dose rates and doses on the degradation of Mw of these materials were investigated to produce a biostimulant for tea plants. To study the effect of dose rate, alginate samples were irradiated at a dose of 20 kGy with dose rates of 7.800, 1.250, and 0.625 kGy/h using the Gamma Chamber 5000, BRIT, India, at the Center for Biotechnology, Ho Chi Minh City and the Nuclear Research Institute in Dalat, Vietnam. The influence of H2O2 on the radiation-degraded level of alginate was also investigated. The absorbed dose was determined by using B3 DoseStix dosimeters.

25-year-old tea plants in Tan Cuong and 20-year-old F1 plants in Dong Hy were used to investigate the biological stimulant ability of alginate and xanthan irradiated separately and their mixture. The effects of the as-prepared product on bud density, bud weight, bud yield, and several tea quality factors were investigated to apply this natural mixture as a growth stimulant and disease-resistance agent for tea plants.

The results showed that gamma-ray irradiation caused the degradation of alginate and xanthan. The radiation-degraded yield (Gs) with Co-60 gamma ray decreased as the dose rate increased for alginate samples irradiated with the same dose of 20 kGy. In addition, the results in Table 1 showed, when alginate solution with H_2O_2 was irradiated under the same conditions, the Gs values increased with the increase of H_2O_2 concentration. Oligoalginate with Mw of about 9,800 g/mol was obtained by irradiating a 4% alginate solution in 2% H_2O_2 at a dose of 20 kGy, which was used as a growth stimulant for peanut and maize plants in our previous research which

was summarised in the project report of 2015 titled "Research and application of radiation technology to create products that increase the efficiency of foliar fertilizer use". Irradiation degraded the glycoside bond and formed a carbonyl group (C=O), as proved in the UV-Vis and FTIR spectra of the irradiated alginate, but due to the C=O group forming at the end of the chain, it hardly affects the structure of alginate.

Table 1. Effects of H_2O_2 concentration on Mw and radiation-degraded yield (Gs) of the alginate solution 4% (w/v) at 20 kGy

Concentration H_2O_2 (%)	0	0,5	1,0	2,0
Mw ($\times 10^3$g/mol)	49,60	16,98	11,72	9,79
Gs (µmol/J)	0,0611	0,1643	0,2309	0,2505

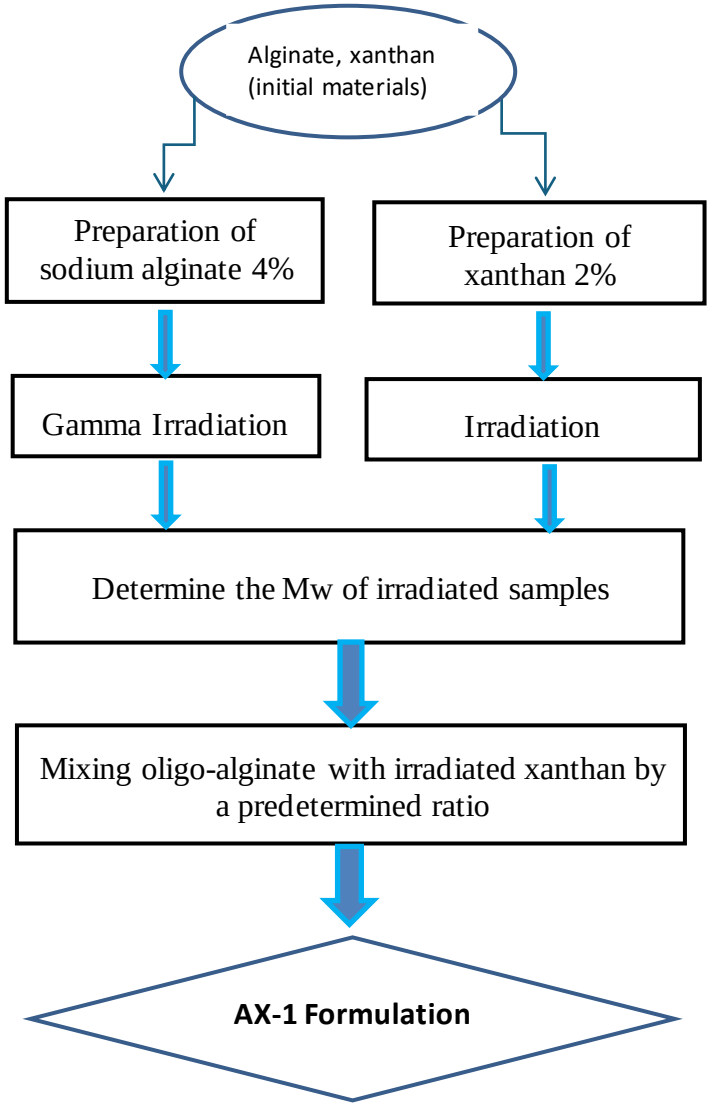

Figure 1. Diagram of the preparation process of biological stimulant AX-1 from irradiated xanthan and alginate

The results showed that irradiation of xanthan in the dry state or solution reduced its molecular weight and viscosity, making it suitable for use as an adhesive or spreading agent, as reported in our previous research. By applying the process given in Figure 1, AX-1 product containing 1.2% oligoalginate, Mw ~8-10 ×10^4 g/mol and 1% xanthan, Mw ~160-180 ×10^4 g/mol was prepared at the Hanoi Irradiation Center for testing and evaluating biological effect on tea plants. Based on the results of the previous study on corn and peanut plants, 60 ppm oligoalginate and 50 ppm irradiated xanthan, corresponding to a 200-fold dilution of AX-1 product, were used to test on tea plants.

Table 2. Effects of the AX-1 on density and weight of tea bud

No	Experimental formulation	Dong Hy				Tan Cuong			
		Bud density		Bud weight		Bud density		Bud weight	
		Bud/m^2	Increase (%)	g/100 bud	Increase (%)	Bud/m^2	Increase (%)	g/100 bud	Increase (%)
1	Control	296.8^a	-	83.32^a	-	285.4^a	-	87.56^a	-
2	CT1	305.4^{ab}	2.90	86.24^{ab}	3.50	295.4^{ab}	3.50	89.32^{ab}	2.01
3	CT2	325.4^{ab}	9.64	90.82^{ab}	9.00	310.6^{ab}	8.83	95.02^{ab}	8.52
4	AX-1	338.8^b	14.15	94.65^b	13.60	321.4^b	12.61	101.34^b	15.74
5	*$LSD_{0.05}$*	*39.9*		*1.30*		*34.0*		*11.53*	
6	*CV (%)*	*6.3*		*6.5*		*5.6*		*6.2*	

The effects of biological product AX-1 on the growth and development of tea plants were investigated and compared with control, CT-1 (irradiated xanthan concentration of 50 ppm), and CT2 (irradiated alginate of 60 ppm). The results in Table 2 showed that the tea bud's density and weight in all treated experiments increased compared to the control. While treatment with irradiated xanthan solution (CT1) had a low effect, treatment with irradiated alginate (CT2) highly increased the density and weight of tea buds, although there was no statistically significant difference. Moreover, the AX-1 product significantly increased bud density by 14.15% and 12.61%, and bud weight by 13.6% and 15.74% compared to the control formula on Dong Hy and Tan Cuong tea plants, respectively. Thus, the AX-1 product was significantly effective in stimulating growth for tested tea plants.

Table 3. Effects of the AX-1 on tea bud yield

No	Experimental formulation	Đong Hy		Tan Cuong	
		Tea bud yield (kg/ha)	Increase %	Tea bud yield (kg/ha)	Increase %
1	Control	13,720[a]	-	15,488[a]	-
2	CT1	14,218[ab]	3.63	16,146[ab]	4.25
3	CT2	14,927[ab]	8.80	16,782[ab]	8.35
4	AX-1	15,354[b]	11.91	17,448[b]	12.65
5	*$LSD_{0.05}$*	*1,614*		*1,729*	
6	*CV (%)*	*5.6*		*5.3*	

Table 3 showed that the AX-1 product effectively increased tea bud yield by 11.91% and 12.65% for Dong Hy and Tan Cuong tea plants, respectively. Furthermore, the results in Table 4 indicated that the composition of dry matter, tannin, and caffeine content in tea buds of AX-1 was almost insignificantly changed compared to the control. However, it is necessary to study further sensory parameters (color, smell, taste) that affect the quality of tea buds.

Table 4. The effects of the AX-1 on on dry matter, tannin, and caffeine content tea buds

No	Quality criteria	Đong Hy		Tan Cuong	
		Control	AX-1	Control	AX-1
1	Dry matter content (%)	24.76	26.26	25.18	24.85
2	Tannin (%)	7.38	7.82	6.26	7.5
3	Cafein (%)	1.12	0.95	1.09	1.33

The disease resistance ability of AX-1 product on tea plants was evaluated on tea bud rot disease (*Colletotrichum*) and tea leaf blister disease (*Exsobasidium*). The results in Table 5 showed that the AX-1 product effectively reduced the infection rate of these diseases in Dong Hy and Tan Cuong tea plants.

Table 5. Evaluation of the bioproduct's disease resistance effectiveness on tea plants

No	Experimental formulation	Dong Hy				Tan Cuong			
		Tea bud rot disease *(Colletotrichum)*		Tea leaf blister disease *(Exsobasidium)*		Tea bud rot disease *(Colletotrichum)*		Tea leaf blister disease *(Exsobasidium)*	
		Infection rate (%)	Decrease of Infection rate (%)	Infection rate (%)	Decrease of Infection rate (%)	Infection rate (%)	Decrease of Infection rate (%)	Infection rate (%)	Decrease of Infection rate (%)
1	Control	21.95^{a}	-	9.56 ^{ab}	-	11.08^{a}	-	4.48 ^{ns}	-
2	CT1	21.67^{a}	1.28	10.11^{a}	- 5.75	10.42^{ab}	5.96	4.31 ^{ns}	3.79
3	CT2	19.41^{ab}	11.57	8.84^{bc}	7.53	9.47^{ab}	14.53	4.42 ^{ns}	1.31
4	AX-1	18.76^{b}	14.53	8.04^{c}	15.90	8.81^{b}	20.49	3.96 ^{ns}	11.61
5	*$LSD_{0.05}$*	*2.88*		*1.15*		1.72		0.57	
6	*CV(%)*	*7.1*		*6.3*		8.7		6.7	

$LSD_{0.05}$ represents the significant difference at 0.05 probability level ($P \leq 0.05$), and CV is the coefficient of variation. Values in a column with the same letter are not significantly different according to LSD test at the confidence of 95%, ns: not siugnificant

The process for producing biological AX-1 product with growth-stimulating and disease-resistant activities for tea plants from irradiated xanthan and alginate was studied and established. The as-prepared AX-1 product containing 1.2% oligoalginate (Mw ~8-10 ×10^4 g/mol) and 1% irradiated xanthan (Mw ~16-18 ×10^5 g/mol) was produced at the Hanoi Irradiation Center and investigated biological activities on Tan Cuong and Dong Hy tea plants. The obtained results showed that the AX-1 product exhibited growth stimulation and disease-resistant effects on the tested tea plants. Several productivity characteristics, such as bud density, bud weight, and yield, increased compared to the control and compared to those in the case using irradiated xanthan or alginate. Furthermore, using the AX-1 product reduced the infection rate of both bud rot and tea leaf blistering diseases without significantly changing tea buds' dry matter, tannin, and caffeine content compared to the control. Based on the obtained experimental results, the AX-1 product has the potential for application in the production of safe and high-quality agricultural products, as well as contributing to sustainable agricultural development and minimizing the use of toxic agrochemicals.

STUDYING THE EFFECTS OF GAMMA IRRADIATION ON THE FORMATION, DEVELOPMENT AND SAPONIN CONTENT OF NGOC LINH GINSENG (*Panax vietnamens* Ha *et* Grushv) ROOTS

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Project information:

- Project name: Studying the effects of gamma irradiation on the formation, development and saponin content of Ngoc Linh ginseng (Panax vietnamens Ha et Grushv) roots

- Code: CS/23/08-01

- Managerial Level: Institute

- Duration: 12 months (Jan 2023- Dec 2023)

- Contact email: ank55b1@gmail.com

- Published papers related to the project:

1. Tran Xuan An, Hoang Dang Sang, Hoang Phuong Thao, Nguyen Van Binh, Nguyen Xuan Tung, Tran Huyen Thanh, Tran Bang Diep, "Cultivation and investigation of the effects of irradiation on embryo of ngoc linh ginseng (Panax vietnamensis Ha et Grushv)", Vietnam Conference on Nuclear Science and Technology XV, Nha Trang, 09-11/08/2023.

Ngoc Linh ginseng (*Panax vietnamensis* Ha *et* Grushv) is an endemic plant species in Vietnam, belonging to the genus *Panax*. Many studies have confirmed that this species of ginseng has diverse amounts of saponins. There are many types of saponins that are not found in Korean Ginseng. In nature, this species of ginseng grows and develops slowly and takes about 6 years to harvest. The combination of tissue culture technology and radiation technology can accelerate the growth and development of Ngoc Linh ginseng in an *in vitro* medium.

Ngoc Linh ginseng callus cultured at Hanoi Irradiation Center was used as raw material for this study. Media (1) including SH medium supplemented with 0.5 mg/l NAA; 0.2 mg/l kenitin; 1 mg/l 2,4-D; 50 g/l sucrose; 9 g/l agar with pH 5.8 was surveyed and selected as the optimal medium for embryos development.

Embryos were irradiated with a gamma cell device from the Institute of Agricultural Genetics with a dose range of 10, 20, 30, 40 and 50 Gy. Non-irradiated samples were used as control. Morphological changes of embryos after 28 days of irradiation were observed.

Looking at table 1, we see that the irradiation dose of 20 Gy gives the best rooting effect with a root formation rate/sample of 73.33% and the average number of roots/sample up to 5.93.

The effect of radiation dose creates differences in the number of roots/sample. This

difference is statistically significant with α = 0.05 in the Duncan test, distinguished by the letters a, b, c, d.

Table 1. Effects of irradiation on rootmorphology and development

Irradiation dose (Gy)	Rate of root formation/sample (%)	Roots/sample
0	**66.67**	**3.93^{c}**
10	**66.67**	**3.80^{c}**
20	**73.33**	**5.93^{d}**
30	**73.33**	**3.07^{bc}**
40	**60.00**	**1.87^{ab}**
50	**46.67**	**0.87^{a}**

Post-irradiated embryos were cultured in medium (2) including SH medium supplemented with 1mg/l NAA; 1mg/l IBA; 30 g/l sucrose with pH = 5.8 has the ability to develop into roots of Ngoc Linh ginseng.

Ngoc Linh ginseng roots grown after 90 days were processed, extracted and quantified for total saponin content using UV-Vis absorption spectroscopy method. The results showed that the total saponin content in the 20 Gy irradiated sample was the highest (average 1.97 mg/g dry powder). The total saponin content in the sample irradiated with a dose of 30 Gy is also high (average 1.95 mg/g dry powder), showing that the optimal range of irradiation dose for the best effect is 20-30 Gy (Figure 1).

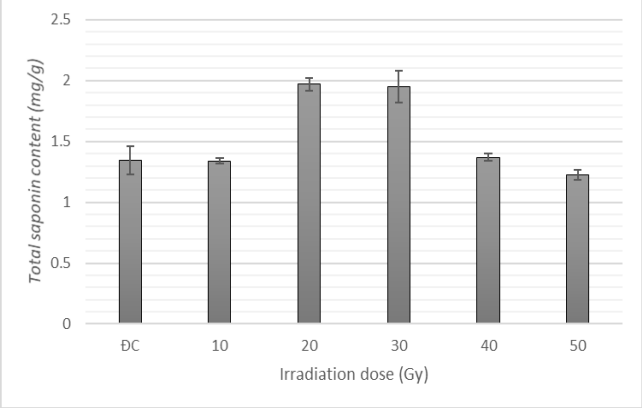

Figure 1. Total saponin content in irradiated and non-irradiated samples

The research results have confirmed the effects of irradiation on the growth and the total saponin content in Ngoc Linh ginseng roots in a positive direction. Further, the research results are scientific bases, promoting the production of secondary compounds in plants using radiation technology, serving the development of the medical, pharmaceutical and health care industries, etc.

STUDY ON PREPARATION OF RADIOACTIVE NANOPARTICLES Fe_3O_4@LAPATINIB – ^{153}Sm AND EVALUATION OF ACUTE TOXICITY, BIODISTRIBUTION IN EXPERIMENTAL ANIMALS CAUSING BREAST CANCER

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Project information:

- **Project name: Study on preparation of radioactive nanoparticles Fe_3O_4@lapatinib – ^{153}Sm and evaluation of acute toxicity, biodistribution in experimental animals causing breast cancer**
- **Code: ĐTCB.05/22/VNCHN**
- **Managerial Level: Ministry**
- **Implementation time: 12 months (Jan 2022- Dec 2023, extended to June 2024)**
- **Contact email: phamthanhminhnridl@gmail.com**
- **Published papers related to the project:**

1. Thanh Minh Pham, Dong Vu Cao, Ho Hong Quang Dang, Phuoc Minh Thanh Mai, Thanh Binh Nguyen, Ngoc Bao Nam Dinh, Thi Khanh Giang Nguyen, Thi Mai Huong Le, Van Dat Doan, Duc Thuan Nguyen and Van Thuan Le, "153Sm-labeled Fe3O4@lapatinib nanoparticles as a potential therapeutic agent for breast cancer: synthesis, quality control, and in vivo evaluation", *Journal of Materials Chemistry B*, 12, 678, 2024.
2. Phan Van Phuc, Le Thi Mai Huong, Mai Phước Minh Thanh, Pham Thanh Minh, "Study on preparation of Fe3O4@lapatinib nanoparticles for application as a targeted drug delivery system in the treatment of breast cancer", *Nuclear Science and Technology*, 13(1), 10-18, 2023.
3. Nguyen Thi Kim Dung, Pham Thanh Minh, Pham Dang Tung, Han Tuan Ngoc, Mai Hong Son, Nguyen Quoc Thang, "Studies of single-dose toxicity of radiolabeled nanoparticle Fe_3O_4@lapatinib - ^{153}Sm in animals", *Journal of 108 - Clinical Medicine and Pharmacy*, 158-167, 2023 (in Vietnamese).
4. Mai Phuoc Minh Thanh, Dang Ho Hong Quang, Dinh Ngoc Bao Nam, Nguyen Trong Hoanh Phong, Nguyen Thi Khanh Giang và Pham Thanh Minh, "Study for Production of Radioactive Nanoparticles Fe_3O_4@lapatinib – ^{153}Sm", *Vietnam Conference on Nuclear Science and Technology*, Nha Trang, 09th-11th August 2023 (in Vietnamese).

In this study, we present the pioneering synthesis of Fe_3O_4@lapatinib-^{153}Sm nanoparticles with the potential to revolutionize breast cancer treatment in the world and Vietnam. The integration of lapatinib facilitates targeted delivery while also conferring therapeutic effects, addressing two crucial facets of cancer management [1]. Additionally, the inherent magnetic properties of Fe_3O_4 grant heightened contrast and targeted delivery for precise imaging, a vital asset in early-stage detection [2]. Incorporating the gamma-emitting ^{153}Sm isotope (with a suitable 103 keV gamma-ray energy) allows SPECT imaging and radiation dose assessment. Meanwhile, the beta-emitting nature of ^{153}Sm (with a maximal energy of 0.81 MeV and a short half-life of 1.9 days) ensures targeted eradication of sub-centimeter-sized cancer cells, minimizing collateral damage to neighbouring healthy tissue [10]. This approach capitalizes on the synergistic benefits of each component, creating a versatile platform for dual-targeted therapy and non-invasive monitoring [3].

A total of 0.95 g of $FeCl_3 \cdot 6H_2O$ and 0.35 g of $FeCl_2 \cdot 4H_2O$ were dissolved in a 150 mL beaker containing 50 mL of double distilled water. Subsequently, 5 mL of a lapatinib solution (30 mg/mL) was introduced, and the mixture was stirred for 15 min to ensure a stable exchange. The prepared 150 mL beaker was placed within a 1000 mL glass flask, and 60 mL of 25% NH_4OH solution was poured into the space between the beaker and the flask. The assembly was sealed, and a nitrogen gas flow was maintained for approximately 5 min to remove oxygen. The solution was then stirred at 800 rpm for 60 min. Following this incubation, the solution exhibited the presence of brown-black Fe_3O_4@lapatinib nanoparticles. Magnetic separation was employed to isolate the nanoparticles from the residual synthesis components. Subsequently, the Fe_3O_4@lapatinib nanoparticles were washed with approximately 100 mL of distilled water, repeated twice until reaching a pH of 7.

Next, 1 mL of Fe_3O_4@lapatinib nanoparticles was mixed with a solution of $^{153}SmCl_3$ at a radioactivity concentration ranging from 5 to 20 mCi/mL. The pH was adjusted within the range of 2 to 10. The mixture was gently agitated and allowed to react for a duration of 5 to 60 min, at various temperatures ranging from 22 to 80°C. After the reaction, any unreacted ^{153}Sm was separated using a magnetic separation system. The resultant Fe_3O_4@lapatinib-^{153}Sm nanoparticles were further washed with approximately 50 mL of a 0.2 M sodium phosphate buffer (pH 7.4) and subsequently resuspended in a 1 mL solution of 0.53 mg/mL sodium citrate.

The synthesis of Fe_3O_4@lapatinib-^{153}Sm nanoparticles involves three main steps: (i) production of ^{153}Sm through neutron activation of 99% enriched $^{152}Sm_2O_3$ targets in a nuclear research reactor; (ii) synthesis of Fe_3O_4@lapatinib nanoparticles; and (iii) labeling of ^{153}Sm onto Fe_3O_4@lapatinib nanoparticles. Fe_3O_4@lapatinib nanoparticles were synthesized using a co-precipitation method from Fe^{2+} and Fe^{3+} ions in the presence of lapatinib under NH_4OH 25% conditions in a nitrogen environment. Lapatinib encapsulated the Fe_3O_4 nanoparticles and prevented their agglomeration, leading to the production of stable nano-sized Fe_3O_4 particles. The binding between Fe_3O_4 and

lapatinib was supported by hydro-bonds, while the radioactive ^{153}Sm were attached to Fe_3O_4@lapatinib through the formation of a complex between $^{153}Sm^{3+}$ and lapatinib. The experimental conditions significantly influence the labeling efficiency of ^{153}Sm onto Fe_3O_4@lapatinib nanoparticles (>99%) were obtained with optimal conditions: the concentration of $^{153}SmCl_3$ is 10 mCi/mL, labeling time 30 min, pH

The crystalline phase composition of the samples was determined using the XRD method showed that the characteristic diffraction peaks of Fe_3O_4 were observed prominently in the Fe_3O_4@lapatinib and Fe_3O_4@lapatinib-^{153}Sm samples. FTIR, FE-SEM and EDX spectra of Fe_3O_4@lapatinib-^{153}Sm were demonstrated the presence of lapatinib and Fe_3O_4. TEM image of Fe_3O_4@lapatinib-^{153}Sm sample clearly depicts spherical-shaped Fe_3O_4 crystals with a size distribution ranging from 10 nm to 40 nm, and an average size of 25 nm.

The saturation magnetizations of Fe_3O_4 and Fe_3O_4@lapatinib-^{153}Sm were determined to be 57.08 and 41.4 emu/g, respectively. The Fe_3O_4@lapatinib-^{153}Sm sample achieved a radionuclide purity of 100%, radiochemical purity >99%, meeting the requirements of sterility and bacterial endotoxin testing. The results of acute toxicity are revealed that the lowest lethal dose within 24 hours was 80 mCi/kg, while the highest dose that did not result in mouse mortality was 20 mCi/kg. The biodistribution graph of Fe_3O_4@lapatinib-^{153}Sm nanoparticles in tumor-bearing mice showed that the nanoparticles were most concentrated in breast cancer tumors at 6 hours after injection and gradually decreased over time until 24 hours, which is related to the elimination process. Thus, after 6 hours, the nanoparticles were begined to be eliminated from the blood. The elimination process was carried out through the feces (stomach, intestines) and through the kidneys (bladder). In addition, the nanoparticles also concentrated in the liver and spleen tissuses. These are two very important tissues in the metabolism process in the circulatory system.

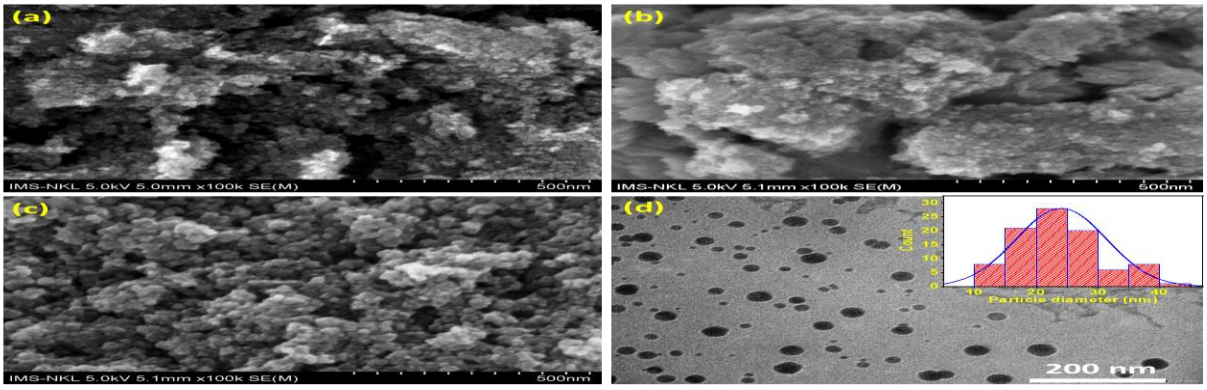

Figure 1. FE-SEM images of (a) Fe_3O_4, (b) Fe_3O_4@lapatinib, (c) Fe_3O_4@lapatinib-^{153}Sm samples, and (d) TEM image and crystaline size distribution of Fe_3O_4@lapatinib-^{153}Sm.

The radiolabeled Fe_3O_4@lapatinib-^{153}Sm nanoparticles with a potential application for breast cancer therapy were successfully synthesized. The optimized labeling

conditions yielded remarkable results, achieving a labeling efficiency of >99% using a $^{153}SmCl_3$ concentration of 10 mCi/mL, pH 7.4, a reaction time of 30 min, and at room temperature. The average diameter of Fe_3O_4@lapatinib-^{153}Sm nanoparticles ranged from 10 to 40 nm, and their superparamagnetic behavior of 41.4 emu/g. The radiopharmaceutical demonstrated exceptional sterility, bacterial endotoxin 3.38 EU/mL and *in vitro* stability. Moreover, our acute toxicity studies on animal models corroborated that the Fe_3O_4@lapatinib-^{153}Sm formulation at a dose of 20 mCi/kg exhibited mild toxicity without inducing mortality. The study into the biodistribution in BT474 xenograft mice has illustrated the rapid clearance of Fe_3O_4@lapatinib-^{153}Sm within 24h. Meanwhile, substantial accumulation and retention were observed in the tumor tissue. Looking ahead, the prospects of Fe_3O_4@lapatinib-^{153}Sm in targeted breast cancer therapy are promising. Further exploration is warranted to investigate the nanoparticle's therapeutic efficacy on tumour models. These crucial steps will provide a deeper understanding of its biological interactions and enable us to refine and enhance its clinical potential.

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2. V. Sachdeva, A. Monga, R. Vashisht, D. Singh, A. Singh and N. Bedi, “Iron Oxide Nanoparticles: The precise strategy for targeted delivery of genes, oligonucleotides and peptides in cancer therapy”, *J. Drug Deliv. Sci. Technol.*, 74, 103585, 2022.
3. K. Vermeulen, M. Van de Voorde, C. Segers, A. Coolkens, S. Rodriguez Pérez, N. Daems, C. Duchemin, M. Crabbé, T. Opsomer, C. Saldarriaga Vargas, R. Heinke, L. Lambert, C. Bernerd, A. R. Burgoyne, T. E. Cocolios, T. Stora and M. Ooms, “Exploring the Potential of High-Molar-Activity Samarium-153 for Targeted Radionuclide Therapy with [153Sm]Sm-DOTA-TATE”, *Pharmaceutics*, 14(12), 2566, 2022.

STUDY ON LABELING OF ATEZOLIZUMAB WITH ^{131}I USING IN THE DIAGNOSIS AND THERAPY OF NON SMALL CELL LUNG CANCER

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Project information:

- Project name: Study on labelling of Atezolizumab with ^{131}I using in the diagnosis and therapy of non small cell lung cancer

- **Code: CS/23/01- 01**

- **Managerial Level: Institute**

- **Implementation time: 12 months (Jan 2023 - Dec 2023)**

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- **Published papers related to the project:**

1. Nguyen Thi Ngoc, Nguyen Thi Thu, Nguyen Thị Khanh Giang, Dang Ho Hong Quang, Nguyen Thanh Binh., "Study on labelling of Atezolizumab with ^{131}I using in the diagnosis and therapy of non small cell lung cancer", Proceedings of the 15th Vietnam Conference on Nuclear Science and Technology (VINANST 15), Nha Trang, Vietnam, 2023.

Non-small cell lung cancer accounts for approximately 80% of all cases of lung cancer, and causes a high death rate. Atezolizumab is a humanized monoclonal antibody, specifically to PD-L1 (programmed death-ligand 1). PD-L1 is a transmembrane protein that is overexpressed in malignant non-small cell lung cancer. Atezolizumab was approved by the FDA for the treatment of non-small cell lung cancer with no alteration in the EGFR or ALK genes in 2019. Recent studies show that Atezolizumab was labeled with ^{124} I, ^{89}Zr, and ^{64}Cu using diagnostic imaging PET-CT. Much preclinical research shows that ^{124}I/^{89}Zr-Atezolizumab uptake was higher at the damaged location of the tumor after 24h. In this research, we labeled Atezolizumab with ^{131}I for creating ^{131}I-Atezolizumab, which specifically targets the PD-L1 molecule on cancer cells, using diagnosis, and treatment of non-small cell lung cancer.

Atezolizumab concentration is 60 mg/ml of Roche Branch. Radioactive isotope ^{131}I has a radioactive concentration of 100-200 mCi/ml, which was produced at the Institute of Nuclear Research. Atezolizumab was labeled with radioisotope ^{131}I by oxidation method using Chloramine T. In our research, factors that influence the radiolabeling efficiency were studied to find optimal conditions including Chloramine T content (1, 5, 10, 20, 40, and 80 mg), Atezolizumab content (10, 100, 200, 400, 800, and 1000 mg), radioactivity ^{131}I (0.1, 0.2, 0.5, 1.0, 2.0, and 4.0), incubation time (5, 10, 15, 20, 30, and 60 minutes), and pH (3, 4, 5, 6, 7, 7.4, and 8). Next, the complex was

purified by Sephadex gel filtration chromatography. Radiolabeling efficiency and radiochemical purity of ^{131}I-Atezolizumab were evaluated by thin layer chromatography TLC in CH_3OH: H_2O (v/v = 85:15) within 20 minutes. The chromatograms were scanned by Cyclone Plus Storage Phosphor System, and were analyzed by Optiquant soft to find the percent of radiolabeling efficiency. Then, ^{131}I-Atezolizumab was studied in the stability study over store time.

The results show that the radiolabeling efficiency in the preparation of ^{131}I-Atezolizumab was more 95% with 200 µg Atezolizumab and the radioactive of ^{131}I was 1.0 mCi under the condition of pH 7.4, 15 minutes at room temperature (Table 1). The ^{131}I-Atezolizumab complex was purified by a sephadex gel chromatography column, and was collected at a fraction of 4-6 ml, and free ^{131}I at a fraction of 8-10 ml (Figure 1A). The quality control result showed that the labeling efficiency was more than 95%, and radiochemical purity was more than 99% at all batches during research. On the chromatography strip, ^{131}I-Atezolizumab remained at the origin Rf = 0.1 – 0.2, while free ^{131}I migrated with the solvent front Rf = 0.8 – 1.0. (Fig.1B). ^{131}I-Atezolizumab was stable in 0.9% NaCl or 1M acetate with ascorbic acid after 16 days.

Table 1: Study results of ^{131}I-Atezolizumab preparation, (*): Labeling efficiency, Atez.: Atezolizumab

ChT (µg)	Label. eff.* (%)	Atez. (µg)	Label. eff.* (%)	^{131}I (mCi)	Label. eff.* (%)	pH	Label. eff.* (%)	Time (minutes)	Label. eff.* (%)	Temperature (^{0}C)	Label. eff.* (%)
1	28.35	10	78.59	0.1	95.20	4	37.82	5	90.65	4	93.78
5	71.01	100	95.16	0.2	94.15	5	61.63	10	87.52	24	91.68
10	85.27	200	98.44	0.5	94.63	6	77.82	15	92.15	37	88.86
20	92.31	400	97.35	1.0	94.03	7	91.79	20	91.65	-	-
40	91.43	800	96.64	2.0	90.03	7.4	92.68	30	92.90	-	-
80	91.60	1000	95.98	4.0	81.61	8	77.95	60	93.50	-	-

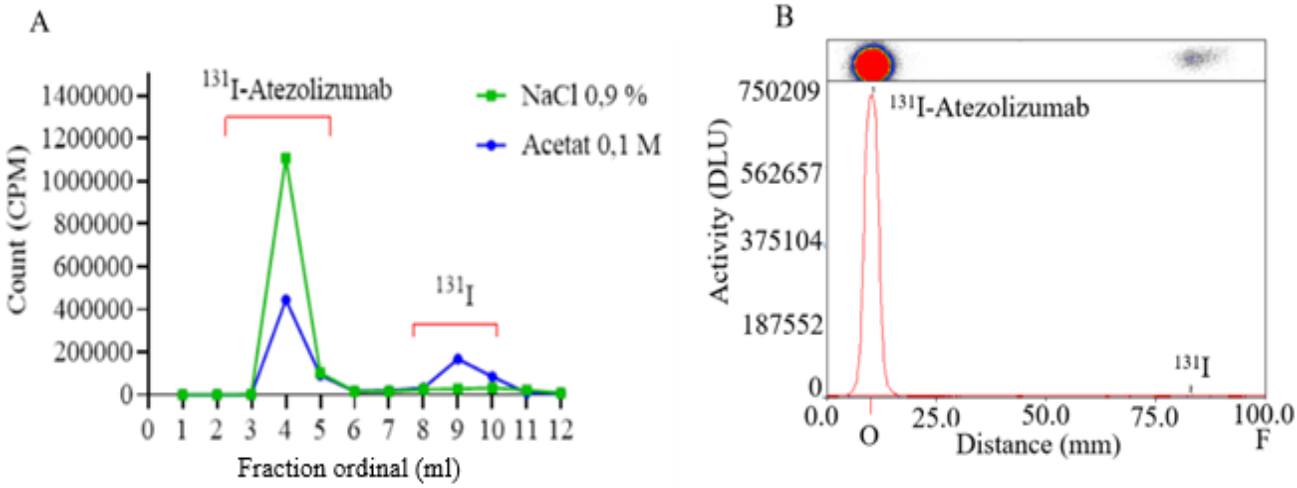

Figure 1: The process of labeled Atezolizumab purification by sephadex (A), and radiochemical purity of ^{131}I- Atezolizumab (B)

From the research results, a procedure for labeling the monoclonal antibody Atezolizumab with radioactive isotope ^{131}I has been developed. Briefly, the procedure consists of following steps: (1) Operating the GMP system; (2) Preparing tools ; (3) Preparing chemicals; (4) Radiolabeling; (5) Controlling the quality of labeling efficiency; (6) Complex purification; (7) Stabilization, packaging, and storage of ^{131}I-Atezolizumab. Besides, more than 100mCi of the ^{131}I-Atezolizumab complex was prepared at the time of the experiment. The labeled complex had a radiochemical purity of more than 98% and a labeling efficiency of more than 95%. These study results were consistent with the published studies. For example, published in the EJNMMI Research, volume 12, article number 70 in 2022, and the article "***Radioimmunotherapy study of ^{131}I-labeled Atezolizumab in preclinical models of colorectal cancer***" wrote that Zhang et al. prepared ^{131}I-Atezolizumab using the Iodogen method, and the labeled complex has a radiochemical purity of more than 96% after separating the Sephadex column. The ^{131}I-Atezolizumab complex was preserved for up to 16 days, which means after two half-lives of ^{131}I, the quality of ^{131}I-Atezolizumab could meet the preclinical studies.

Furthermore, the results of the project were reported at the 15th Vietnam Conference on Nuclear Science and Technology (VINANST 15) in Nha Trang, Vietnam in 2023. To put ^{131}I-Atezolizumab into use, further research on preclinical assessments is needed such as immunological activity, and distribution in animals as well as dosage assessments.

RESEARCH AND EVALUATION OF WATER USE EFFICIENCY INDEX (WUE) FOR COFFEE PLANTS BASED ON THE STABLE ISOTOPE TECHNIQUE WITH $\delta^{13}C$ SIGNAL

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Project information:

- **Project name: Research and evaluation of water use efficiency index (WUE) for coffee plants based on the stable isotope technique with $\delta^{13}C$ signal**
- **Code: CS/23/01- 05**
- **Managerial Level: Institute**
- **Duration: 12 months (Jan 2023 - Dec 2023)**
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- **Published papers related to the project:**

1. Vo Thi Mong Tham, Tran Quang Thien, Le Xuan Thang, Nguyen Minh Dao, Nguyen Huu Nghia, "Implications for eco-physiological study from the carbon and nitrogen stable isotope ratio analysis of coffee leaves", Proceedings of the 15th Vietnam Conference on Nuclear Science and Technology (VINANST 15), Nha Trang, Vietnam, 2023.

This study aims to determine the water use efficiency (WUE) index based on the carbon isotope discrimination ($\delta^{13}C$) to investigate the relationship between carbon absorption and water loss in coffee plants. The contents consist of the followings: (1) The design of the sampling area, collecting coffee leaf samples corresponded to the design of irrigation season and regime; and measuring temperature, rainfall, and humidity parameters in the area; (2) Testing and optimizing the procedure for analysis of $\delta^{13}C$ stable isotope in in coffee leaf samples on the EA-IRMS system at the Dalat Nuclear Research Instiute; (3) Analyzing $\delta^{13}C$ stable isotope in coffee leaf samples in Lam Dong (about 90 samples); (4) Using this stable isotope data for the water use efficiency index calculation of coffee plants and the influence of weather condition factors (temperature, rainfall and humidity) on coffee plants water loss; (5) Evaluating the possibility of using $\delta^{13}C$ stable isotope technique in climate change research (calculation of water use efficiency index) for coffee plants.

The WUE index was a concept, which was introduced 100 years ago by Briggs and Shantz (1913) and showed the relationship between crop yield and water use. Due to the changes of CO_2, water and temperature regimes were the most obviously seen at the leaf level. The principle and basis for the relationship between WUE (Water Use Efficiency) and $\delta^{13}C$ lie in the process of photosynthesis, where plants incorporate carbon into the food chain by assimilating carbon dioxide from the atmosphere or

dissolved in water through three main pathways corresponding to three types of plants: CAM, C_3, and C_4. Because the $^{13}C/^{12}C$ ratio depends on the plant's photosynthesis, respiration, and sugar synthesis, it varied with different plant types, climate areas, and even the intensity of sunlight on the plant. WUE can be described by the following equation:

$$WUE = \frac{b-\Delta^{13}C}{1.6(b-a)}$$

Where a, b are constants according to the environmental conditions of the area; $\Delta^{13}C$ is carbon isotope discrimination

The method of analyzing the $\delta^{13}C$ carbon isotope ratio was implemented on the Isotope Ratio Mass Spectrometry (EA-IRMS) system which was instructed in the Second Edition of IRMS Guide in Good Practice Guide for Isotope Ratio Mass Spectrometry by Philip Dunn published in 2018.

The procedure for the analysis of $\delta^{13}C$ in coffee leaf samples in particular and applying to the other plant samples in general on the EA-IRMS system was studied and established at the Dalat Nuclear Research Institute. The analytical procedure involves the sample treatment and preservation, preparation ofmeasured sample, the analysis of prepared samples, and the results calculation and evaluation. Various technical parameters for the sample running method on the measuring system were optimized including oven temperature, carrier gas speed, analysis run time, and dilution of standard gas. This analytical procedure was written in the form of Vietnamese Standards and was approved by the scientific council of the Dalat Nuclear Research Institute. The quality control process was based on isotope standard ratio samples USGS61, USGS62, USGS63, and content standards sample Sulfanilamide. The validation of analytical procedure showed that the $\delta^{13}C$ linear range -35.05‰ to -1.17‰; Z-core values < 3 (from -2.96 to 0.80). The accuracy of the data during the analysis of stable isotope ratios with $\delta^{13}C$ was ≤ 0.3‰, repeatability <0.2‰, bias <0.41‰, LOD = 0.0053 mgC, LOQ = 0.0176 mgC. The survey results of quality control process for carbon content in plant samples based on Sulfanilamide content standards sample show: the maximum carbon mass introduced into this standard was 0.351 mg, equivalent to 0.8 mg of biological/plant sample; Z-core values <3 (from -0.61 to 1.07); Repeatability <0.74%; Bias <2.67%; Uncertainty <0.91% (percentage from repeatability, bias, and uncertainty results was the content ratio). This indicates that the method had good specificity/selectivity for carbon content analysis in plant samples.

After the procedure was surveyed and optimized, it was tested on actual coffee leaf samples. The leaf sampling process was conducted based on IAEA-TECDOC-1870 guidelines in January and February 2023 in Duc Trong District, Lam Dong Province, categorized by leaf layers (upper canopy, lower canopy) and leaf types (young leaves, old leaves). The variation of $\delta^{13}C$ in corresponding 9 samples indicates that the upper canopy (- 27.527 ± 0.123 ‰) was higher than the lower canopy of the tree (-29.112 ± 0.126 ‰). $\delta^{13}C$ values in 6 samples from old to young tree branches tended to increase

gradually by approximately 0.1‰ from -28.575 ± 0.125 ‰ to -26.900 ± 0.123 ‰. In comparison with the data of Angela Pierre Vitoria (2016), the present values showed the similarity to previously published work. This could be explained by the difference in CO_2 exchange during photosynthesis between old and young leaves as well as the upper canopy (younger leaves) and lower canopy (older leaves) of the coffee plant.

To apply the WUE index assessment, the project collected and analyzed $\delta^{13}C$ and carbon content values of 90 coffee leaf samples in the experimental garden in Duc Trong District, Lam Dong Province, corresponding to different irrigation regimes (100, 200, 300, 400 liters and no irrigation) and seasons (Dry season: January, February, March and April 2023; Rainy season: July, and October 2023). Simultaneously, the meteorological parameters (temperature (17 – 25 °C), humidity (54 -73 %), and rainfall (6 – 810 mm/month)) in the research area during each month (January – October) were monitored. The $\delta^{13}C$ value changed from -29 to -26.5 ‰; Carbon content values were from 42 – 48%. For C_3 plants (coffee plants), there was a range of $\delta^{13}C$ value published in literatura from -34 to -21 ‰; According to Sayak Basu (2015), the results values of present study are fit well.

Based on meteorological data (temperature, humidity and precipitation) and the $\delta^{13}C$ and carbon content data of 90 coffee leaf samples the calculation of $\Delta^{13}C$ and WUE at the investigated location was carried out, the statistical test results were given to determine the correlation of $\delta^{13}C$, carbon content, WUE with weather index values. Water use efficiency index and $\delta^{13}C$ were positively correlated with temperature (T°C), humidity (H%), and annual precipitation (Rmm) while carbon content was negatively correlated.

The methods to calculate water use efficiency index for crops corresponding to the growing season were developed (Figure 1). The results showed that in the rainy season, the water use efficiency index was nearly 14% higher than that in the dried season; In the dry season WUE was 0.19 whereas in the rainy season, the amount of water in plants increased with the WUE index (0.22) and p-value = 0.017.

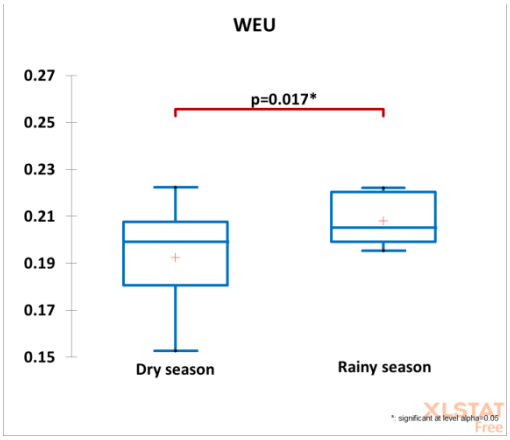

Figure 1. Results of the statistical tests for WUE following dry and rainy seasons.

The water use efficiency index, which was changed by the care period, tree growth and harvesting of the tree was determined. In the dry season, the WUE value was ~ 0.153 and increased to about ~ 2 in the rainy season. This study only investigated the method to determine WUE based on $\delta^{13}C$ of leaves. Surveying and evaluating the water use efficiency of coffee trees in Lam Dong in particular, and the Central Highlands, in general needs to be conducted with different varieties, ages, climate and weather conditions. Further study may provide a better understanding and an overall picture of the most effective irrigation regime and calculation of the most optimal water use efficiency of the coffee garden types.

2.6. RADIATION SAFETY AND RADIOACTIVE WASTE MANAGEMENT

RESEARCH ON THE POSSIBILITY OF PREDICTING THE ATMOSPHERIC DISPERSION OF RADIONUCLIDES FOR EARLY WARNING AND RESPONSE TO A TRANSBOUNDARY RADIATION AND NUCLEAR ACCIDENT

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Project information:

- **Project name: Research on the possibility of predicting the atmospheric dispersion of radionuclides for early warning and response to a transboundary radiation and nuclear accident**
- **Code: 06/CS/HD/NV**
- **Managerial Level: Institute**
- **Implementation time: 12 months (January 2023 to December 2023)**
- **Contact email: phamkimlong@vinatom.gov.vn**
- **Published papers related to the project:**

1. Pham Kim Long, Pham Duy Hien, Nguyen Hao Quang, Hoang Sy Than. "Research on the possibility of predicting the atmospheric dispersion of radionuclides after a transboundary radiation and nuclear accident". The 15th Vietnam Conference on Nuclear Science and Technology, Nhatrang, Vietnam, 2023 (in Vietnamese).

This study aimed to examine the present problem posed in the case of today's transboundary radiation and nuclear accident, it is possible to predict the dispersion of radionuclides in the following days, or determine which areas the radioactive plume might have spread over, how long it will take as well as the potential radiological impacts. The simulations are based on the Lagrangian particle dispersion model combined with the forecasted meteorological data in the case of a hypothetical accident at the Fangchenggang nuclear power plant (Figure 1). The obtained results give a glimpse of the predictability of the dispersion of the radioactive plume in the case of a transboundary radiation and nuclear accident. Thereby, it helps to promptly support for an early warning or quickly implement an emergency preparedness and response if the accident can be harmful for human health and the environment.

A hypothetical accident scenario at China's Fangchenggang Nuclear Power Plant (FP-NPP) during 7 days from 0:00 on 7 April to 13 April 2023. The FLEXPART version 10.4 was driven by the forecast meteorological data from The National Center for Environmental Prediction (NCEP) Global Forecast System (GFS-FCS). The forecasted results are compared to those obtained from the GFS-ANL analysis data. In this scenario, the source term of ^{131}I in every 24 hours is 1E+16 Bq as referenced from the accident scenario with a frequency of 1 in 50,000 per year.

Figure 1. Fangchenggang Nuclear Power Plant and Vietnam's receptor points

Simulated results of ^{131}I released in the atmosphere from FP-NPP at 24h, 48h, 72h, 96h, 120h and 144h are shown in Figure 2. The obtained results give a glimpse of the predictability of the dispersion of the radioactive plume in the case of a transboundary radiation and nuclear accident. Quantitative results obtained at the receptor points shows a good agreement. The time difference from the forecast results at the receptor points can be a few hours compared to the results from the analysis results. Long forecast days and the distance is too far from the source, which will lead to bad forecast results. It's better to forecast within about 3 days to minimize errors.

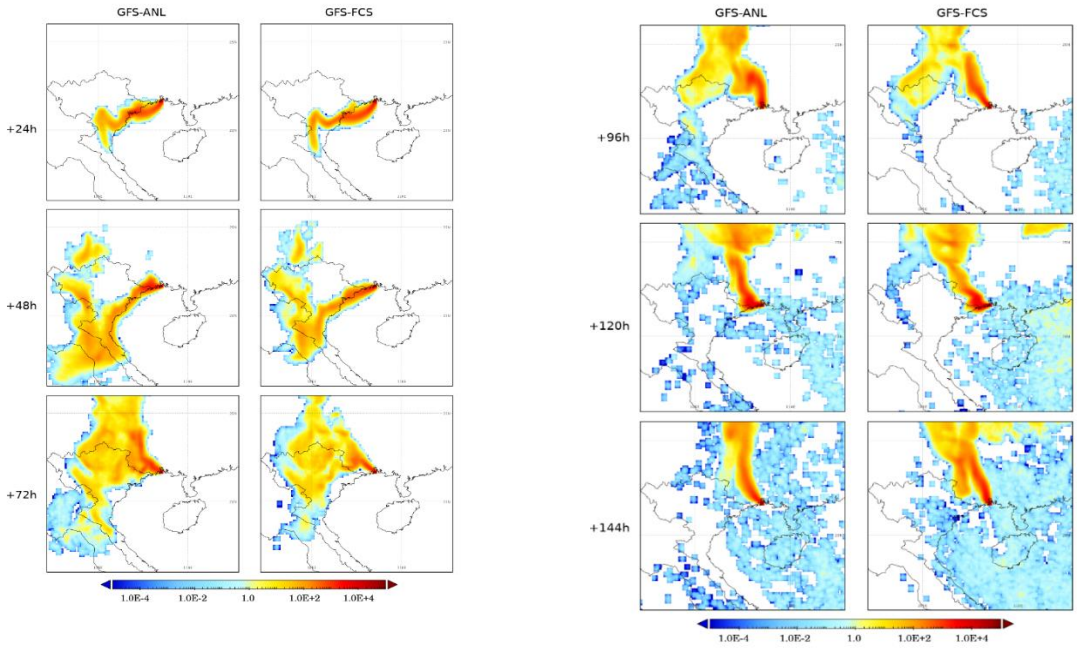

Figure 2. Concentrations of ^{131}I in air from a hypothetical accident (starting at 0:00 on April 7) after 24h, 48h, 72h, 96h, 120h and 144h with GFS-FCS and GFS-ANL datasets

Therefore, in order to respond promptly and effectively in the case of a transboundary radiation and nuclear accident, it's necessary to effectively operate the National Environmental Radiation Warning and Monitoring Network and improve the capability on simulation of atmospheric dispersion of radinuclides to be able to support the National Emergency Preparedness and Response Plan.

DEVELOPING TECHNICAL-ECONOMIC NORMS FOR PUBLIC SERVICES USING THE NATIONAL BUDGET ON NATIONAL ENVIRONMENTAL RADIATION MONITORING AND WARNING SYSTEM; RADIATION MEASUREMENT IN RADIATION SAFETY

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Project information:

- **Project name: Developing economic-technical norms for public services using national budget on national environmental radiation monitoring and warning system; radiation measurement in radiation safety**
- **Code: ĐTCB.02/23/VKHKTHN**
- **Managerial Level: Ministry**
- **Implementation time: 12 months (Jan 2023- Dec 2023)**
- **Publications related to the project:**

1. Duong Duc Thang, Duong Van Hao, Nguyen Huyen Trang, Le Dinh Cuong, Nguyen Thi Thu Ha, Vuong Thu Bac, Gross beta and alpha activities in the selected commercial freshwater fish species in Vietnam, Proceedings of the 15th Vietnam Conference on Nuclear Science and Technology (VINANST 15), Nha Trang, Vietnam, 2023.

2. Duong Duc Thang, Duong Van Hao, Nguyen Huyen Trang, Le Dinh Cuong, Nguyen Thi Thu Ha, Vuong Thu Bac, Gross beta and alpha activities in the selected commercial freshwater fish species in Vietnam, accepted by the journal Nuclear Science and Technology Information (in Vietnamese).

National environmental radiation monitoring and warning are important activities that have been carried out by different organizations through the implementation of projects using the national budget. However, up to now, there are still no consistent technical procedures and economic-technical norms that are practical to carry out the same type of work between organizations. The same type of work but each organization has different implementation costs. This has caused many difficulties for national management agencies in appraising, allocating budgets, managing, approving, and implementing scientific and technological projects in the field of atomic energy and radiation safety using national budgets. Therefore, it is necessary to develop economic-technical norms for various types of public services using the national budget in the field of atomic energy.

The purpose of this study: developing processes and technical-economic norms for public services using the national budget on national environmental radiation monitoring and warning system; radiation measurement in radiation safety.

In this study, the legal bases used include:

1. Law on Environmental Protection No. 72/2020/QH14;

2. Decision No. 2099/QD-TTg dated December 27, 2017, issued by the Prime Minister: Issuing the list of public services using the national budget in the national management sector of the Ministry of Science and Technology.

3. Circular No. 21/2019/TT-BKHCN dated December 18, 2019, issued by the Minister of Science and Technology: Regulations on the process of establishing economic-technical norms for public career services using the national budget in the national management sector of the Ministry of Science and Technology.

4. Decision No. 2395/QD-BKHCN dated August 31, 2020, of the Ministry of Science and Technology on the issuance of a plan for the implementation of Circular No. 21/2019/TT-BKHCN, which regulates the process of establishing economic-technical norms for public career services using the national budget in the national management sector of the Ministry of Science and Technology.

5. Circular No. 20/2017/TT-BTNMT dated August 8, 2017, issued by the Ministry of Natural Resources and Environment: Promulgating economic-technical norms for environmental monitoring activities.

6. Circular No. 01/2023/TT-BTNMT issued by the Ministry of Natural Resources and Environment, promulgating national technical standards on ambient environmental quality.

7. Circular No. 16/2013/TT-BKHCN dated July 30, 2013, issued by the Ministry of Science and Technology, regulating the national technical standards on the Network of Environmental Radiation Monitoring and Warning.

8. Circular No. 23/2023/TT-BTC provides guidelines for the management, depreciation calculation, and asset depreciation of fixed assets in agencies, organizations, units, and fixed assets entrusted by national enterprises for management, excluding national capital components in enterprises.

9. Circular No. 10/2021/TT-BTNMT dated June 30, 2021, issued by the Ministry of Natural Resources and Environment: Regulations on environmental monitoring techniques and the management of information and data on environmental quality monitoring.

The method used in this study was the method of developing economic-technical norms according to the Article 10 of Circular No. 21/2019/TT-BKHCN, including:

1. General statistical method

Based on annual statistical data or in reporting periods (statistical data ensures reliability and legality for three (03) consecutive years before the time of building economic-technical norms) and rely on practical experience or comparative parameters to develop economic-technical norms.

2. Standard method

Based on technical standards and legal regulations on working time and rest regime to develop labor norms for each job.

Based on technical standards and legal regulations, determine the consumption level for each job. The develop economic-technical norms for equipment and supplies could be developed based on the calculated consumption level.

3. Analytical and experimental methods

Implement survey and experimental activities according to the outline of each process and work content to analyze and calculate each factor constituting the norm (select jobs that cannot be determined through the two above-mentioned methods or could not be determined exactly without actual testing).

This study applied procedures developing economic-technical norms according to Article 12 of Circular No. 21/2019/TT-BKHCN, including:

1. Economic-technical norms of each public service using the national budget in the field of state management of the Ministry of Science and Technology are established according to the procedures for promulgating legal documents.

2. Economic-technical norms are built in two steps:

a) Step 1: Developing a procedure for implementing public service;

b) Step 2: Developing economic - technical norms.

The content of economic-technical norms shall be developed pursuant to Article 14 of Circular No. 21/2019/TT-BKHCN, includes component norms for labor, equipment, and materials.

1. Labor norm: the necessary labor consumption level of workers according to their expertise and skills to complete the implementation of a public service to meet the criteria and standards set by the competent authority.

2. Machine and equipment norms: the necessary usage time for each type of machine and equipment to complete the implementation of a public service to meet the criteria and standards set by the competent authority.

3. Material norm: the consumption level of each type of material and supply necessary to complete the implementation of a public service to meet the criteria and standards issued by the competent authority.

This study applied labor norms prescribed in Article 15 of Circular No. 21/2019/TT-BKHCN Labor norms as prescribed in Article 15 of Circular No. 21/2019/TT-BKHCN, including direct labor norms (implementation) and indirect labor norms (management and service). Labor norms are the direct and indirect labor time needed to produce a product (or to perform a work step or perform a specific job) and the labor time served during the process. Specifically:

Labor norms = Direct labor norms (performance) + Indirect labor norms (management, service)

in which:

- Direct labor norm is the time to complete a public service;

- Indirect labor norms are determined according to the percentage (%) of direct labor.

Equipment norms apply as prescribed in Article 16 of Circular No. 21/2019/TT-BKHCN.

a) The unit is shift (each shift is in 08 hours).

b) Duration of use of equipment and support equipment as prescribed in Circular No. 23/2023/TT-BTC.

Contents of norms for using machines and equipment that must be built include:

1. The list and types of machines and equipment are to be determined;

2. The basic technical parameters of machines and equipment are to be determined;

3. The usage time of each type of machine and equipment, including: the time the machine runs under load (consumption of materials, electricity, fuel during the process) and machine idle time (no material consumption), is to be determined;

4. The machine and equipment norms are to be summarized.

Material norms apply as prescribed in Article 17 of Circular No. 21/2019/TT-BKHCN.

1. The list and types of supplies and materials needed for production according to each content of work creating a unit of product are to be determined.

2. The quantity/volume for each type of material is to be determined, based on the type of equipment and the time the machine runs under load (material consumption);

3. The rate (%) of recovery is determined, based on the characteristics and properties of the materials, in order to calculate the rate (%) of recovery;

4. The basic technical requirements of materials are determined, and the technical specifications of each type of material suitable for performing a public service are described.

The project has completed the goal of developing procedures and technical-economic norms for public services using the national budget on national environmental radiation monitoring and warning system; radiation measurement in radiation safety. From sets of procedures and economic-technical norms, we will build a set of public service unit prices using the national budget for national environmental radiation monitoring and warning system, and radiation measurement in radiation safety.

RESEARCH AND DEVELOPMENT OF A MEASUREMENT SYSTEM FOR ACTIVITY DISTRIBUTION OF GAMMA-RAY EMITTING RADIONUCLIDES IN WASTE DRUM AT NUCLEAR RESEARCH INSTITUTE USING TOMOGRAPHY GAMMA SCANNING TECHNIQUE

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Nuclear Research Institute, Dalat, Lam Dong Province

Project information:

- Project name: Research and development of a measurement system for activity distribution of gamma-ray emitting radionuclides in waste drum at nuclear research institute using Tomography Gamma Scanning technique

- **Code: DTCB.12/21/VNCHN**
- **Managerial Level: Ministry**
- **Implementation time: 33 months (Jan 2021 - Sep. 2024)**
- **Contact email: phamphuongnri@yahoo.com**
- **Published papers related to the project:**

1. Phuong Pham Hoai et al., Research for Establishment of method and design, production of a measurement system for assay activity and activity distribution of gamma emitting radionuclides in the waste drum by Tomography Gamma Scanning technique, Proceedings of the 14th Vietnam Conference on Nuclear Science and Technology (VINANST 14), Dalat, Vietnam, 2021

2. Dat Trang The et al., Establishment of Tomography Gamma Scanner to assay heterogenous radioactive waste, Proceeding of the 7th Vietnam Conference on Nuclear Science and Technology for young researchers in the Atomic Energy Industry, Hanoi, Vietnam, 2022

3. Phuong Pham Hoai, Dien Nguyen Nhi, Tan Nguyen Xuan, Dat Trang The, Dong Ong Quang, Cuong Nguyen Kien. Development of a Compact Digital Multichannel Analyzer based on FPGA, Journal of Nuclear Science and Technology (JNST), Vietnam

4. Phuong Pham Hoai, Huy Le Viet, Dien Nguyen Nhi, Dat Trang The, Tan Nguyen Xuan, Kien Nguyen Van. Count loss correction for accuracy enhancement of gamma spectroscopy based on FPGA, Journal of Science and Technology of Nuclear Installations (JSINI), HINDAWI

At nuclear reactor sites, radioactive wastes are processed and packaged in a 200-litter cylindrical drums as a common standard. These drums are routinely inspected to meet specific regulations for radioactive waste management. Radioactive waste contained in a drum may be heterogeneous in distribution of material density and radioactivity. Originally pioneered by R. Estep at Los Alamos National Laboratory (LANL), the TGS technique has been developed and commercialized by Canberra Industries in recent years. In Vietnam, CT/SPECT techniques

have been applied extensively in industry. However, nondestructive assay technique for activity distribution of gamma emitting radionuclides in the waste drum is limited so far and a practical measurement system is not available in Vietnam. In addition, when the distribution of material density and activity is highly inhomogeneous, the uncertainty of measurement can be > 500%.

The objectives of the study include: (1) Design and build a nondestructive measurement system for activity distribution determination of gamma-emitting isotopes using Tomography Gamma Scanning (TGS) technique for 200-litter cylindrical radioactive waste drums and (2) Enhancement of the capacity in research of the human resources at Dalat Nuclear Research Institute.

In this study, the TGS technique with the HPGe detector was used to realize the distribution of radioactive sources (SPECT) and material density inside the drum (CT). The obtained data was analyzed using an algebraic reconstruction technique (ART) algorithm. The results are shown in a two-dimensional (2-D) rectangular cell map of gamma rays in each segment. Cell maps of activity distribution in each segment are calculated based on SPECT technique and CT map of linear attenuation coefficient. TGS technique presents an accurate result of the activity distribution in each segment.

TGS system was manufactured using system engineering approach. The design, construction, and installation carried out include:

- Collimator for radiation source and detector,
- Mechanical system for three-dimensional scanning of drum, positioning, and controlling the process of moving, rotating and lifting,
- Experimental model of 200 litter cylindrical drum,
- Electrical and electronic system for automatically controlling the TGS mechanical system,
- High voltage module for HPGe detector and power supply modules,
- Digital multiple channel analyzer (DMCA) with FPGA for HPGe detector.

Software for interface and control was written and implemented including mechanical system control, gamma-ray spectrum acquisition and analysis, distribution of linear attenuation coefficient μ (cm-1), distribution of gamma-emitting radioisotopes activity in waste drum.

Figure 1 (e) shows the material density distribution inside the drum including paper, fabric, wood, and concrete, etc. Figure 1 (f) shows the distribution of radioactivity of radioactive sources. The TGS system measures the drum containing materials from low to medium density (<2.0 g/cm^3), and two radioactive sources Co-60 and Cs-137. Experimental results indicated that the distribution of material density and radioactivity of radioactive sources are consistent with the model prepared.

The TGS system was validated, calibrated and evaluated in performance of measuring the model waste drum. In addition, the TGS system was used to monitor some radioactive waste drums at Dalat Institute of Nuclear Research. Through performance evaluation, the TGS

system was proven in ability of stable, automatical, consistent, and reliable. During the implementation of the research project, the capacity in research of staff participated was significantly enhanced.

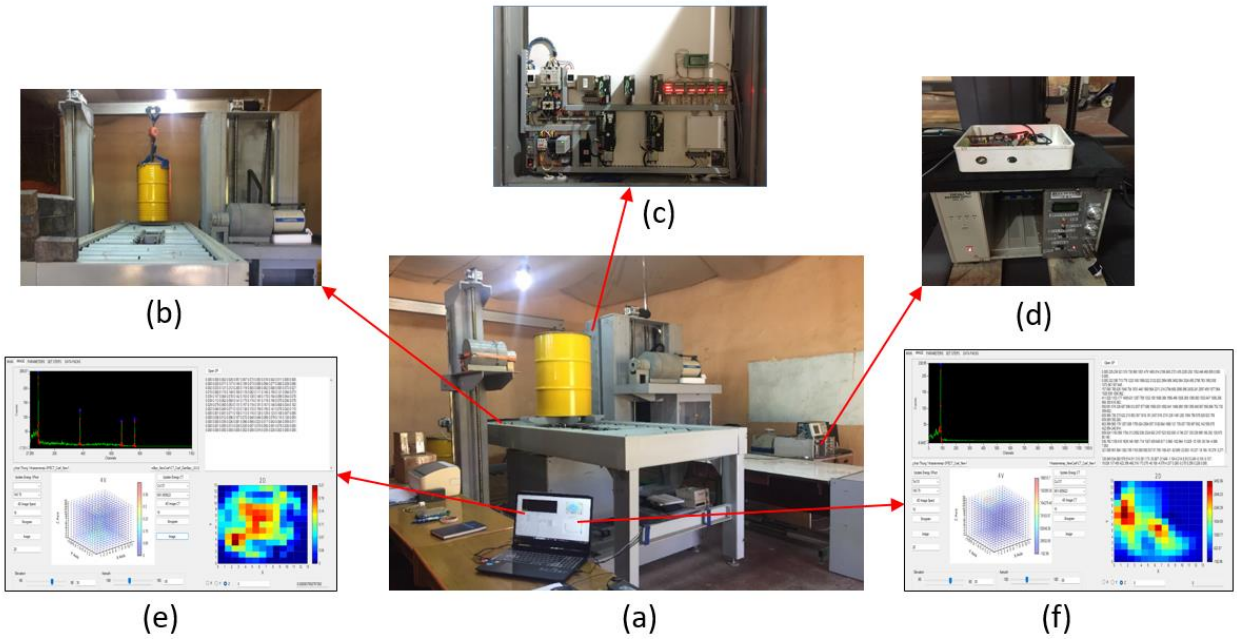

Figure 1. TGS system for radionuclides identification and determination of activity distribution of gamma-emitting isotopes in radioactive waste drums at the Dalat Nuclear Research Institute. (a) Photo of the TGS system. (b) Mechanical system for positioning and controlling the process of moving, rotating and lifting the drum. (c) Electrical and electronic system for the TGS mechanical system controlling. (d) High voltage module and DMCA module of the gamma spectrometer system using HPGe detector. (e) Interface of the gamma spectrum analyze, the linear attenuation coefficient value (μ cm-1), and 2- and 3-dimensional images of μ distribution. (f) Interface of radioactivity values of gamma-emitting isotopes, and 2- and 3-dimensional images of radioactivity distribution.

Through this research project, our research team has mastered TGS techniques, DSP techniques and FPGA technology in designing and manufacturing nuclear equipment systems. The maintenance and manufacture of nuclear measurement systems could be actively conducted for CT and SPECT applied in industry and nuclear medicine. The research project has met the requirements of the Vietnam Atomic Energy Law, Circular No. 22/2014/TT-BKHCN of the Ministry of Science and Technology and IAEA on Regulations on radioactive waste management.

Based on the preliminary achievements through this project, the future works of the team include: Radioactive waste management at the Dalat Nuclear Research Institute using the developed TGS system; Research on combination of the TGS system with the SGS (Segmented Gamma Scanner) system; Research on a hybrid TGS system using HPGe detector and NaI detector; Optimization of the collimator and measurement geometry, and flexibility of the system for monitoring particular waste drums.

2.7. RADIATION TECHNOLOGY

STUDY ON THE APPLICATION OF GAMMA IRRADIATION TECHNIQUES TO ESTABLISH A PROCEDURE FOR PREPARING SE NANOPARTICLES BY USING NA-ALGINATE AS A STABILIZER AND TO ORIENT THE PRODUCTION OF SUPPLEMENTS TO SUPPORT CANCER TREATMENT

Tran Thu Hong, Le Xuan Cuong, Pham Bao Ngoc, Nguyen Ngoc Thuy Trang, Le Van Toan, Tran Thi Ngoc Mai

Center of Radiation Technology and Biotechnology, Nuclear Research Institute, 01 Nguyen Tu Luc Street, Ward 8, Dalat, Lam Dong

Project information: Study on the application of gamma irradiation techniques to establish a procedure for preparing Se nanoparticles by using Na-alginate as a stabilizer and to orient the production of supplements to support cancer treatment.

- **Project name: Tran Thu Hong**
- **Code: CS/23/01-04**
- **Managerial Level: Center of Radiation Technology and Biotechnology, Nuclear Research Institute**
- **Implementation time: 12 months (Jan 2023- Dec 2023)**
- **Contact email: tranthuhongnri@gmail.com**
- **Published papers related to the project:**

1. Tran Thu Hong et al., Green synthesis and characterization of selenium nanoparticles stabilized by sodium alginate under cobalt-60 gamma rays, Poster report of the 15th Vietnam Conference on Nuclear Science and Technology (VINANST 15), Nha Trang, Vietnam, 9-11 September 2023.

Selenium (Se) is a trace and essential micronutrient for the health of humans and animals, but it also causes toxicity at a high dose. Se is one of the top four nutrients that may act as antioxidants, along with vitamin C, vitamin E and β-carotene. In addition, Se has influences on preventing cardiovascular diseases, diabetes, cancer and many other diseases. Se deficiency may cause the dysfunction of important organs in the human body and lead to the occurrence of various diseases. Se is an essential trace element for many enzymes and plays a crucial role in maintaining human life activities. Therefore, the replenishment of Se deficiency is extremely necessary. For the medical applications a lot of reports have confirmed that nano-sized Selenium particles (Nano Se), with sizes <100 nm, possess equivalent or higher biological efficacy and lower toxicity in comparison with other forms of Se.

Although many studies have been carried out around the world and have proven that Nano Se have beneficial effects in preventing and treating cancer, but in Vietnam the research on Nano Se is still a new issue and lacks comprehensive information. Therefore, we carried out the project entitled "Study on the application of gamma irradiation techniques to establish a procedure for preparing Se nanoparticles by using Na-alginate as a stabilizer, and orient the production of supplements to support cancer treatment".

Nano Se was made by using gamma radiation from Co-60 source (GC-5000, BRIT, India) at a dose rate of 1.2 kGy/hour. After that, the factors affecting the size of Nano Se such as irradiation dose, Se concentration, Na-Alg stabilizer concentration and pH were investigated. Besides, the properties of Nano Se had been evaluated using TEM, FTIR, Raman, XRD and EDS. In addition, the antioxidant activity and biological effects of Nano Se were evaluated.

The synthesis process for Nano Se was established, in which the optimal conditions were at a Se concentration of 2.50 mM, Na-Alg solution of 4%, pH 7, and a saturating conversion dose of 25 kGy. Additionally, the freeze-drying method from solution to powder could make Nano Se convenient to be preserved and used (Fig. 1).

Figure 1. Process of nano selenium synthesis by gamma irradiation technology

TEM image showed that Nano Se particles were spherical and had an average diameter of 17.7 nm. (Fig. 2). The EDS spectrum also indicated that the composition of Nano Se using Na-Alg as a stabilizer included the elements C (34.27%), O (52.00%), Na (13.03%) and Se (0.71%). Along with that, the XRD spectrum showed that Nano Se was in amorphous form (Fig. 3).

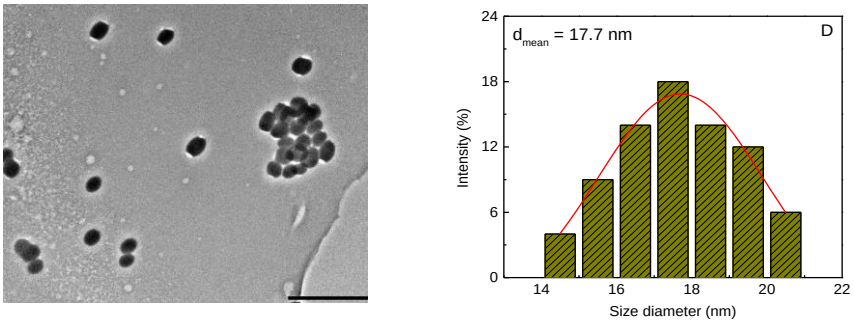

Figure 2. TEM image and particle size distribution of Nano Se

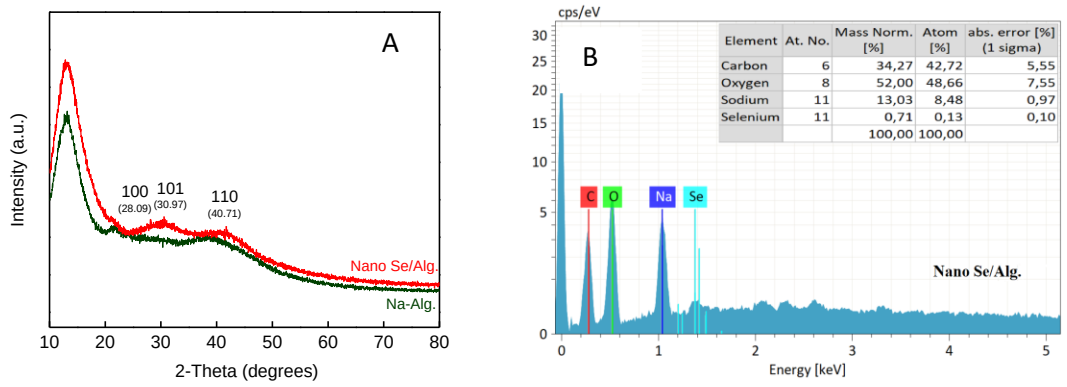

Figure 3. XRD spectrum (A) and EDS spectrum (B) of Nano Se

The antioxidant activity of Nano Se was demonstrated through the removal of $ABTS^{\bullet+}$ free radicals. The results displayed while Nano Se captured 95% of $ABTS^{\bullet+}$ free radicals in just 10 minutes, the Na-Alg took 40 minutes to capture 60% of $ABTS^{\bullet+}$ (Fig. 4). Besides, the results showed that Nano Se also inhibited 68% of MCF-7 breast cancer cells in *in vitro* condition (Fig. 5).

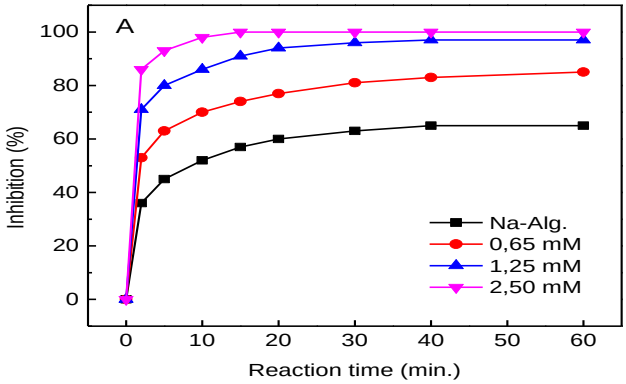

Figure 4. $ATBS^{\bullet+}$ free radical scavenging ability over time of Na-Alg and Nano Se at different concentrations.

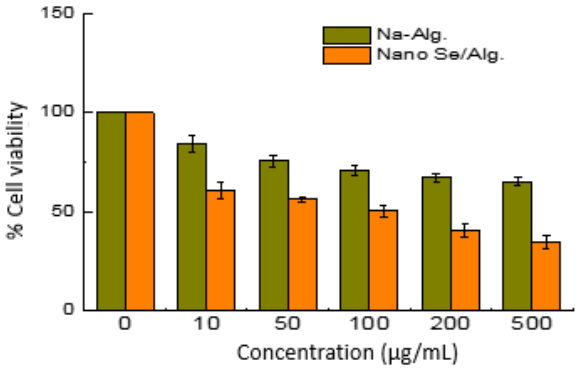

Figure 5. Toxicity of Na-Alg and Nano Se solutions to MCF-7 cells at different concentrations

In this study, Nano Se stabilized with Na-Alg by using gamma irradiation was synthesized successfully. Initially, Nano Se indicated the ability to inhibit the growth of MCF-7 breast cancer cells. However, further study is still needed to shed more light into the mechanism of Nano Se impact on cancer cells as well as to test the animals. Therefore, this aim of this study is to produce the Nano Se as food supplement, which provides essential nutrients and enhances resistance in cancer prevention and treatment to increase the value of the product.

2.8. RADIOCHEMISTRY AND MATERIALS SCIENCE

STUDY ON THE INFLUENCE OF LATTICE DEFECTS, NANO POROUS STRUCTURES AND DOPING SITES ON QUANTUM YIELD OF $Al_2O_3:Mn^{4+}$ BY POSITRON ANNIHILATION SPECTROMETER

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[4]Institute of Fundamental and Applied Sciences, 6 Tran Nhat Duat, Dist.1, Hochiminh City

Project information:

- **Project name:** ***Study on the influence of lattice defects, nano porous structures and doping sites on quantum yield of $Al_2O_3:Mn^{4+}$ by Positron Annihilation Spectrometer***
- **Code: CS/23/02-01**
- **Managerial Level: Institute**
- **Duration: 12 months (Jan 2023- Dec 2023)**
- **Contact email: phamhue.vl@gmail.com**
- **Published papers related to the project:**

1. Pham Thi Hue, Phan Trong Phuc, Nguyen Thi Ngoc Hue, Lo Thai Son, La Ly Nguyen, Nguyen Hoang Long, Luu Anh Tuyen *"Influence of doping and surfactants on the fomation of lattice defects and nano porous structures in $Al_2O_3:Mn^{4+}$ nanophosphors"*, Proceedings of the 15th Vietnam National Conference on Nuclear Science and Technology (VINANST 15), 09th August 2023 - 11th August 2023, Nha Trang, Vietnam (in Vietnamese).

2. Hue Thi Pham, Hue Thi Ngoc Nguyen, Tiep Van Nguyen, Trung Vu Minh Nguyen, Phuc Trong Phan, Nguyen La Ly, Son Thai Lo, Trang Thi Quynh Le, Trung Ngo Dang, Duy Hoang Nguyen, Hung Quang Nguyen, Tuyen Luu Anh, "*Influence of doping concentration on defects, nanopores and photoluminesence property of γ-$Al_2O_3:Mn^{2+}$,Mg^{2+} nanowire-phosphor studied by positron annihilation spectroscopy*", Radiation Physics and Chemistry, submitted Dec 22, 2023; Under Review Dec 25, 2023.

Metal oxide nanomaterials doped Mn^{4+} ions have gained great attention from scientists around the world because of their potential applications in the micro-LED technology. However,our understanding of the Mn^{4+} doping mechanism and the influence of the doping process on the formation of defects or nanopores in order to increase quantum yield and thermal conductivity for mini-sized LED devices has been still very limited so far. This comes from the fact that there has been a lack of conventional methods for structural investigations at the atomic and nano scale, which leads to many difficulties for approaching the information of the structural characterizations and controlling property of material.

In this study, the red-photoluminescence nanomaterial $Al_2O_3:Mn^{4+},Mg^{2+}$ (ALO) was synthesized by the combination of hydrothermal synthesis and the calcination at different temperatures and using glucose as a reducing agent and different ion pairs for doping process.

The crystalline structure, concentration of doped Mn^{4+}/Mg^{4+} ions, quantum yield (QY) and photoluminescence excitation (PLE)/ photoluminescence (PL) spectra of the samples were investigated by using XRD, FE-SEM and PMAS, respectively. Specially, the lattice defects, nanoporous structures and sites of doped Mn^{4+}/Mg^{4+} in ALO samples were examined in detail by the positron annihilation spectroscopies (PAS) that include the positron annihilation lifetime (PAL), Doppler broadening (DB), and electron momentum distribution (EMD) measurements.

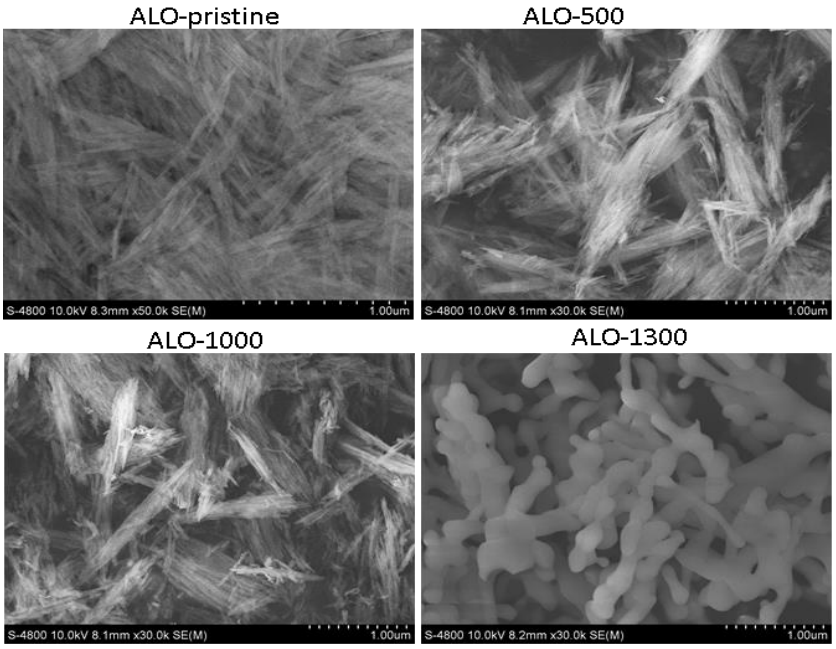

Figure 1. SEM images of initial sample (ALO-G-pristine) and samples calcined at 500 °C (ALO-G-500), 1000 °C (ALO-G-1000) and 1300 °C (ALO-G-1300).

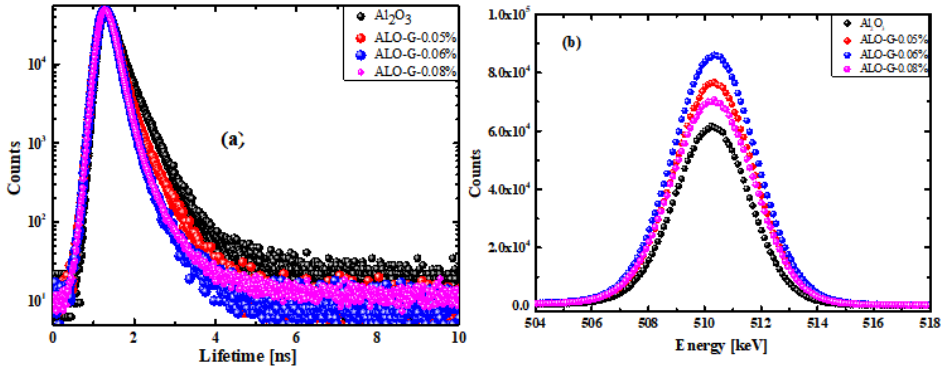

Figure 2. Experimental PAL (a) and DB (b) spectra of studied samples.

Table 1. Positron lifetimes and annihilation intensities obtained for studied samples doped with Mn^{4+}/Mg^{4+} at 0 % (Al_2O_3), 0.05 % (ALO-G-0.05%), 0.06 % (ALO-G-0.06%) and 0.08 % (ALO-G-0.08%)

Sample	Al_2O_3	ALO-G-0.05%	ALO-G-0.06%	ALO-G-0.08%
τ_1 [ns]	0.141 ± 0.004	0.143 ± 0.004	0.139 ± 0.004	0.151 ± 0.001
I_1 [%]	38.69 ± 0.72	79.88 ± 0.48	90.69 ± 0.69	92.76 ± 0.15
τ_2 [ns]	0.360 ± 0.003	0.413 ± 0.006	0.380 ± 0.013	0.449 ± 0.004
I_2 [%]	60.51 ± 0.72	19.98 ± 0.48	9.12 ± 0.69	6.85 ± 0.15
τ_3 [ns]	2.036 ± 0.071	3.140 ± 0.500	2.040 ± 0.310	14.14 ± 0.340
I_3 [%]	0.80 ± 0.03	0.14 ± 0.02	0.19 ± 0.03	0.39 ± 0.005

Table 2. Doped Mn^{4+} concentration and QY of samples.

Sample	Mn^{4+} (% mol)	QY (%)
ALO-G-0.05%	0.05	62
ALO-G-0.06%	0.06	67
ALO-G-0.08%	0.08	59

The results show that the morphology of ALO was in the nanofiber shape (several tens nm) with the length in range of ~300-400 nm at a cannined temperature range of 500 – 1000°C, then combined to form into nanorods with the diameter of ~190 nm as the cannined temperature was up to 1300°C. Crystal phases such as α, δ, γ with different optical properties formed by the calcination temperature range of 500-1300°C were found, in which the Mn^{4+}, Mg^{2+} ions pair (molar ratio of approximately 1) and the cannined condition at 1300°C were the most suitable to create materials with the optimum luminescent properties of red-emitting. From these results, we analyzed the Al^{3+} ions pair substitution process by the Mn^{4+}, Mg^{2+} ions pair, the structural defects and nanopores at the different doping concentrations from 0.05 - 0.08%mol by positron annihilation spectrometry. The results indicate that the doping concentration of 0.06%mol was optimal for improving quantum yield and photoluminescence process. Furthermore, the ALO-G-0.06% sample was tested through fabricating LED devices, which shows that only a small shift in the red region appeared when the temperature increased from 298 K to 573 K. Moreover, the color rendering and stability of obtained material were equivalent to different commercial materials. However, the thermal and moisture resistance of our material is higher than that of commercial materials due to the characteristics of the Al_2O_3 structure, thus, it is a promising material to replace other materials in the future.

STUDY ON DETERMINATION OF GROSS ALPHA, BETA RADIOACTIVITIES IN TREATED WASTE WATER FROM THE BEACH SAND MINERAL PROCESSING

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Project information:

- **Project name: Study on determination of gross alpha, beta radioactivities in treated waste water from the beach sand mineral processing**
- **Code: CS/22/03-01**
- **Managerial Level: Institute**
- **Implementation time: 12 months (Jan 2023- Dec 2023)**
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- **Published papers related to the project:**

1. Doan Thanh Son, Ngo Quang Huy, Do Thi Anh Tuyet, Le Quoc Viet, Ngo Van Tuyen, Vuong Huu Anh "Determination of gross alpha and beta radioactivities in treated waste water from the beach sand mineral processing", *Journal of Analytical Sciences,* No.3, *ISSN-0868-3224 (*inVietnamese);

2. Doan Thanh Son, Ngo Quang Huy, Do Thi Anh Tuyet, Le Quoc Viet, Ngo Van Tuyen, Vuong Huu Anh, "Determination of gross alpha and beta radioactivities in treated waste water from the beach sand mineral processing", reported inthe 15th Conference of Nuclear Science and Technology, Aug. 2023, Hanoi, Vietnam.

Liquid wastes from the beach sand mineral processing contain radioactive substances, mainly radionuclides in the U, Th, Ra series. To remove these radionuclides by precipitation, a large amount of chemicals such as NaOH, Na_2S, PAC, Na_2CO_3 were introduced into the waste solution, causing the main alkaline metal salts such as NaCl dissolved in wastewater solution to be very large (up to several or tens of g/L). The large amount of dissolved salt reduces alpha and beta counting efficiency. This makes the direct determination of the gross alpha and beta activities in treated wastewater solutions from the beach sand mineral processing get high errors, or even completely impossible to determine. The study of separating alpha and beta radioactive elements from the high salt background facilitates the determination of total alpha and beta radioactivity in wastewater samples from the beach sand mineral processing accuracy is extremely necessary. Therefore, the project " Study on determination of gross alpha, beta radioactivities in treated waste water from the beach sand mineral processing " was carried out.

To increase the accuracy of alpha and beta activity measurements in samples with high amounts of dissolved solids, the separation of radionuclides from the salt matrix which was done by co-precipitation of $BaRa(SO_4)_2$ and addition with $Fe(OH)_3$ was studied. The waste sample volume of 500 mL was taken and put in a 1000 mL beaker. 30 mL of 1M sulfuric acid

was added, the sample was heated for boiling, then stirred for 3 minutes to expel CO_2 gas (this process avoids CO_2 forming soluble complexes with U compounds), then cooled. The sample was then heated to 50^0C and 3 mL of 2.5mg/mL Ba^{2+} solution was added to precipitate $BaSO_4$. After that, it was stirred at the above temperature for 30 minutes to obtain optimal precipitation, then left to cool and mixed again. The sample was heated to 50^0 C. 2mL of 5mg/mL Fe^{3+} solution and 20mL of 6M NH_4OH solution were added to precipitate $Fe(OH)_3$. The sample was continuously stirred for 30 minutes and the precipitate solution containing radioactive elements was allowed to pass through night to precipitate large particles. The precipitate was then filtered on slow-flow filter paper and transferred quantitatively to the specialized stainless steel counting tray, which was 13 cm in diameter for measurement on the LB5500 gross alpha and beta activity device from Canberra (USA).

Figure 1. LB5500 alpha and beta total radioactive activity measuring device

The series of samples M1....M8 was created by fixing the amount of dissolved substance (NaCl). The exact amount of natural radioactive standard solution was added to the samples. Radioactive precipitation and separation of these samples were carried out as in the procedure. After that, the alpha and beta activities in precipitated samples were measured and then compared with alpha and beta activities in the original radioactive standard solution to calculate recovery efficiency.

Regarding the determination of the recovery coefficient when radioactive elements were separated from sample matrices with high amounts of dissolved solids by precipitation, the results are shown in Table 1.

Table 1. Alpha and beta recovery efficiency when separating radioactive elements by precipitation

Samples symbol	Initial alpha activity (Bq/L)	Recovery alpha activity (Bq/L)	Alpha recovery efficiency (%)	Initial alpha activity (Bq/L)	Recovery beta activity (Bq/L	Beta recovery efficiency (%)
M1	0.131	0.113	86.31	0.203	0.183	90.15
M2	0.282	0.248	87.92	0.403	0.371	92.06
M3	0.561	0.502	89.51	0.803	0.749	93.28
M4	1.124	1.038	92.32	1.604	1.543	96.20
M5	2.251	2.121	94.21	3.102	3.045	98.16
M6	3.313	3.171	95.72	4.602	4.558	99.04
M7	4.500	4.294	95.42	6.198	6.082	98.13
M8	9.005	8.693	96.53	12.040	11.837	98.31

The results show that when precipitation to separate radioactive elements from the sample matrix, the recovery efficiency of alpha and beta upon precipitation reached very high values from 86.31% to up to 98.31%. After the separation from the high salt background, the Limit of Detection (LOD) and Limit of Quantitation (LOQ) values of the method for wastewater samples were determined as such: (LOD) with total alpha 0.0074 Bq/L, (LOQ) 0.022 Bq/L; (LOD) value with total beta 0.021 Bq/L,(LOQ) 0.06 Bq/L

The evaluation of the repeatability and accuracy of the determination of total alpha and beta activities was conducted by the comparison with the standard values of the secondary standard samples CTC1, CTC2 and CTC3. These samples were created based on the method of determining the recovery by adding IAEA -2021 CRM1 standard to solutions containing natural radioactive substances to form secondary standard samples. After determining the exact values of the standard samples CTC1, CTC2 and CTC3, NaCl salt was added to resemble the real sample and the precipitation steps were proceeded as shown in Table 2.

Table 2. Results of assessing the accuracy of alpha and beta activities with 3 secondary standard samples CTC1, CTC2 and CTC3

Samples symbol	Radioactivity	Standard value (Bq/L	Average value after precipitation (Bq/L)	Recovery efficiency(%)	Sample results (Bq/L)	Maximum allowable deviation(%)	Bias (%)	Z-Score
CTC1	Alpha	0.60	0.52	90.02	0.58	20	3.71	0.31
	Beta	0.85	0.78	93.98	0.83	20	2.38	0.42
CTC2	Alpha	1.45	1.39	93.01	1.49	20	3.08	0.54
	Beta	1.80	1.75	97.96	1.80	20	1.34	0.26
CTC3	Alpha	7.20	6.96	95.01	7.33	20	1.75	0.33
	Beta	8.80	8.25	98.00	8.42	20	4.34	0.61

Table 2 shows that the results of the bias and z-score values of the analyzed sample after precipitation with the initial standard activity were all within the allowable limits. The method of determining total alpha and beta activities on the LB5500 device has high repeatability and accuracy.

In summary, thanks to the precipitation separating radioactive elements from the sample with high levels of dissolved solids, it is easy and accurate for the determination of gross alpha and beta activities in wastewater samples from the beach sand mineral processing. The radioactive precipitation method has great application in the analysis of post-treatment wastewater samples from the beach sand mineral processing. Also, it is possible to be applied to the analysis of wastewater from the processing of marine mineral ores processing of naturally occurring radioactive ores (NORM) currently existed in Vietnam.

STUDY ON SYNTHESIS OF COLLOIDAL SILICA AS A RAW MATERIAL FOR FOLIAR FERTILIZER

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Project information:

- **Project name: Study on synthesis of colloidal Silica as raw material for foliar fertilizer**
- **Code: CS/23/03-02**
- **Managerial Level: Institute**
- **Duration: 12 months (Jan 2023- Dec 2023)**
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- **Published papers related to the project:**

1. Doan Thi Thu Hien, Nguyen Thi Men, Hoang Van Duc, Nguyen Nho Lan, Tran Xuan Vinh, Vu Thi Phuoc, Nguyen Thi Kim Dung "Study on preparation of raw material for Silica foliar fertilizer from sodium metasilicate pentahydrate and rice husk ash**",** Vietnam Journal of Science and Technology*, (*inVietnamese);

2. Doan Thi Thu Hien, Nguyen Thi Men, Hoang Van Duc, Nguyen Nho Lan, Tran Xuan Vinh, Vu Thi Phuoc, "Synthesis of colloidal Silica as raw material for foliar fertilizer", reported in the Proceedings of Vietnam conference on nuclear science and technology VINANST - 15, Aug. 2023, Khanh Hoa, Vietnam.

As a nutrient, silica is essential in fostering plant development, increasing crop productivity, and improving the quality of agricultural products. Colloidal silica has been produced for a long time using various methods and is widely used in different industries depending on the particle size of SiO_2 and the stability of the colloidal silica solution. Colloidal silica for agricultural applications requires its synthesis in significant quantities at a reasonable cost. To ensure the production of large quantities of colloidal silica in an acceptable form that plants can readily absorb, it is necessary for a high-yield synthetic silica process. Therefore, the project "Research on the synthesis of colloidal silica as a raw material for foliar fertilizers" was undertaken. The ion exchange method using strong acid cation exchange resin (H^+) was chosen to synthesize colloidal silica from glass water as a raw material for foliar fertilizers. This approach is being studied in Vietnam for the first time.

The study and selection of technological parameters for synthesizing colloidal silica as a raw material for foliar fertilizers with technical standards, including SiO_2 concentration ≥ 3.5% (sufficient as a concentrated raw material for foliar fertilizer), particle size of SiO_2 adhesive ≤ 12nm (suitable size for plant uptake), and storage time ≥ 6 months (convenient for preservation), have been conducted by using the ion exchange method with strong acid cation exchange resin (H^+). The experimental process consists of the following steps: (1): Adjust the

concentration of the glass water solution to an appropriate level and let it flow through a column containing strong acid cation exchange resin (H^+) to create a silicic acid solution (colloidal solution). (2): Stabilize the silicic acid solution after passing through the exchange column containing strong acid cation exchange resin (H+) by adjusting it to an alkaline environment and aging it to prevent gelation. (3): Analyze and evaluate the product. The Fourier transform infrared spectroscopy (FTIR) method was used to analyze the structure of product solutions. The ICP-OES method was used to determine the product's SiO_2 content. The size of $SiO_2.n\ H_2O$ colloidal particles was determined using the dynamic light scattering method on the Litesizer™ 500 particle analyzer (ANTON PAAR). The results of Studying the Influence of Technological Parameters on the Stability and Quality of Colloidal silica : Concentration of Glass Water ($Na_2O.2{,}6\ SiO_2$), Flow Rate, pH Level, Alkaline Concentration, Aging Temperature, and Aging Time are presented in Table 1.

Table 1. Results of research on the influence of technological parameters

Technology parameters	**Glass water concentration (Glass water/clean water)**	**Flow rate (Exchange time)**	**pH**	**Alkalinity concentration (% in V)**	**Aging temperature**	**Aging time**
	2/8 (by volume) (Lit)	100mL/min (1 hour/5 liter batch)	9	0,03	70^0C	2-3 hour
Affection	SiO_2 concentration in the product	Not obvious (Within the experimental framework of the project)	Product status	pH of product	Product stabilization	

With the selected parameter conditions as mentioned above, the synthesized colloidal silica product meets the technical requirements as outlined in Table 2.

Table 2. Colloidal silica Product Results

Time	**SiO_2 concentration (% by volume)**	**Solution state**	**$SiO_2.n\ H_2O$ size (nm)**
Initinal	3,8	Liquid	4,75
After 6 months	3,8	Liquid	5,6

The experimental preparation of glass water from low-cost materials such as SMS (Sodium Metasilicate Pentahydrate) and rice husk ash used high pressure reaction method to create high molar glass water at a reasonable cost. Glass water was synthesized from Sodium Metasilicate Pentahydrate (SMS) and rice husk ash under a pressure of 4-6 atm (by heating) and stirred for approximately 1 hour and 30 minutes. The result was glass water with a molar ratio of 3.2 ($Na_2O.3.2SiO_2.H_2O$). This glass water was used as a replacement for industrial glass water to synthesize silica colloid with the same technological parameters as those selected for the above industrial glass water results in a product with a $SiO_2.n\ H_2O$ colloidal particle size of ≤ 12nm (2.6nm) and the storage time ≥ 6 months.

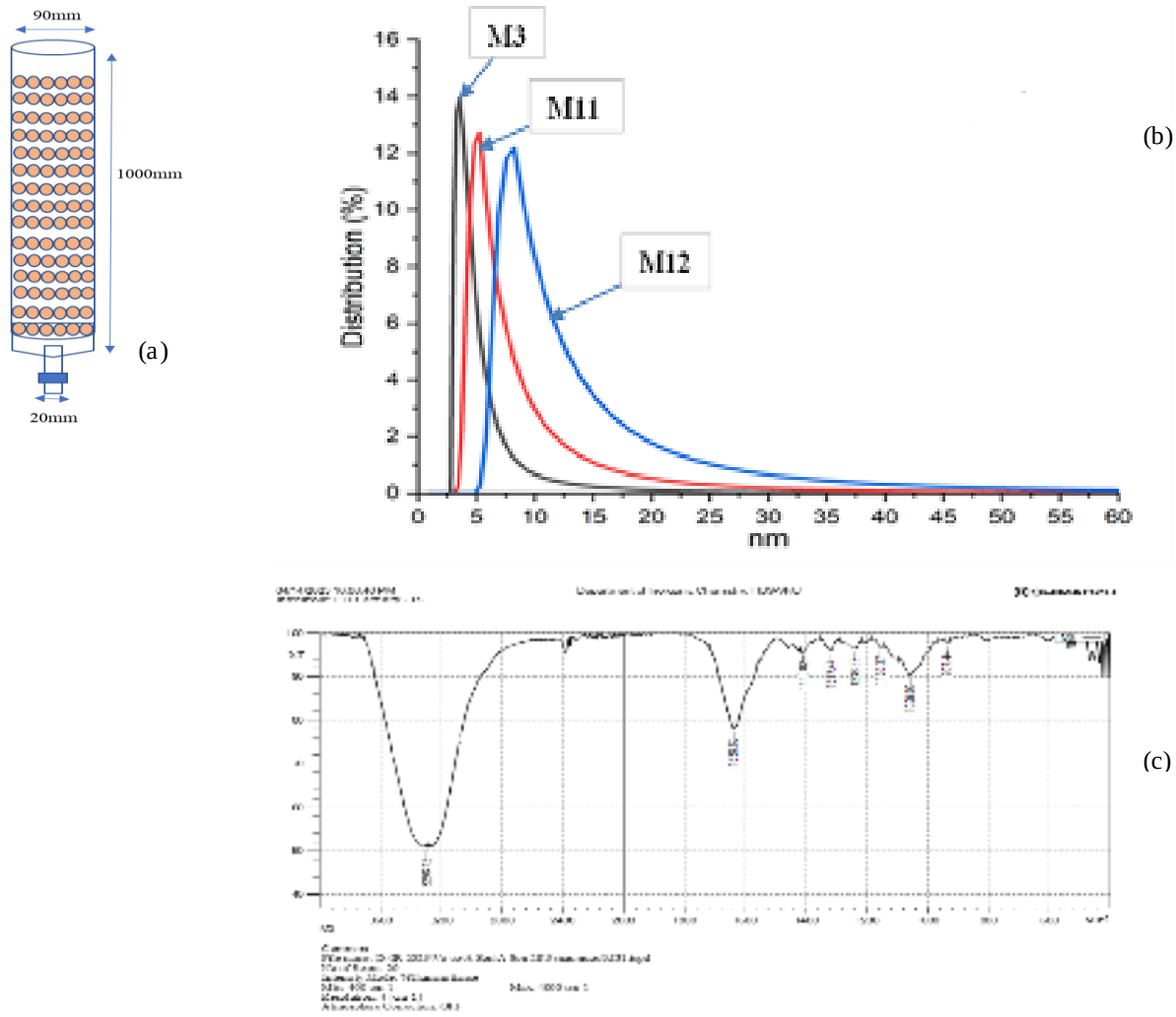

Figure 1. (a) Ion exchange column system, (b) Colloidal particle size distribution, (c) FTIR spectrum of the product

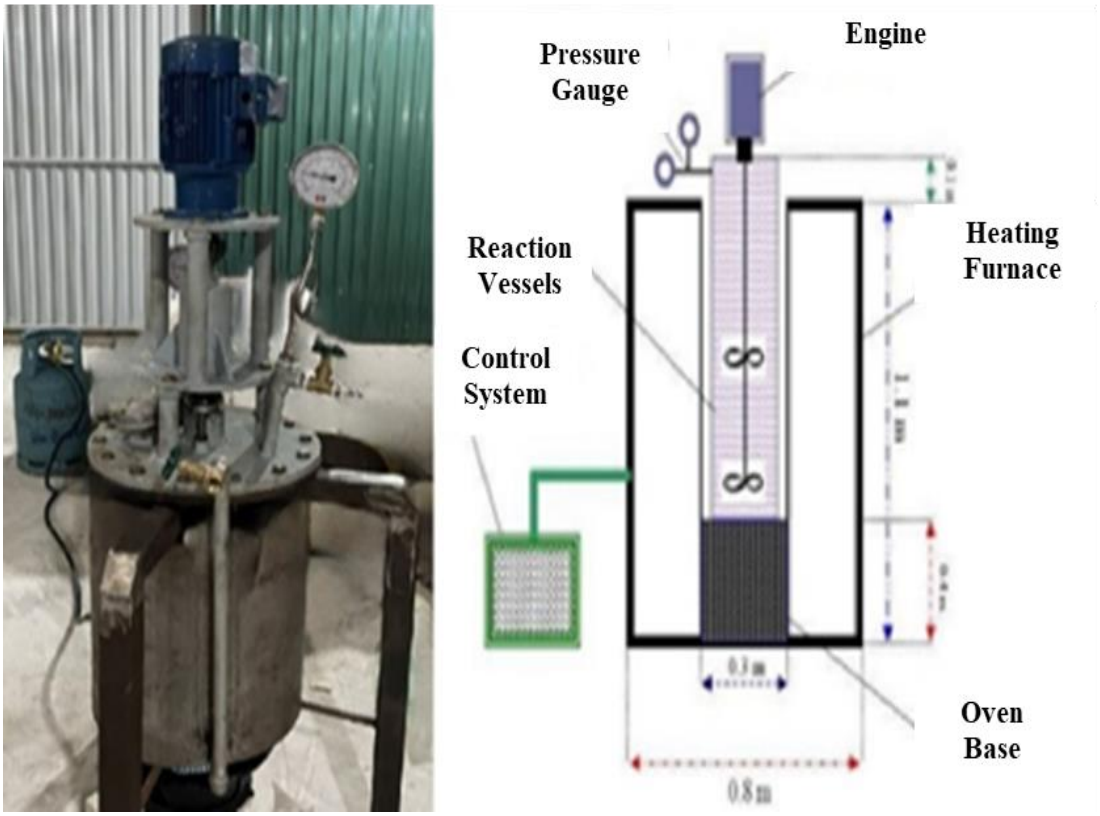

Figure 2. High pressure glass water preparation equipment system

In summary, within the framework of implementation, the project has established a technological procedure for preparing colloidal silica by using strong acid cation exchange resin (H+) as a raw material for foliar fertilizer from glass water for the first time in Vietnam and prepared high molar glass water from SMS and rice husk ash. Colloidal silica products meet the required technical standards and are suitable as raw materials for foliar fertilizers.

STUDY ON PREPARATION OF THE HIGH DENSITY COMPOUND U_3O_8 ORIENTING TO LEU NUCLEAR FUEL FOR RESEARCH REACTOR

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Project information:

- Project name: Study on preparation of the high density compound U_3O_8 orienting to LEU nuclear fuel for research reactor

- Code: DTCB.10/22/VCNXH

- Managerial Level: Ministry

- Allocated Fund: 780,000,000 VND

- Duration: 24 months (Jan 2022- Dec 2023)

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- Published papers related to the project:

1. Nguyen Trong Hung, Le Ba Thuan, Nguyen Thanh Thuy, et al. (2022) "Selective recovery of thorium and uranium from leach solutions of rare earth concentrates in continuous solvent extraction mode with primary amine N1923", Hydrometallurgy 213, 105933.

2. Nguyen Trong Hung, Le Ba Thuan, Nguyen Thanh Thuy, et al. (2023) "Uranyl Ammonium Carbonate Precipitation and Conversion into Triuranium Octaoxide", HELIYON (under the 2nd review).

3. Nguyen Trong Hung, Nguyen Thanh Thuy, et al. (2023) "Optimizing the sintering to produce high-density U_3O_8 powder", Chemistry and Application, No1(68)/3-2024.

4. Nguyen Trong Hung, Nguyen Van Tung (2022) "Nuclear fuel for research reactor: a review", The 7th Conferences on Nuclear science and technology for young researcher.

5. Nguyen Trong Hung (2023) "Study on precipitation and conversion of ammonium uranyl nitrate (AUC) into triuranium octaoxide (U_3O_8)", VINANST 15.

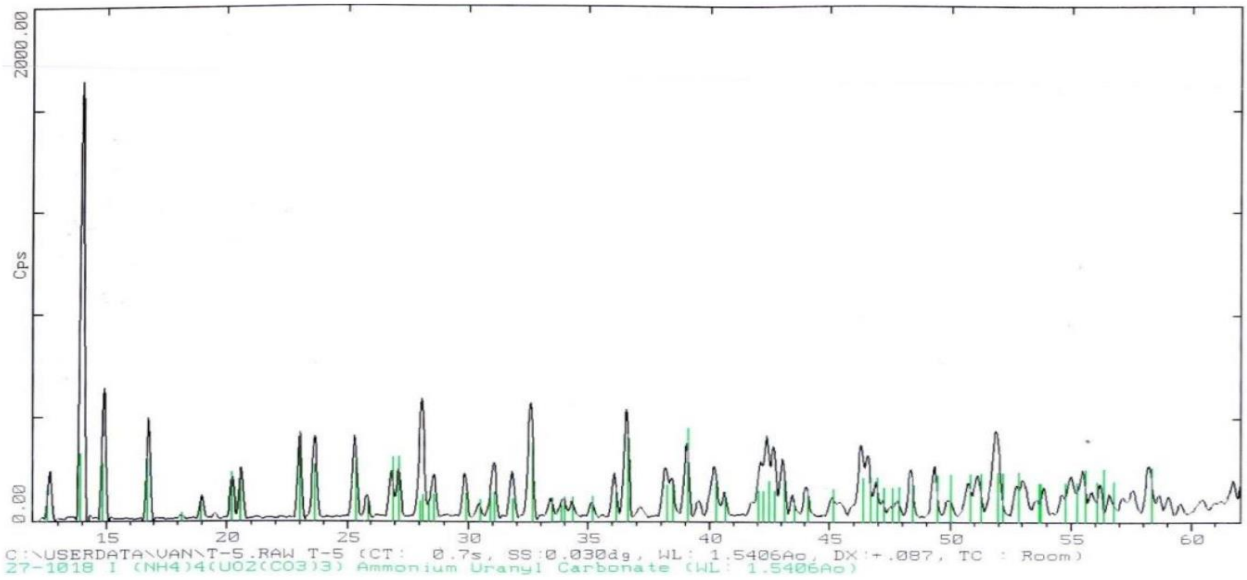
The compound U_3O_8 is used as nuclear fuel for research reactor cores. The conversion from highly enriched uranium-235 (HEU) fuel to low-enriched uranium-235 (LEU) fuel requires increasing the uranium-235 density of the fuel. Therefore, for LEU fuel in the form of U_3O_8+Al, in particular, U_3O_8 needs to have a high density to achieve the designed fuel density. This report will present the research results on the synthesis of high-density U_3O_8 compounds via the precipitation routes of ammonium uranyl carbonate (AUC) and uranyl peroxide (UO_4) from the UO_2F_2 (UF) compound, which serves as a simulated solution for the UF_6 hydrolysis process.

Studies on the precipitations of AUC and UO_4 have been conducted. Based on the research findings of the project, the optimal precipitation conditions for AUC and UO_4 have been identified, as indicated in Table 1.

Table 1. Optimal precipitation conditions for AUC and UO_4.

Parameters	AUC precipitation	UO_4 precipitation
Uranium concentration	100 g/L	15 g/L
Concentration of $(NH_4)_2CO_3$ (AC)	400 g/L	--
Concentration of H_2O_2	--	25%
Molar ratio of $(NH_4)_2CO_3$/U (C/U)	8	--
pH of the pricipitation	8	3
The precipitation temperature	Room temperature	Room temperature
Aging time	Over night	Over night

Figure 1 depicts the X-ray diffraction (XRD) spectra (captured using the SIEMENS D5005 instrument) of the AUC and UO_4 precipitates. The XRD results show that the AUC precipitate has highly pure crystallization. The AUC crystals exhibit a 2θ angle of 14° and possess a monoclinic crystal structure, belonging to the space group *C2/c*, with lattice parameters a=10.68Å, b=9.38Å, and c=12.85Å; α=γ=90°, β=96.45°. The XRD peak data for the UO_4 precipitate clearly indicate the formation of the compound $UO_4.2H_2O$, exhibiting highly pure crystallization with a 2θ angle of 17°. The UO_4 crystals have an orthorhombic crystal structure, belonging to the space group *Immm*, with lattice parameters a=6.501Å, b=4.209Å, and c=8.774Å; α=β=γ=90°.



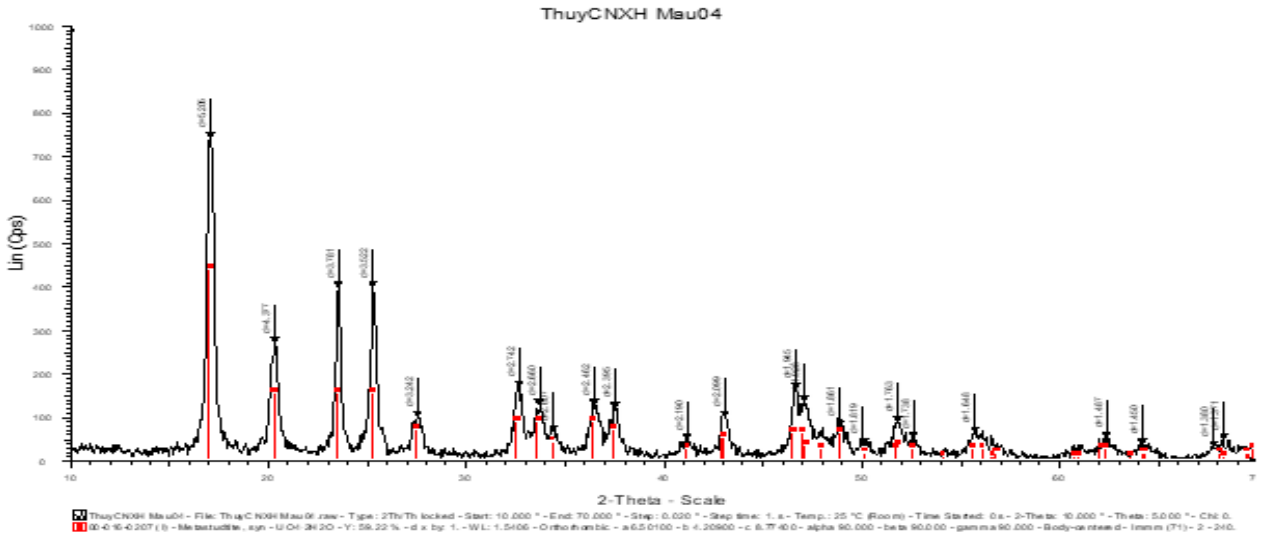
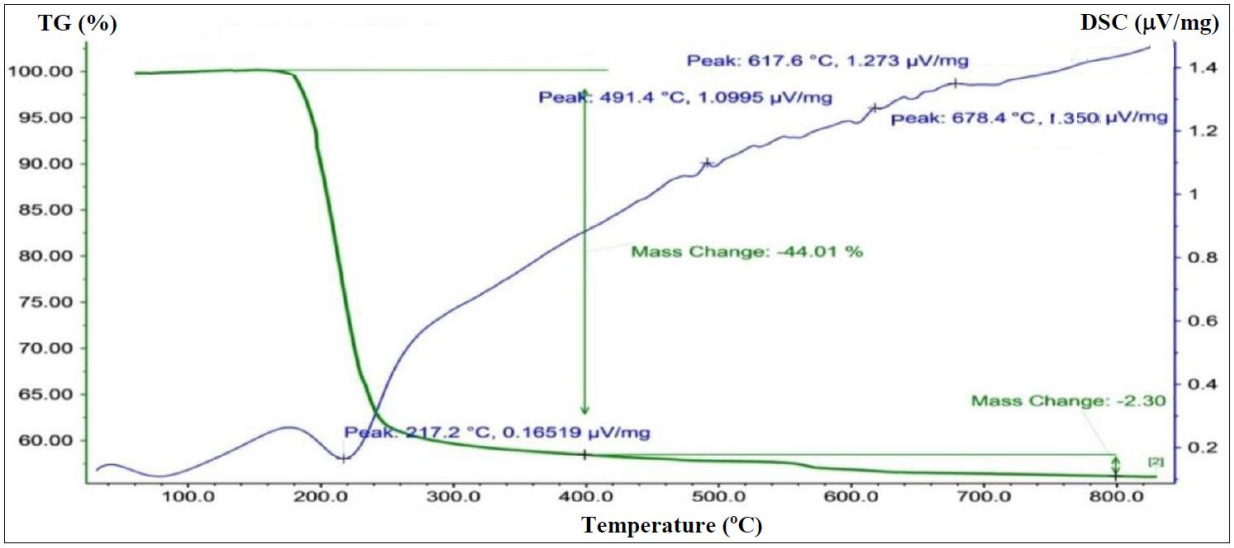


Figure 1. XRD spectra of AUC precipitate (up) and UO_4 precipitate (down).

The AUC and UO_4 precipitates were studied for conversions into U_3O_8. Figure 2 illustrates the thermogravimetric analysis (recorded on the SETARAM instrument) of the AUC and UO_4 precipitates. Based on the thermogravimetric analysis graphs (Figure 2), it can be observed that in the temperature range of 150-400°C, there is a conversion of AUC into the UO_3 compound, corresponding to a weight loss of 44.01%. Similarly, in the temperature range of 100-490°C, there is a conversion of UO_4 into the UO_3 compound, corresponding to a weight loss of 16.34%. The conversion of AUC or UO_4 follows the reaction equations:

$$(NH_4)_4UO_2(CO_3)_3 = UO_3 + 4NH_3 + 3CO_2 + 2H_2O \text{ and } UO_4 = UO_3 + 1/2O_2$$



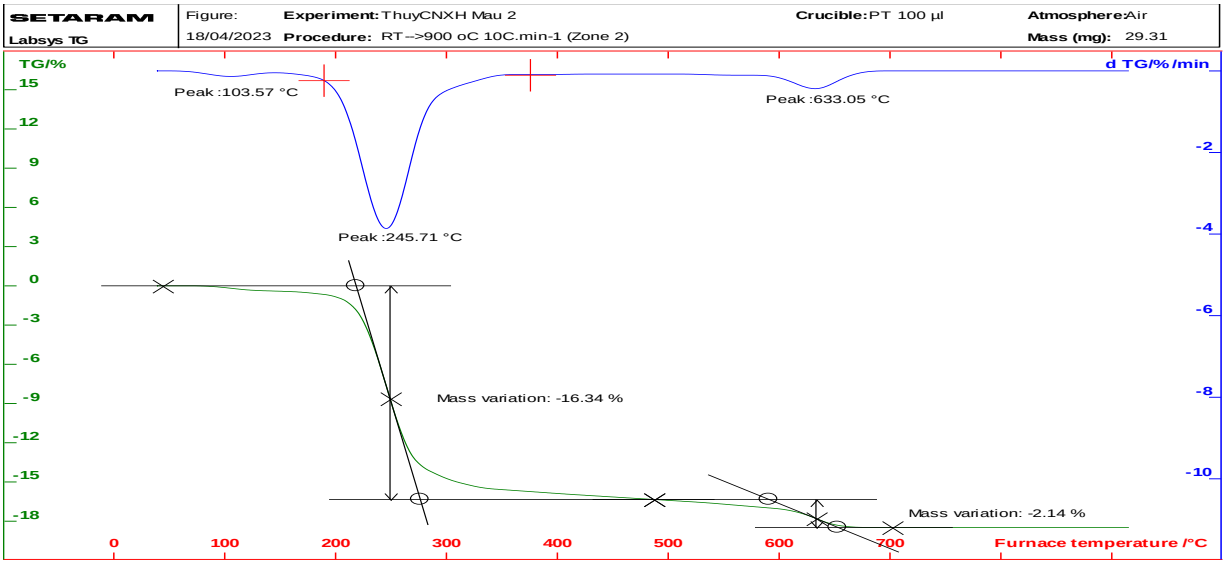


Figure 2. Thermogravimetric analysis curves of AUC precipitate (up) and UO_4 precipitate (down).

The next step is the conversion of UO_3 ex-AUC and UO_3 ex- UO_4 into U_3O_8 according to the respective equations:

$$3UO_3 = 2UO_3.UO_2 + 1/2O_2$$

The UO_3 ex-AUC conversion to U_3O_8 occurs in the temperature range of 400-900°C, corresponding to a weight loss of 2.30%; while the UO_3 ex-UO_4 conversion to U_3O_8 is in the temperature range of 500-700°C, corresponding to a weight loss of 2.16%.

Next, U_3O_8 ex-AUC and UO_4 powders were sintered to obtain high-density U_3O_8 products. The Response Surface Methodology (RSM) based on a central composite face-centered (CCF) design has been employed in an experiential manner to optimize the sintering process of U_3O_8 powder. The independent variables are the sintering temperature (°C) and the sintering time (hours), while the dependent variable is the density of the U_3O_8 powder (g/cm^3).The density of the U_3O_8 powder is determined according to the ASTM C373-88, Reapproved 2006 - Standard Test Method for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products. Sintering experiments on U_3O_8 powder (using a tube furnace from Nabertherm, with a maximum operating temperature of 1800°C) were conducted based on the experiment design plan (following the RSM-CCF model). The results were utilized as input data in the MODDE 5.0 software to establish a mathematical equation describing the density of the U_3O_8 powder (the bulk density of U_3O_8 powder determined according to ASTM C373-88 standards) in relation to the sintering temperature and time factors. The regression equations describing the dependence of the density of U_3O_8 ex-AUC (Equation 1) and U_3O_8 ex-UO_4 (Equation 2) on the sintering temperature and time are as follows:

$$Y(AUC)=7.6+0.15X_1+0.15X_2 -0.08X_2^2 -0.05X_1X_2 \quad (1)$$

$$Y(UO_4) = 7.6 + 0.16X_1 + 0.14 X_2 \quad (2)$$

Here, Y(AUC) and Y(UO_4) represent the density (g/cm^3) of U_3O_8 ex-AUC and ex- UO_4 powders, respectively; X_1 denotes the sintering temperature, and X_2 represents the sintering time.

From equations (1) and (2), the optimization results from MODDE 5.0 software have indicated that the optimal conditions are a sintering temperature of 1400°C and a sintering time of 9 hours for both the AUC and UO_4 precipitation methods. Under these conditions, the density of U_3O_8 powders reaches 7.8 g/cm^3.

Based on the research results, a technical flowsheet for high-density U_3O_8 powder preparation at lab scale has been established (Figure 3). Excess 140 grams of U_3O_8 ex-AUC and UO_4 product with a density of ≥ 7.4 g/cm^3 has been successfully prepared, meeting the impurity content standards according to ASTM C788-03.

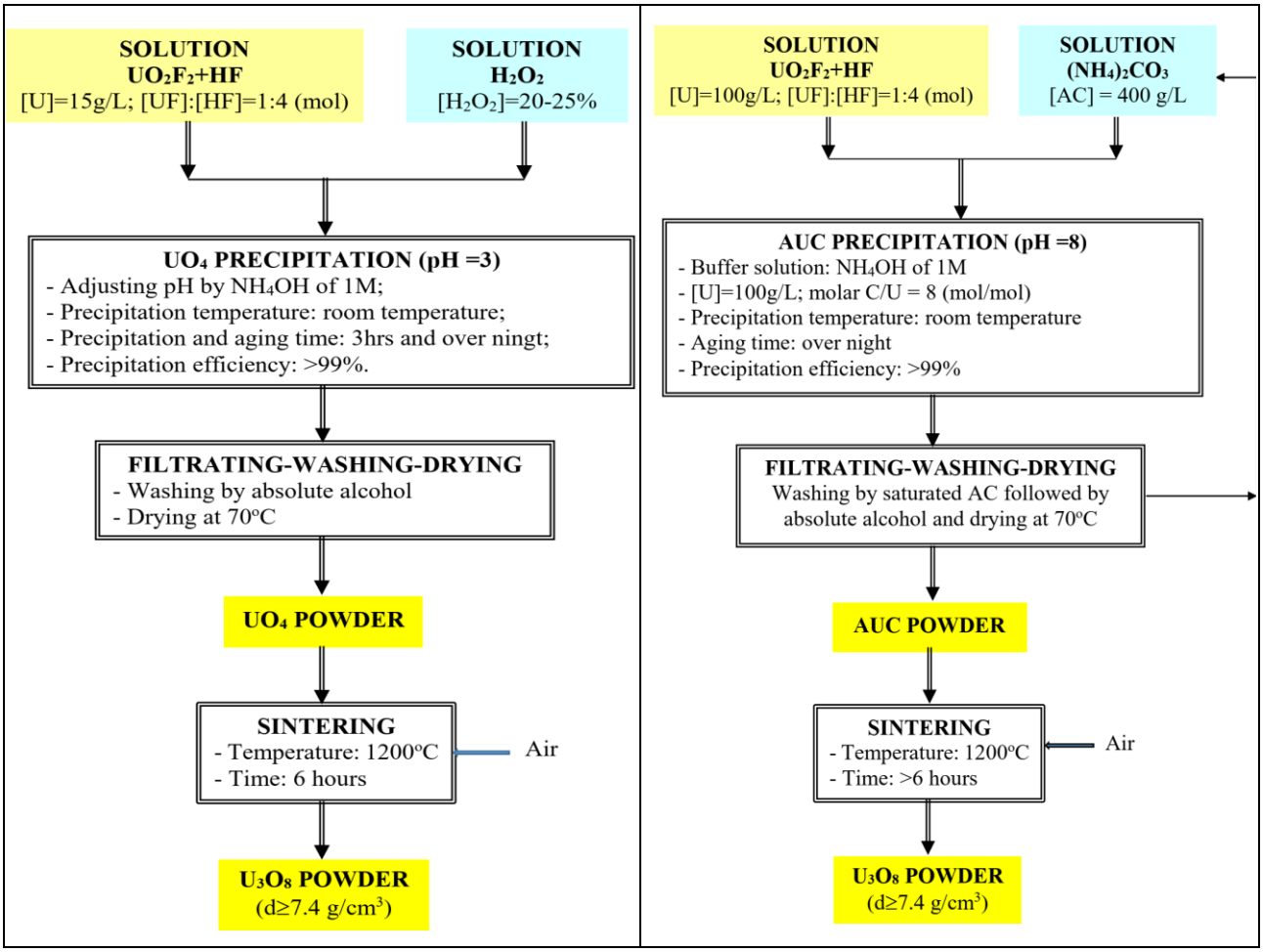


Figure 3. The technical flowsheet for high-density U_3O_8 ex-UO_4 (left) and ex-AUC (right) nuclear fuel powder preparation at lab. scale.

The following are some recommendations for further research on the topic, including: (i) Focus on experimental research in the production of dispersed nuclear fuel rods in the form of Al-U_3O_8 cermets (this direction will involve collaboration with the Nuclear Research Institute), and (ii) Propose the next research project: Investigate the synthesis of nuclear fuel cermet Al-Uranium Oxide (fuel meat) using powder metallurgy techniques.

STUDY ON UPGRADING THE TOTAL RARE EARTH OXIDE CONTENT BY FLOTATION TECHNIQUE FROM ROASTED BASTNAESITE CONCENTRATE

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Project information:

- **Project name: Study on upgrading the total rare earth oxide content by flotation technique from roasted bastnaesite concentrate**
- **Code: CS/23/03-03**
- **Managerial Level: Institute**
- **Duration: 12 months (Jan 2023- Dec 2023)**
- **Contact email: tnq2007@gmail.com**
- **Published papers related to the project:**

1. Trinh Nguyen Quynh, Duong Van Su, Tran Van Son, Bui Ba Duy, Truong Thi Ai, Nguyen Hong Ha, Cao Duy Minh, Ngo Quang Huy and Kon'kova Tatiana Vladimirovna Separation of total rare earth oxides from roasted bastnaesite concentrate using flotation method, Proceedings of Vietnam Conference on Nuclear Science and Technology VINANST-15. Nha Trang, Vietnam. August 2023, pp. 482-487.

2. Trinh Nguyen Quynh, Bui Ba Duy, Truong Thi Ai, Ngo Quang Huy, Nguyen Hong Ha, Tran Van Son, Duong Van Su Flotation upgrading total rare earth oxides from roasted bastnaesite concentrate. The accepted article. Mining Industry Journal, No. 6, Dec., 2023 (in Vietnamese).

3. Trinh Nguyen Quynh, Kon'kova T. V., Duong Van Su, Bui Ba Duy, Ngo Quang Huy Separation of total rare earth oxides from roasted bastnaesite concentrate using flotation method. Advances in Chemistry and Chemical Technology. Mendeleev university of chemical technology, Moscow 2023, Vol. 37, No.14, pp. 54-56. ISSN 1506-2017(in Russian).

Bastnaesite ($REFCO_3$) is an important principal resource of light rare earth (mainly Ce_2O_3) and has the largest proven reserve among all rare earth minerals in the world. Vietnam has bastnaesite rare earth resources in Dong Pao (Lai Chau province) and has potential for exploitation. Processing bastnaesite by chemical methods has disadvantages such as high cost and negative impact on the environment. Research on obtaining REO from bastnaesite by physical methods is a new trend nowadays. Based on the characteristics of easy decomposition, bastnaesite is calcined with CaO to produce rare earth oxides (REO), which can be obtained by flotation methods. The calcination reactions are as follows:

$$REFCO_3 = REOF + CO_2\uparrow$$

$$CaO + 2REOF = RE_2O_3 + CaF_2$$

$$2Ce_2O3 + O_2 = 4CeO_2$$

The ability to recover REO from a roasted mix depends on several factors, in which the ratio of solid to liquid phases (S/L), environmental pH and the selectivity of collectors play important roles. The purpose of this study includes determining the optimal conditions for heat treatment of Dong Pao bastnaesite concentrate with CaO to obtain rare earth oxides and providing an initial flotation process to upgrade content of rare earth oxides from roasted bastnaesite concentrate, using styrene phosphonic acid (SPA) collector.

Dong Pao rare earth concentrate containing REO = 30 – 36% was used as the research object. The conversion and calcination process of Dong Pao bastnaesite with CaO was carried out at 650°C and the calcination time of 1h. The efficiency of the bastnaesite conversion into rare earth oxides was calculated based on the amount of obtained Ce^{4+} compared with the total Ce^{3+} and Ce^{4+} in the original bastnaesite sample. The calculation formula is:

$$Ce^{4+} / \sum (Ce^{3+} + Ce^{4+}) = \text{ratio decomposition (\%)}$$

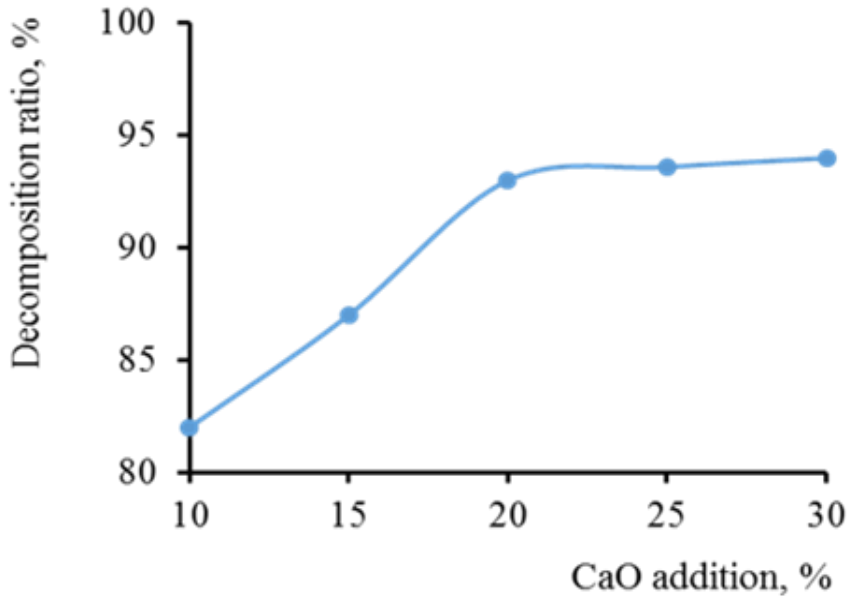

Figure 1. The conversion efficiency of bastnaesite depends on the used amount of CaO.

The effect of CaO's used amount on the phase transition efficiency of the bastnaesite sample during the calcination process was investigated. The amount of CaO used for the survey was 10% to 30% of the amount of bastnaesite. The research results obtained (Fig. 1) have shown that at the investigation temperature of 650°C, the appropriate used amount of CaO is 20% compared to the mass of bastnaesite concentrate. This is due to the fact that at the ratio CaO/bastnaesite = 20% the dosage of CaO might be sufficient for the decomposition of minerals, and at this time CaO continued to be increasingly added, there were not many changes in decomposition ratios.

Thermal analysis of TGA (Fig. 2) in the condition of up to 1000°C of bastnaesite mixed sample with 20% CaO show that very small amount of quality loss from 80°C to 100°C was attributed to the loss of surface water. Above 400°C, the TGA curve was very steep, which

indicates some substances evaporated from the sample. The mass-missing effect that occured at about 600°C was attributed to the complete decomposition of bastnaesite. The thermal effect took place at a temperature range of 800 – 1000°C corresponding to the complete decomposition of $CaCO_3$ products in the calcination mixture. The quality of sample from the beginning to the ending of the experiment lost ~ 13 wt.%.

The results are consistent with those of previous studies, and bastnaesite underwent a temperature-induced dissociation into the assembly of LnOF and CO_2.

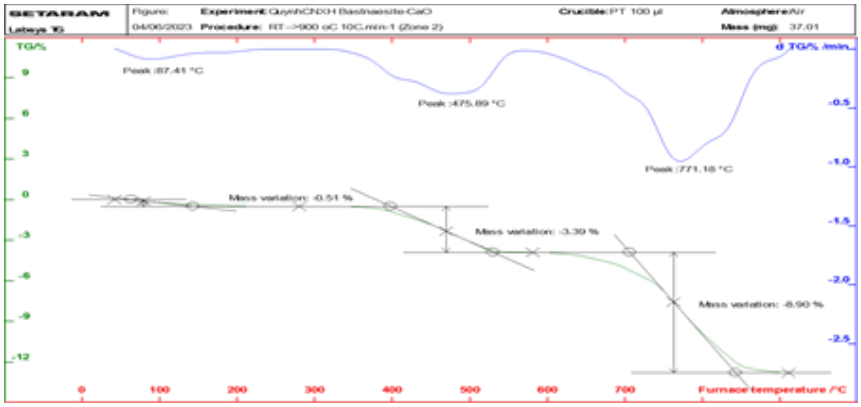

Figure 2. Thermogravimetric analysis (TGA) curves of CaO/bastnaesite mixture

Figure 3. Denver flotation machine for mineral flotation tests

The REO flotation tests were carried out by using Denver-type flotation machine with a cell volume of 1000ml and 1500 r/min impeller speed (Fig. 3). In each test, one sample (100gr) was dispersed in the cell with distilled water at room temperature. The pH was adjusted to a designed value with HCl or NaOH solutions. Then the collector SPA was added and stirred for 3 min, followed by flotation for 5 min. The froth products (concentrates) and tailings were weighed after filtration and drying. The phase composition of the flotation product was analyzed by XRD and the REO content was determined.

Among the conditions of flotation, the solid/liquid phase ratio (S/L) is related to the density of the dispersion system in the flotation, which directly affects the floating or sinking

separation ability of minerals. The higher the density of slurry solution and the higher the material density, more the ability of REO to disperse and interact with collector will be reduced. The research results are presented in Figure 4.

The effect of pH values on flotation recoveries of REO was investigated (Tab.1). This result is due to the fact that in the low pH range, the role of SPA is changeable, while in the alkaline pH range, a neutralization reaction between SPA and alkaline agents may occur.

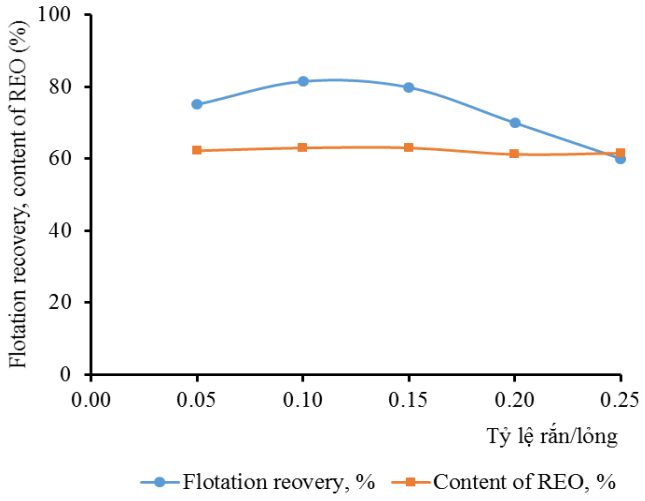

Figure 4. Effect of S/L ratio on REO flotation efficiency

Table 1. The effect of environmental pH on REO flotation efficiency

pH	2	3	4	5	6	7	8
REO flotation recovery, %	50,13	66,01	76,63	81,79	80,09	63,39	46,20
Content of REO, %	60,09	62,14	65,31	61,53	62,07	53,08	47,23

The experiments to evaluate the effect of the amount of SPA used on REO flotation recovery were carried out (Tab. 2). The results show that the optimal value of the SPA/feed parameter selected was 300mgr/100gr.

Table 2. The effect of the used amount of SPA on REO flotation efficiency

SPA/feed, mg/100g	100	200	300	400	500
REO flotation recovery, %	40,13	55,07	80,49	79,90	80,17
Content of REO, %	62,19	63,06	64,01	61,20	61,55

The flotation scheme is established based on the optimal parameters obtained as mentioned above. Applying the process, from 1300g of initial feed we obtained 550g of solid product containing 60 – 64% REO. The REO flotation recovery reached 80 - 81% under the conditions of phase ratio S/L = 100g/1000ml, pH = 5-6 and used amount of collector SPA/feed = 300mg/100g. The research results are in good agreement with many published works in the world, thereby confirming the suitability of research trends in bastnaesite concentrate processing in Vietnam.

However, this is a new problem in our country today and needs to be researched further on many types of ores, especially in the cases applied to primary bastnaesite ores (13-18% REO) that have not been upgraded by any methods before.

The research has achieved the initially set goals, one of which was setting up a firm basis to confirm that this research direction is completely appropriate. The research shows that it is possible to overcomes the disadvantages of previous traditional research methods, including reducing chemical costs, mitigating negative impacts on the environment, and bringing economic efficiency. The research product is REOs concentrate with high grade and few impurities, thus it is very suitable for further deep processing of rare earth concentrates.

STUDY ON THE PHOTON AND NEUTRON RADIATION SENSITIVITY CHARACTERISTICS OF THE THERMOLUMINESCENCE MATERIAL K_2GdF_5:Tb

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Project information:

- Project name: Study on the photon and neutron radiation sensitivity characteristics of the thermoluminescence material K_2GdF_5:Tb

- Code: ĐTCB.03/22/VNCHN

- Managerial Level: Ministry

- Implementation time: 24 months (Jan 2022 – Dec 2023)

- Contact email: ngvhung58@gmail.com

- Published papers related to the project:

1. Van-Toan Phan, Van-Hung Nguyen, Hung-Thai Pham, Van-Dung Pham, Dinh-Khoa Tran, Hoai-Nam Tran, "Thermoluminescence properties of K_2GdF_5:Tb material irradiated in neutron-gamma fields of 241Am-Be source", Nuclear Technology & Radiation Protection, ISI, Q2, Serbia, Vol.39, No.1 (2024), pp.37-46, Doi: 10.2298/NTRP2401037P.

2. Phan Van Toan, Nguyen Van Hung, Pham Van Dung, Pham Hung Thai and Ngoc Thiem Le, "Thermoluminescence characteristics of in-house synthesized K_2GdF_5:Tb powder for photon and neutron", Nuclear of Science and Technology, Vol.14, No.1 (2024), pp.01-06.

3. Phan Van Toan, Nguyen Van Hung, Le Viet Phong, Pham Van Dung, Pham Hung Thai, Doan Thi Ngoc No, Dinh Thi Quynh Giang, "Studying a homogeneity for manufactured batches of thermoluminescence material of K2GdF5:Tb for photon and neutron radiation", Selected reports for the 15th Vietnam Conference on Nuclear Science and Technology VINANST-15, 8/2023, Nha Trang, ISBN: 9786046719977, Tr.220-224.

4. Phan Bao Quoc Hieu, Nguyen Ngoc Anh, Pham Ngoc Son, Nguyen Van Hung, Nguyen Bich Thuy, Phan Văn Toan, Le Viet Phong, "Development of a neutron spectrometer for neutron dosimetry at the Dalat Nuclear Research Institute", Selected reports for the 15th Vietnam Conference on Nuclear Science and Technology VINANST-15, 8/2023, Nha Trang, ISBN: 9786046719977, Tr.242-247.

In the world, there have been some of studies on the frabrication of thermoluminescent material K_2GdF_5:Tb by hydrothermal method with different Tb^{3+} doping

concentrations, and investigating some radiation-sensitive characteristics of the material. When this material is irradiated with photon and neutron radiation sources, special attention is paid to neutron radiation because the material with Gd component is sensitive to thermal neutrons. Initial studies show that K_2GdF_5:Tb is sensitive to photon and neutron radiation. In Vietnam, Nha Trang Institute of Technology Research and Application (NITRA) has successfully fabricated the material K_2GdF_5:Tb by solid-state reaction method with different Tb doping concentrations, and on some main sensitivity characteristics of this material when irradiated with gamma and neutron radiation sources at high dose ranges. The research at NITRA is just the beginning and there are still some issues that need to be researched and developed: based on the evaluation standards of the International Electrotechnical Commission (IEC) on photon dose and the International Organization for Standardization (ISO) on neutron dose to investigate radiation dose characteristics such as: the investigation of gamma components and neutron components (thermal and fast neutron) from neutron radiation sources into dose characteristics; the homogeneity for manufactured batches of thermoluminescence material of K_2GdF_5:Tb for photon and neutron radiation, reproducibility of thermoluminescent signal (TL signal) according to different standard irradiation dose values; the neutron radiation dose characteristics (thermal and fast); the energy-dependent dose response (Energy response); the determination of detection threshold of dose for photon radiation (gamma, X-ray) and neutron; the scattering and absorption of photon and neutron radiation on materials when irradiated on a tissue-equivalent phantom (PMMA and water); the assessment of measurement uncertainty (Uncertainty) for materials on photon and neutron radiation dose characteristics;, etc. Therefore, the topic " Research on the photon and neutron radiation sensitivity characteristics of the thermoluminescence material K_2GdF_5:Tb" is set out to solve the above problems - This is the reason for implementing the project.

In terms of raw materials, the project uses 3 main chemicals in powder form with a purity of 99.99% from Merck, Germany used in the fabrication of K_2GdF_5:Tb material, including: Hydrated KF ($KF.2H_2O$) (crystalline form, strongly hygroscopic, melting point 858^{o}C (anhydrous), boiling point 1,502^{o}C, atomic weight 57.998 g/mol, density 2.480 g/cm3), GdF_3 (white powder, melting point 1231^{o}C, boiling point 3273^{o}C, atomic weight 214.234 g/mol, density 7.047 g/cm3), TbF_3 (white powder, melting point 1172^{o}C, boiling point 2277^{o}C, atomic weight 215.924 g/mol, density 7,230 g/cm3).

Regarding equipment for material manufacturing: using Nabertherm N7/H furnace (Germany) with inert gas supply system (Figure 1). This is a specialized furnace in material manufacturing with C540 temperature controller using modern software and inert gas pipeline. Maximum temperature 1280^{o}C, furnace volume 11 liters, 1-phase power source and capacity 3.6 kW. To dry the sample after washing, use a ASLI high temperature oven with inert gas supply system of China (Figure 2) with temperature range up to 200^{o}C.

The investigation of photon and neutron radiation sensitivity characteristics of K_2GdF_5:Tb thermoluminescent material samples was conducted by using standard radiation dose irradiation systems to irradiate the sample, then measuring the sample to investigate

the thermoluminescent signal of the material sample meeting IEC and ISO standards. Some irradiation systems are used to conduct the material survey: gamma source - Cs-137 with activity of 70.8 mCi in 2022), gamma source - Co-60 with activity of 4.69 Ci (9/2022), the gamma radiation dose field of these two radioactive sources is determined by the secondary standard dosimeter "Farmer Dosimeter"; X-ray generator - Rikaku, Japan “RF-200EGM2” (high voltage 70 ~ 200 kV, current intensity: 5 mA; neutron reference system using Am-Be source (see Figure 6), emission intensity is $5.4181.10^6 \pm 6\%$ n/s in 2022 and neutron reference system using Cf-252 source (see Figure 7) with emission intensity $2.82.10^6$ n/s on May 19, 2022. The neutron radiation dose field of the neutron source (Am-Be and Cf-252) was determined by Nested Neutron Spectrometer - NNS using He-3 proportional counter tube used to measure neutron energy spectrum.

Figure 1. Nabertherm N7/H furnace

Figure 2. ASLI high temperature oven

Figure 3. The TLD reader system - Rexon UL-320

Figure 4. Gamma source - Cs-137

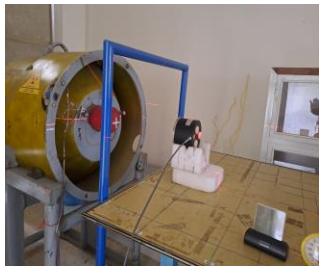

Figure 5. Gamma source - Co-60

Figure 6. Neutron source - Am-Be

Figure 7. Neutron source - Cf-252

Thermoluminescent material K_2GdF_5 doped with Tb^{3+} ion with a concentration of 10 mol% was synthesized by solid-phase reaction using reaction equation (1) as follows:

$$2KF + 0{,}9*GdF_3 + 0{,}1*TbF_3 \rightarrow K_2GdF_5{:}Tb \quad (1)$$

The process of fabricating K_2GdF_5:Tb material includes 8 steps as follows: Preparation (raw materials, equipment, tools), calculating and weighing the mass of raw materials, drying $KF.2H_2O$, mixing and grinding samples, sintering mix-samples (performing solid-phase

reaction), grinding, washing and drying the product, annealing the product, weighing and packaging the final product. The total time to carry out the material manufacturing process to create the final product (K2GdF5:Tb powder material) is about 11 days. This is the process of manufacturing K2GdF5:Tb material carried out at the Material Manufacturing Laboratory built at the Institute of Nuclear Science and Technology during the implementation of the project, based on a number of main and modern equipment. The particle size of the product was measured on the LA-960 particle size meter with an average result of 45 µm. The K_2GdF_5:Tb material sample prepared at Nuclear Research Institute was sent to the Materials Analysis Laboratory to investigate the material structure based on the XRD method on the D8 Advance Eco machine, Germany. The results of the X-ray diffraction spectrum analysis are presented in Figure 8, along with the standard spectrum of the K_2GdF_5:Tb material in the JCPDS No.77-1924 standard card presented in Figure 9. Comparing the X-ray diffraction spectrum of the K_2GdF_5:Tb material sample prepared by the Nuclear Research Institute with the standard X-ray diffraction spectrum of the K_2GdF_5:Tb material sample in the JCPDS No.77-1924 card shows that these two spectra have similar shapes.

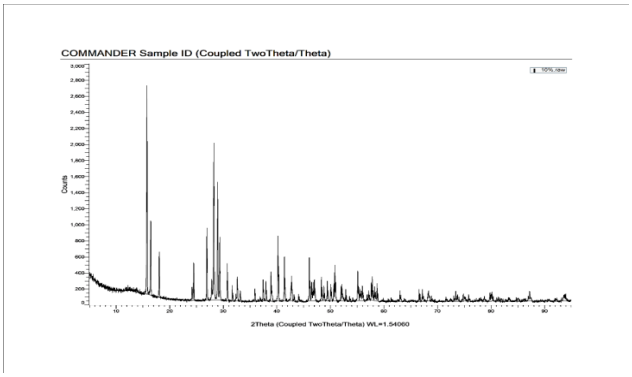

Figure 8. The X-ray diffraction spectrum of the K_2GdF_5:Tb (10% Tb^{3+}) material sample prepared by the Nuclear Research Institute

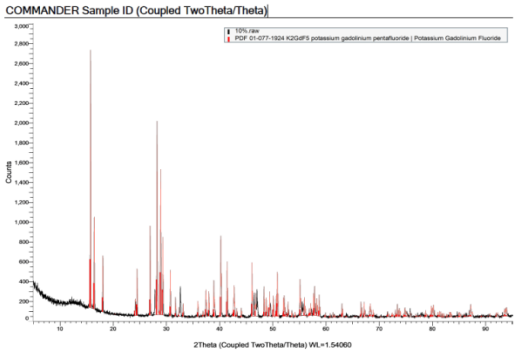

Figure 9. The standard X-ray diffraction spectrum of the K_2GdF_5:Tb material sample in the JCPDS No.77-1924 card

The results of measuring the TL signal of the material sample using a Rexon UL-320 reader system show that the typical TL curve (TL spectrum) when irradiating the material sample with fast neutrons and Am-Be thermal neutrons is presented in Figure 10 and Figure 11, respectively.

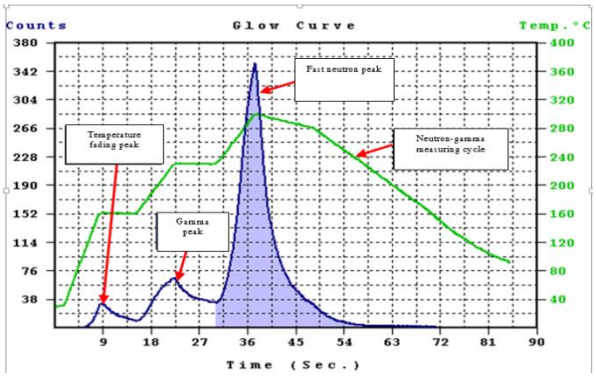

Figure 10. TL glow-curve of K_2GdF_5:Tb irradiate to fast neutron

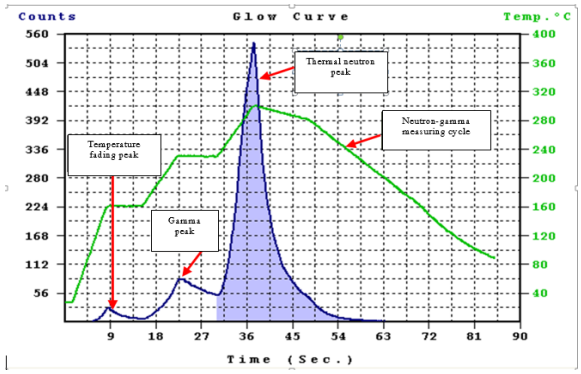

Figure 11. TL glow-curve of K_2GdF_5:Tb irradiate to thermal neutron

The guidelines and criteria specified in IEC/ISO were applied to study the radiation dose characteristics for photons and neutrons as follows: Batch homogeneity of manufactured materials: BH < 28%, satisfying the criterion BH ≤ 30%, reproducibility (R) of TL signal according to different standard dose values: For photons, R < 7.5% (satisfying the criterion R ≤ 7.5%); for neutrons, R < 0.4% (satisfying the criterion R ≤ 20%), self-irradiation: SI ≈ 0.05 mSv/month, satisfying the criterion SI < 0.1 mSv/month, the detection threshold: LOD ≈ 0.02 mSv, satisfying the criterion LOD < 0.1 mSv, linearity dose (LR): for photons satisfying the criterion LR ≤ 10% in the range 0.1 mSv – 1.0 Sv; with neutrons satisfying the criterion LR ≤ 10% in the range of 0.1 – 20 mSv, the energy dependence: for X-rays and neutrons (thermal and fast) there is a strong dependence, the decrease in thermoluminescence signal over time (fading): F decreased sharply after 98 days (46% for X-rays, 24% for gamma Co-60, 27% for thermal neutron Am-Be), The scattering and absorption of photon and neutron radiation on materials when using phantoms (PMMA and water): For photons, the scattering coefficient increases respectively from water phantom to PMMA phantom, for thermal neutrons, the scattering coefficient decreases respectively from water phantom to PMMA phantom, the uncertainties combined (Uc) and uncertainties expanded (Ue) measurement of photon radiation dose characteristics for materials are 28% and 55% respectively. Thus, the project has completed all the contents registered in the description, in which the important thing is to build and complete the process of manufacturing K_2GdF_5:Tb(10%) material at the Institute of Nuclear Research and has manufactured 18 batches of K_2GdF_5:Tb(10%) material in powder form (with a total mass of 51.1 grams) used as products.

2.9. COMPUTATION AND OTHER RELATED TOPICS

IMPROVING THE EFFICIENCY OF *IN VITRO* REGENERATION OF ARTICHOKE (*Cynara scolymus* L.) THROUGH MERISTEM AND THIN CELL LAYER CULTURE TECHNIQUES

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Tay Nguyen Institute for Scientific Research, 116 Xo Viet Nghe Tinh street, Da Lat, Lam Dong

Project information:

- **Project name: Improving the efficiency of *in vitro* regeneration of Artichoke (*Cynara scolymus* L.) through meristem and thin cell layer culture techniques**
- **Code: CS/23/01-03**
- **Managerial Level: Institute**
- **Duration: 12 months (Jan 2023 - Dec 2023)**
- **Contact email: thucbiovhn@gmai.com**
- **Published papers related to the project:**

1. The cryotherapy technique in producing virus-free Artichoke (*Cynara scolymus* L.) plantlet, *Rencontres de Quy Nhon VI: International Biology Conference 2023, ICISE Quy Nhon, Vietnam, September,* 20-22, 98, 2023.

Artichoke (*Cynara scolymus* L.), is a member of the Asteraceae, is a perennial plant with high value in both food and medicinal uses. They are commonly cultivated in mountainous provinces in the North (Sapa - Lao Cai; Tam Dao - Vinh Phuc) and Dalat - Lam Dong. However, the yield and quality of Artichoke plants are currently seriously declining due to genetic degeneration. Meanwhile, the *in vitro* propagation process on Artichoke has not been thoroughly researched and very few publications on Artichoke micropropagation in Vietnam have been reported. Therefore, creating virus-free Artichoke material through meristem culture and studying the *in vitro* regeneration process through thin cell layer (TCL) culture is crucial in the process of Artichoke micropropagation. In this study, we established a micropropagation process for Artichoke through meristem culture and TCL culture. Therefore, experiments were conducted to select the optimal meristem size (or treatment with cryotherapy) to produce ToMV virus-free *in vitro* Artichoke material (a common virus that damages Artichoke in Vietnam); subsequently, plant growth regulators (cytokinin, auxin) were studied for their ability to regenerate shoots from Artichoke tTCL leaf explants *in vitro*, and the rapid multiplication and *in vitro* root formation stages were also investigated. In addition, different types of substrates (agar, gelrite, perlite, vermiculite, rockwool) and aerated culture have been tested to improve *in vitro* rooting to increase the survival rate of seedlings when grown in nursery conditions.

The results show that shoots meristem size of 0.5 mm (or *in vitro* shoots of 2.0 mm treated with liquid nitrogen for 30 minutes) were the optimal explant source for obtaining ToMV virus-free *in vitro* shoots of Artichoke; the regeneration of shoots from Artichoke tTCL leaf explants were cultured on Murashige and Skoog (MS) medium supplemented with 1.0 mg/L TDZ combined with 0.2 mg/L NAA, 30 g/L sucrose, and 8 g/L agar gives the best result. In addition, the shoot quality was improved when shoots were cultured on MS medium supplemented with 1,0 mg L-1 BA in 25 days and subcultured into ½ MS medium (reduced a half macronutrient) without plant growth regulators in 15 days. As well, shoots cultured on liquid MS medium supplemented with 6 mg/L IBA and rockwool substrate had the highest rooting percentage (90%) and number of roots per plantlet (5 roots). Meanwhile, shoots cultured on MS medium supplemented with 6 mg/L IBA and 8 g/L agar, using a nylon bag with two gas exchange membranes also achieved a rooting percentage (81.33%) equivalent to that of rockwool substrate. *In vitro* plantlets grew best on ECON1 (Nguon Sinh Thai Co., Ltd.) and Klasmann TS2 substrates (Rose Park Vietnam Import and Distribution Joint Stock Company) mixed in a 1:1 ratio (Figure 1.). These obtained results will contribute to improving the efficiency of Artichoke micropropagation and can provide disease-free plantlets for the Artichoke production chain towards sustainable development.

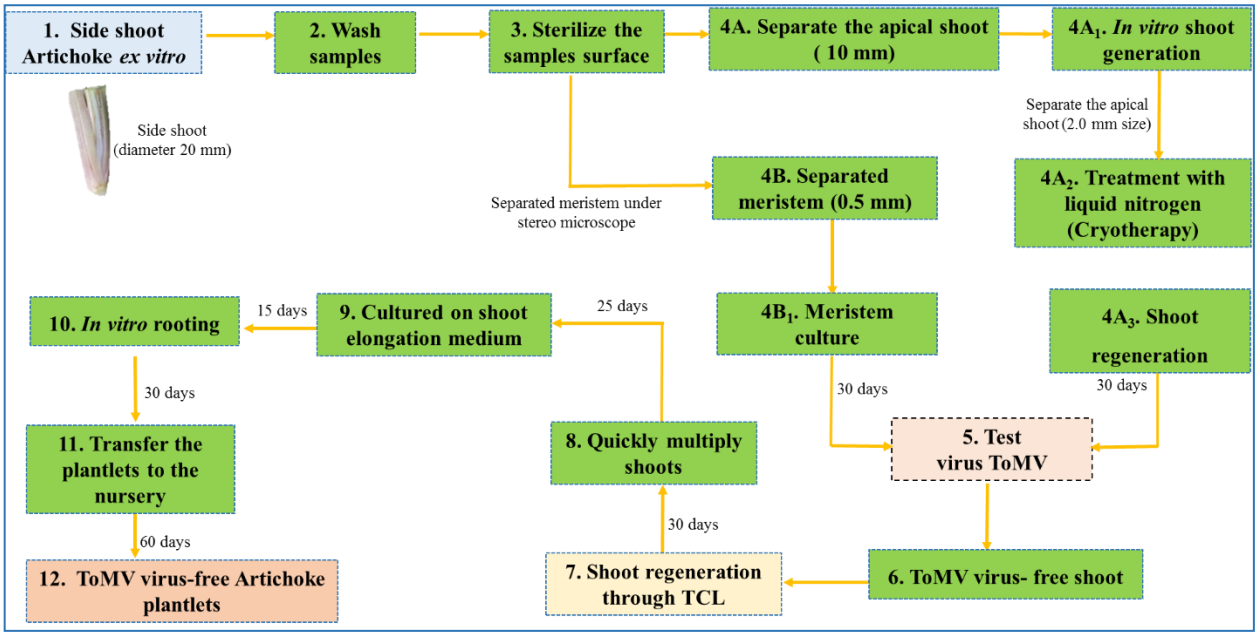

Figure 1. Micropropagation process of ToMV virus-free Artichoke plantlets through meristem and thin cell layer culture.

The process is presented step-by-step as follows:

Step 1: Side shoots of Artichoke *ex vitro* (diameter 10 mm) were selected as the initial explant source.

Step 2: Shoot explants were washed under tap water for 30 minutes to remove dirt and debris from the surface.

Step 3: Shoot explants were sterilized with $HgCl_2$ (0.1%, for 5 minutes), and rinsed 5 times with sterile distilled water in a laminar flow cabinet.

Step 4A: Shoots were isolated with a 10 mm diameter.

Step 4A1: Isolated shoots were cultured on MS medium supplemented with 0.1 mg/L BA, 30 g/L sucrose, and 8 g/L agar.

Step 4A2: Shoots formed in step 4A1 were separated and treated with liquid nitrogen for 30 minutes.

Step 4A3: Artichoke *in vitro* shoots after cryotherapy treatment were cultured on MS medium supplemented with 0.1 mg/L BA, 30 g/L sucrose, and 8 g/L agar.

Step 4B: The meristems were separated under a stereo microscope with a diameter of 0.5 mm.

Step 4B1: The meristems were cultured on MS medium supplemented with 0.1 mg/L BA, 30 g/L sucrose, and 8 g/L agar.

Step 5: The ToMV virus was tested using RT-PCR (Reverse Transcription–Polymerase Chain Reaction) technique.

Step 6: After testing for ToMV virus-free, the shoots were used for the shoot multiplication step on MS medium supplemented with 0.1 mg/L BA, 30 g/L sucrose, 8 g/L agar.

Step 7: Thin cell layer (TCL) culture technique was applied to generate new shoot from ToMV virus-free shoot (obtained from step 6). Leaf explants were cut with a size of 0.5 x 0.5 cm and cultured on MS medium supplemented with 1 mg/L TDZ combined with 0.2 mg/L NAA, 30 g/L sucrose, and 8 g/L agar.

Step 8: Regenerated shoots from leaf explants were rapidly multiplied on MS medium supplemented with 1 mg/L BA, 30 g/L sucrose and 8 g/L agar.

Step 9: After 25 days of culture, the shoot clusters were transferred to MS medium without plant growth regulators, 30 g/L sucrose and 8 g/L agar for 15 days.

Step 10: *In vitro* rooting: single shoots with a height of ≥ 2.0 cm are cultured on MS medium supplemented with 6 mg/L IBA with rockwool substrate (or 8 g/L agar) in a nylon bag with two gas exchange membranes (1.2 cm in diameter).

Step 11: Transfer *in vitro* plantlets grown on ECON1 and Klasmann TS2 substrates (mixed in a 1:1 ratio) to a nursery with natural light and 40% shading.

Step 12: After 60 days of cultivation, disease-free Artichoke plantlets are harvested.

STUDY ON ESTABLISHING A PROFILE AND MAKING SOME FACILITY IMPROVEMENTS IN A MICROBIOLOGY LABORATORY AT THE HANOI IRRADIATION CENTER TO COMPLY WITH ISO/IEC 17025:2017 STANDARDS

Hoang Dang Sang, Tran Bang Diep, Tran Xuan An, Hoang Phuong Thao, Nguyen Van Binh, Tran Huyen Thanh, Nguyen Xuan Tung

Hanoi Irradiation Centre, Minh Khai- Tu Liem- Hanoi

Project information:

- Project name: Study on establishing a profile and making some facility improvements in a microbiology laboratory at the Hanoi Irradiation Center to comply with ISO/IEC 17025:2017 standards

- **Code: ĐTCB.05/21/TTCX**

- **Managerial Level: Ministry**

- Implementation time: 30 months (Jan 2021- Sept 2023)

- **Contact email: hoangdangsang@gmail.com**

- Published papers related to the project:

1. Hoang Dang Sang, Tran Xuan An, Hoang Phuong Thao, Nguyen Van Binh, Nguyen Thi Thom, Nguyen Xuan Tung, Tran Bang Diep. Validation of method total aerobic microbial count in samples of functional food serves to construct a microbiological laboratory to iso 17025: 2017 at the Hanoi Irradiation Center. *Information of Nuclear Science and Technology*, 73, 2022, p. 46-50 (In Vietnamese).

2. Tran Xuan An, Hoang Dang Sang, Nguyen Van Binh, Hoang Phuong Thao, Nguyen Thi Thom, Nguyen Xuan Tung, Tran Bang Diep. Validation of method total aerobic microbial count in samples of functional food serves to construct a microbiological laboratory to iso 17025: 2017 at the Hanoi Irradiation Center. *Report at the 7 th Conference on Nuclear Science and Technology for Young Scientists*. Hanoi 06-07/10/2022(In Vietnamese).

3. Hoang Dang Sang, Tran Bang Diep, Tran Xuan An, Hoang Phuong Thao, Nguyen Van Binh, Tran Huyen Thanh, Nguyen Xuan Tung. Study evaluating the trend of test results regarding the quantification of yeast and mold using the bacterial colony counting technique at the department of radiation technology research - Hanoi Irradiation Center. *Report at the 15 th National Conference on Nuclear Science and Technology*. Nha Trang 09-11/08/2023 (In Vietnamese).

ISO/IEC 17025:2017, a general requirement for the competence of testing and calibration laboratories, is the most widely used standard by laboratories today. With the aim of enhancing service quality and meeting the requirements of those who use radiation service, the Department of Radiation Technology Research at the Hanoi Irradiation Center conducted this research to achieve ISO/IEC 17025:2017 accreditation in the field of Microbiology. The project was carried out with the following main contents:(1) Establishment

of capacity profile for microbiological analysis in food, functional food at the Hanoi Irradiation Center, (2) Determination of the scope of testing (including test objects, test parameters, testing methods), facilities, and laboratory environmental conditions, (3) Assessment of facilities and environmental conditions, development of equipment control, reference materials, chemicals, and testing environment control plans, (4) Conducting research to verify and reconfirm the validity of test methods, (5) Proficiency testing and inter-laboratory comparisons, (6) Calibration and standardization of all measurement instruments and related tools, (7) Internal audits and management reviews, (8) Assessing the standard compliance of the entire laboratory's procedures, records, and testing capabilities and evaluating test methods for recognition.

After a 30-month implementation period, the key products of the project consist of the followings: (1) Quality policy and quality objectives for testing; (2) Quality manual (1 manual), management processes (19 procedures), and control record sets (17 sets); (3) Standard Operating Procedures (SOP) related to four testing methods (9 SOP).

Simultaneously, the testers have been qualified by the proficiency testing programs. All chemicals and materials have been fully equipped.

All equipment has been calibrated and standardized by an independent organization base on requirement of ISO/IEC 17025:2017 mention. The project team conducted an assessment to verify four testing methods based on the Vietnamese National Standards (TCVN) (Table 1)

Table 1. List of testing apply for accreditation

TT	Materials or product tested	The name of specific tests	Limit of quantitation (if any)/range of measurement	Test method
1.	Food, functional foods	Enumeration of aerobic microorganisms Part 1: Colony count at 30 degrees C by the pour plate technique	10 CFU/ g 1 CFU/ mL	TCVN 4884-1:2015 (ISO 4833-1:2013)
2.		Enumeration of aerobic microorganisms Part 2: Colony count at 30 degrees C by the surface plating technique	10 CFU/ g 1 CFU/ mL	TCVN 4884-2:2015 (ISO 4833-2:2013)
3.		Enumeration of yeast and mould Colony count technique Colony count technique in products with water activity greater than 0,95	10 CFU/ g 1 CFU/ mL	TCVN 8275-1:2010 (ISO 21527-1:2008)

TT	Materials or product tested	The name of specific tests	Limit of quantitation (if any)/range of measurement	Test method
4.		Enumeration of yeast and mould Colony count technique Colony count technique in products with water activity less than or equal to 0,95	10 CFU/ g 1 CFU/ mL	TCVN 8275-2:2010 (ISO 21527-2:2008)

In March 2023, the certification assessment application was approved by the BoA (Bureau of Accreditation). On June 13-14, 2023, experts conducted an evaluation at the Department of Radiation Technology Research

BỘ KHOA HỌC VÀ CÔNG NGHỆ
VĂN PHÒNG CÔNG NHẬN CHẤT LƯỢNG

MINISTRY OF SCIENCE AND TECHNOLOGY
BUREAU OF ACCREDITATION (BoA)

Member of ILAC/APAC MRA

CHỨNG CHỈ CÔNG NHẬN

Certificate of Accreditation

Phòng thí nghiệm:

PHÒNG NGHIÊN CỨU CÔNG NGHỆ BỨC XẠ
TRUNG TÂM CHIẾU XẠ HÀ NỘI

Laboratory:

DEPARTMENT OF RADIATION TECHNOLOGY RESEARCH
HANOI IRRADIATION CENTER

Địa điểm PTN/ Lab location:

Km 12, đường 32, phường Minh Khai, quận Bắc Từ Liêm, Hà Nội
đã được đánh giá và phù hợp các yêu cầu của
has been assessed and found to conform with the requirements of

ISO/IEC 17025:2017

Lĩnh vực công nhận
Field of Accreditation
SINH
Biological
Mã số
Accreditation No

VILAS 1507

GIÁM ĐỐC
VĂN PHÒNG CÔNG NHẬN CHẤT LƯỢNG
(Director of Bureau of Accreditation)

VĂN PHÒNG CÔNG NHẬN CHẤT LƯỢNG

TRẦN THỊ THU HÀ

Ngày/ Date of Issue: 27/07/2023 (Annex of decision: 1494/QĐ-VPCNCL date 27/07/2023)
Hiệu lực công nhận/ Period of validation: up to 27/07/2026
Hiệu lực lần đầu/ Beginning of accreditation: 27/07/2023

Figure 1. Accreditation certificate for the Department of Radiation Technology Research laboratory - Hanoi Irradiation Center

On July 27, 2023, the Department of Radiation Technology Research at the Hanoi Irradiation Center received quality recognition and certification in compliance with ISO/IEC 17025:2017 requirements in the field of Microbiology, with the VILAS (Vietnam Laboratory Accreditation Scheme) code number 1507 (Figure 1).

After obtaining the VILAS certification, the project team proceeded to develop a dossier for registering testing activities in accordance with Decree 107/2016 and Decree 54/2018/NĐ-CP. The online submission process at the Ministry of Science and Technology's Public Service Portal was completed with the file number: 000.00.20.G06-230823-0190.

STUDY ON THE ANALYSIS OF PERSISTENT ORGANIC POLLUTANTS (POPs) IN SEDIMENT SAMPLES BY ECD-GAS CHROMATOGRAPHY

Nguyen Thi Hang[1], Nguyen Nho Lan[1], Ngo Thi Thu Thuy[2], Luu Thi Thu Hoa[3], Nguyen Thi Kim Dung[3]

[1]Institute for Technology of Radioactive and Rare Elements, 48 Lang Ha, Dong Da, Ha Noi
[2]Hanoi Irradiation Center, Km12 – Str.32, Minh Khai, Bac Tu Liem, Ha Noi
[3]Nuclear Training Center, 140 - Nguyen Tuan, Thanh Xuan, Ha Noi

Project information:

- **Project name**: **Study on the analysis of Persistent Organic Pollutants (POPs) in sediment samples by ECD-gas chromatography**
- **Code**: **CS/23/03-04**
- **Managerial Level**: **Institute**
- **Duration**: **12 months (Jan 2023 – Dec 2023)**
- **Contact email**: **nguyenhanghhk32@gmail.com**
- **Published papers related to the project**:

1. Nguyen Thi Hang, Nguyen Nho Lan, Ngo Thi Thu Thuy, Luu Thi Thu Hoa,Nguyen Thi Kim Dung "Determination of PCBs in marine sediment samples using GC-ECD method", *Journal of Analytical Sciences*, Vol.28, No.03, 2023 (in Vietnamese).

2. Nguyen Thi Hang, Nguyen Nho Lan, Ngo Thi Thu Thuy, Luu Thi Thu Hoa,Nguyen Thi Kim Dung "Study on the optimization of ECD-GC parameters to identify some persistent organic pollutants (POPs) in marine sediments", Abstracts of the 15th Vietnam Conference on Nuclear Science and Technology (VINANST 15), Nha Trang, Vietnam, 2023.

Persistent organic pollutants (POPs) have been regulated by the Stockholm Convention for safe management, emission reduction and destruction since 2004, which were divided into 3 groups: Group A includes 19 families of substances that must be eliminated in production and use: 14 pesticides and 5 industrial chemicals (including PCBs (polychlorinated biphenyl)); Group B includes 2 substances that need to be limited in production and use, including pesticides such as DDT (1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane) and its derivatives, and the industrial chemicals such as PFOS (perfluorooctane sulfonic acid) and its salts, and PFOS-F (perfluorooctane sulfonyl fluoride); Group C includes two unintentionally generated substances PCDF (polychlorinated debenzo-p-dioxins and HBCD/HBCDD (hexabromocyclododecance). These chemicals (mostly containing organochlorine derivatives) have been originally used as pesticides, termite repellents. In addition, they have been used in some industries such as wood preservation, paint additives, plastics,..., or unintentionally produced as a byproduct of industrial combustion, wood or plastic waste burning, or released from cigarette smoke, and car exhaust pipes. Due to the sustainability and hydrophobicity, POPs were easily bound to

the particles in lakes and rivers, which then flowed out to the sea. Along with the natural evaporation process, they could enhance their mobility, widespread distribution in the environment, especially on sediment. From sediment, they could be accumulated in benthic species and organisms higher in the food chain. Therefore, accurately determining the content of DDTs and PCBs is very necessary and meaningful to assess the current pollution status of DDTs and PCBs in the environment, leading to a complete ban on their use and replacement with other groups of substances that do not pollute the environment. This study was thus granted to participate in the collaboration between VINATOM and IAEA under a practical agreement in the field of investigation and assessment of inorganic and organic pollutants in marine environment.

In this study, the gas chromatography with ECD detector (GC-ECD) was used to analyze POPs in some marine sediment samples collected from the coastal area of Soc Trang Province.

The GC-ECD equipment (8890, Agilent) with a HP-5 capillary column (30m × 0,25mm × 0,25µm) and electron capture detector was operated according to the manufacturer's instructions. Technical parameters were optimized for POPs analysis.

The POPs extraction procedure from marine sediment samples (Figure 1) was developed on the basis of literatures and re-examined to optimize extraction conditions such as extraction solvent n-hexane:acetone, extraction duration within 2 hours with mechanical shaking technique combined with ultrasonic support, cleaning POPs with concentrated sulfuric acid, water adsorbence, and removal with Na_2SO_4.

The correlation coefficient (R^2) of the calibration curve in the range between 5 and 100 µg/L POPs concentration, as well as the detection limit (MDL) and quantification limit (MQL) of the method which were evaluated by spiked technique of adding standards to the sample matrix were shown in Table 1. The accuracy of the analytical method was evaluated through the repeatability and recovery efficiency, by analyzing 7 replicates CRM (Congeners in Harbor Sediment) PCB sediment and CRM (Pesticides on soil) samples. The studied results were reported in Table 1 for PCBs and in Table 2 for DDTs.

The chromatograms of DDTs and PCBs in CRMs were depicted in Figure 2 (A and B).

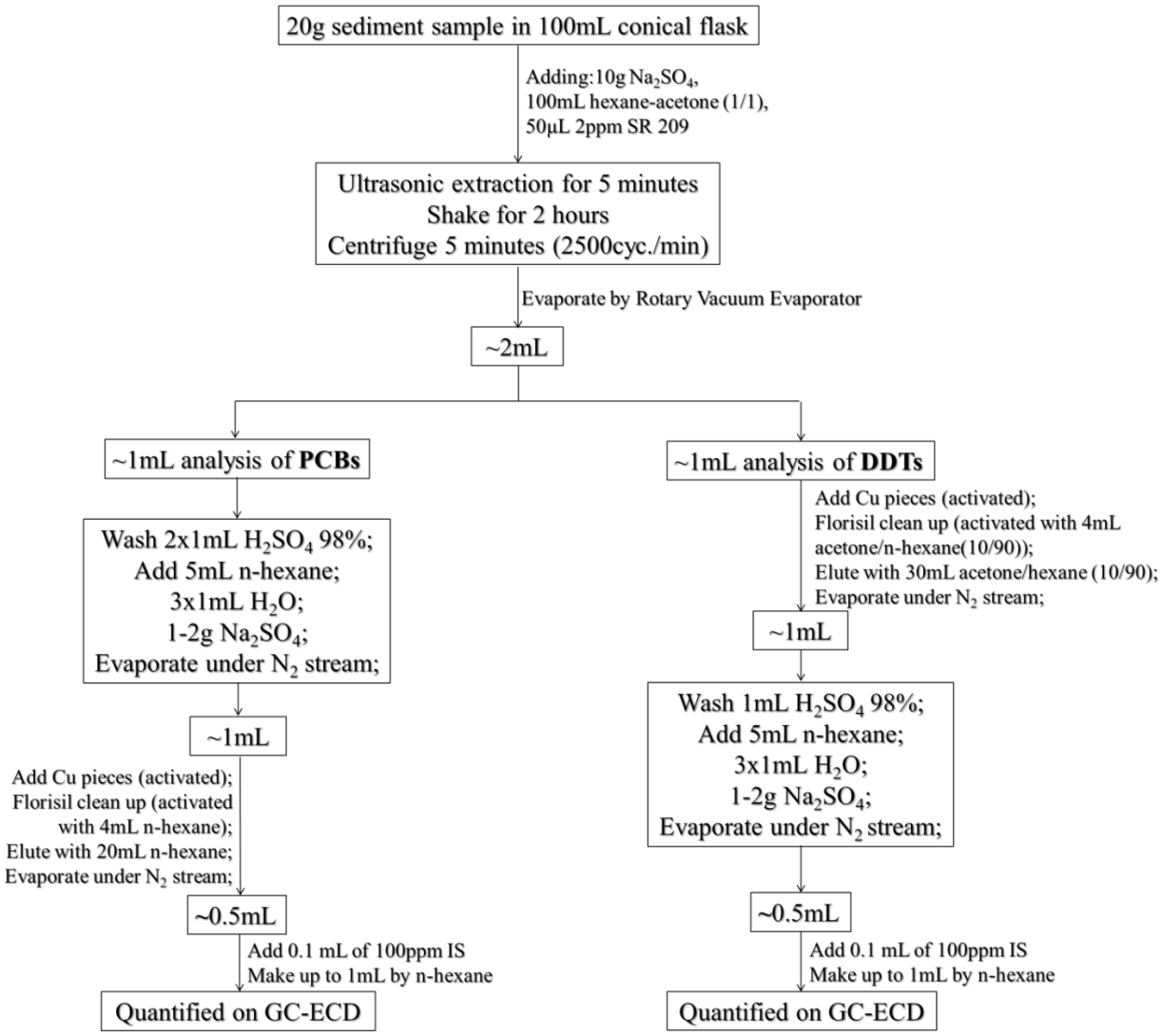

Figure 1. Scheme of treatment, extraction and cleaning of sediment samples

Table 1. Correlation coefficient of calibration curve, MDL, MQL, repeatability, and recovery efficiency of PCBs

Evaluation parameters of POPs analysis method	Value
Correlation coefficient (R^2) of the standard curve	> 0.99
Method detection limit (MDL) for determining PCBs	3.91 µg/kg (calculated based on total PCB congeners)
Method quantification limit (MQL) for determining PCBs	12.92 µg/kg (calculated based on total PCB congeners)
Repeatability (% RSDr) for PCBs	2.7
Recovery efficiency (%)	70 - 120

Table 2. Correlation coefficient of standard curve, MDL, MQL, repeatability, and recovery efficiency of DDTs

Evaluation parameters of POPs analysis method	Value
Correlation coefficient (R^2) of the standard curve	> 0.99
Method detection limit (MDL) for determining DDTs	0.62 µg/kg (calculated based on total DDT congeners)
Method quantification limit (MQL) for determining DDTs	2.04 µg/kg (calculated based on total DDT congeners)
Repeatability (%RSDr) for DDTs	2.6
Recovery efficiency (%)	70 - 120

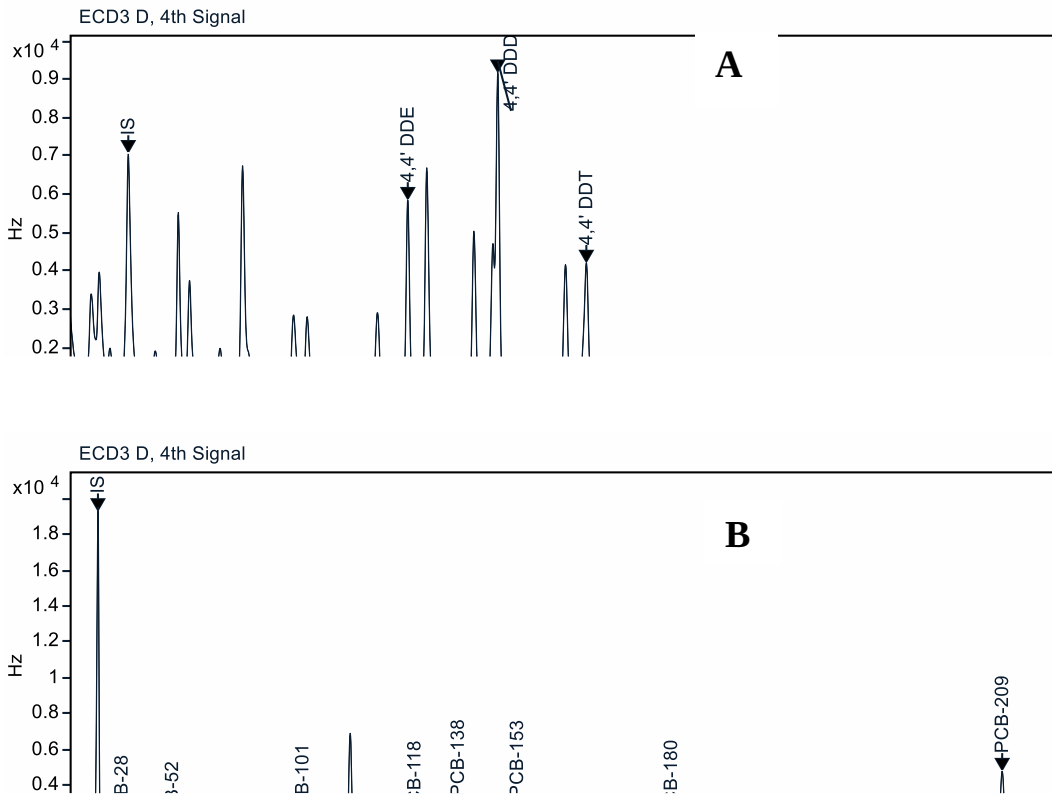

Figure 2. (A): GC/ECD chromatogram of CRM DDTs (Pesticides on soil)
(B):GC/ECD chromatogram of CRM PCBs (Congeners in Harbour Sediment)

Based on the evaluation criteria for the validition of the analytical method was confirmed by AOAC, the obtained results met the requirements and the GC-ECD method was proved completely suitable for analyzing POPs in marine sediment samples.

The result of POPs analysis in some sediment samples (sampling location diagram shown in Fig.3) using the established procedures in this study was given in Table 2.

Figure 3. Diagram of coastal sediment sampling locations in Soc Trang province

Table 2. POPs content in some marine sediment samples collected at coastal area (see Fig.3)

PCBs	PCBs content in marine sediment samples (µg/kg)							
	S3	**S4**	**S7**	**S112**	**S124**	**S139**	**TĐ1**	**TĐ2**
PCBs								
PCB28	KPH	<MQL	0.21±0.03	0.31±0.03	KPH	KPH	<MQL	KPH
PCB52	KPH	<MQL	<MQL	0.21±0.01	KPH	0.20±0.02	<MQL	0.21±0.02
PCB 101	<MQL	<MQL	1.22±0.13	2.11±0.18	KPH	0.23±0.02	1.01±0.03	KPH
PCB 118	<MQL	0.81±0.06	1.31±0.11	2.21±0.21	KPH	<MQL	1.12±0.21	<MQL
PCB138	0.50±0.01	0.41±0.03	1.01±0.12	3.11±0.42	0.21±0.02	0.51±0.04	0.42±0.03	<MQL
PCB153	0.30±0.02	0.52±0.06	1.51±0.11	3.01±0.31	<MQL	0.41±0.05	4.51±0.52	1.21±0.21
PCB180	0.31±0.01	<MQL	0.92±0.13	1.00±0.12	KPH	0.32±0.02	1.13±0.21	1.12±0.11
ΣPCBs	5.55±0.22	8.70±0.75	29.87±2.72	57.22±6.40	0.21±0.02	7.94±0.89	40.95±5.03	12.70±1.75
DDTs								
2,4'-DDE	0.40±0.04	KPH	0.35±0.04	KPH	0.36±0.04	KPH	0.54±0.05	KPH

4,4'-DDE	0.35±0.04	0.49±0.05	0.42±0.05	0.43±0.05	KPH	0.53±0.06	0.61±0.07	0.65±0.06
2,4'-DDD	0.32±0.03	0.52±0.06	0.82±0.07	KPH	KPH	KPH	KPH	KPH
4,4'-DDD	KPH	1.51±0.17	0.64±0.14	KPH	KPH	KPH	0.72±0.08	0.52±0.06
2,4'-DDT	1.60±0.12	2.01±0.23	1.05±0.14	KPH	0.31±0.03	KPH	1.21±0.15	KPH
4,4'-DDT	0.39±0.04	0.37±0.04	0.55±0.05	0.35±0.04	0.45±0.05	0.37±0.04	1.53±0.16	KPH
ΣDDTs	3.06±0.27	4.90±0.55	3.83±0.35	0.78±0.08	1.12±0.11	0.91±0.08	4.61±0.40	1.17±0.11

Despite POPs toxins found in surface sediments of the coastal area at Dinh An estuary in Soc Trang province, the total content of POP groups was still within the allowable limits of National Technical regulation on sediment quality QCVN 43:2017/BTNMT in which the total PCB content was documented as 189 µg/kg, and the DDD, DDE, DDT contents were of 7.8 µg/kg, 374.0 µg/kg and 4.8 µg/kg, respectively.

The procedure for POPs analysis in marine sediment samples by gas chromatography with electron capture detector, with the limit of determining some POPs below 0.1 ng/g of sediment was reported as “type II” product of this project. The next study in the near future with other locations in the survey area will be carried out under the marine research cooperation program between VINATOM and IAEA.

STUDY ON ESTABLISHING AN ANALYTICAL PROCEDURE OF METHYL MERCURY IN MARINE SEDIMENT SAMPLES BY USING A MODERN METHOD

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Institute for Technology of Radioactive and Rare Elements, 48 Lang Ha, Dong Da, Ha Noi

Project information:

- **Project name: Study on establishing an analytical procedure of methyl mercury in marine sediment samples by using a modern method**
- **Code: CS/22/10-03**
- **Managerial Level: Institute**
- **Implementation time: 18 months (Jan. 2022- Jun. 2023)**
- **Contact email: nguyenthuyhang0811@gmail.com**
- **Published papers related to the project:**

1. Nguyen Tien Dat, Phan Quang Trung, Nguyen Thi Hong Tham, Dang Trung Tin, Nguyen Thi Hang, Nguyen Nho Lan, Nguyen Thuy Hang, Nguyen Thi Kim Dung "Determination of methyl mercury in marine sediment samples using GC-MS method", *Journal of Analytical Sciences,* **Vol. 29** No.2, pp.19-25, 2023, *ISSN-0868-3224 (*in Vietnamese);

2. Nguyen Thi Hang, Nguyen Thuy Hang, Thai Thi Thu Thuy, Nguyen Nho Lan, Nguyen Thi Kim Dung "Study on establishing an analytical procedure of methyl mercury in sediment", Proceeding of the 7th Conference on Nuclear Science and Technology for young scientists of VINATOM, Hanoi, Vietnam, Oct. 6-7, 2022, Agenda and Abstracts, page 30 ;

Mercury (Hg) and its compounds are considered as the health hazards, but their toxicity mainly depends on the existing chemical form: the organomercury form such as methylmercury or dialkylmercury, which is more toxic than its inorganic compounds. The common organomercury compounds in the environment include methylmercury (CH_3Hg^+), ethylmercury ($C_2H_5Hg^+$), phenylmercury ($C_6H_5Hg^+$) and dimethylmercury ($(CH_3)_2Hg$). Methylmercury (MeHg) or monomethyl mercury (MMHg) is formed by the natural processes. In the environment, mercury ions (Hg^{2+}) are methylated mainly by microbial activities and the smaller part through abiotic pathways. The environment, where MeHg is produced consists of sediment, wetlands and coastal marshes, as well as the anoxic environment of lakes and habitat of anaerobic micro-organisms such as the rhizosphere of floating macrophytes. MeHg becomes a dangerous contaminant due to its huge bioaccumulation potential. The accumulation of MMHg concentration in piscivorous fishes from below ng/L in seawater to more than 1,000,000 ng/kg has drawn major interests from a human health standpoint. Mercury in water and sediment are primarily bound to humic substances. After methylation, MeHg typically does not accumulate in sediments to more than 1.5% of the

totally contained mercury. Methylation-demethylation reactions are considered widespread in the environment and subsequently each ecosystem achieves its own steady state for mercury forms.

The analytical methods for MeHg include gas chromatography (GC) are coupled to one of the following detectors: ECD, MS, CVAFS, ICP-MS, and liquid chromatography LC (or HPLC) are coupled to AAS, or ICP-MS. In order to determine MeHg by GC, it is necessary to separate it from the sample matrix. Gas chromatography-mass spectrometry (GC-MS) has been studied to quantify MeHg in marine fish, seawater and industrial wastewater after making phenylation of the derivative, followed by its extraction into a toluene/water two-phase system, or using an absorbed column or employing a solid-phase micro-extraction (SPME) system to concentrate it. MeHg extraction from the samples matrix of biology or lake sediment or CRMs was studied by many authors using acid (HCl, H_2SO_4, HBr, HI) or alkaline (NaOH, KOH) agents. The results from their publications showed that MeHg recovery efficiency reached higher values when alkaline was applied.

In this study, the modern method selected for the analysis of MeHg in some marine sediment samples collected from the coastal area of Soc Trang province is GC-MS.

GC-MS instrument (QP2010 plus, Shimadzu, Japan) with capillary column and Negative Chemical Ionization (NCI) source was operated according to the manufacturer's instructions. The parameters of this instrument were optimized for methylmercury analysis under the operating conditions.

The procedure of MeHg extraction from marine sediment samples (Fig.1) was developed on the basis of literatures, and further investigated to optimize the extraction conditions such as using 25% KOH in ethanol, mixing time within 30 to 45 minutes (in ultrasonic bath at about 40°C), and cleaning MeHg by stripping with 1% L-Cysteine solution at pH6, which resulted in CH_3Hg recovery efficiency over 95%.

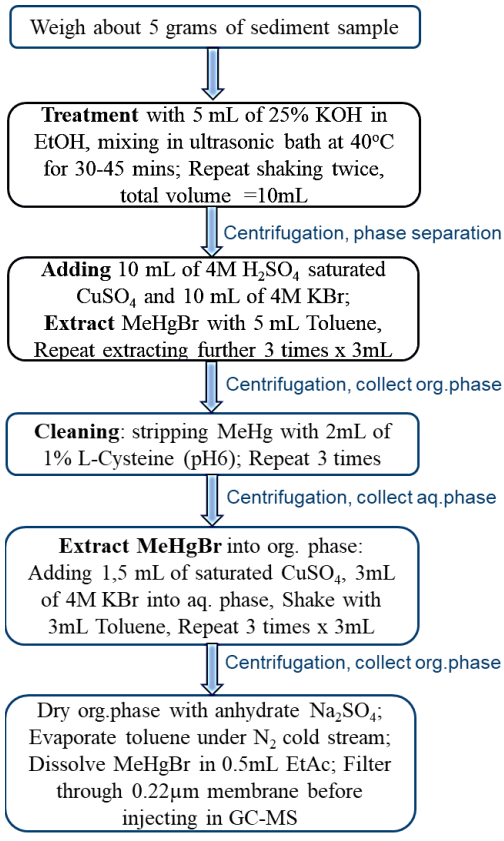


Figure 1. Flow chart of treatment, extraction and cleaning of sediment samples

The results of determining the correlation coefficient (R^2) of the standard calibration curve in the range of 0.2 to 2.8 ng CH_3HgBr, as well as the detection limit (MDL) and quantification limit (MQL) of the method were validated by using a spike technique and adding standards to the sediment sample matrix, which are shown in Table 1. The accuracy of analytical method was evaluated through the repeatability, reproducibility and

recovery efficiency, by the analysis of seven replicates of CRM IAEA-433 sediment sample (the spectra of sample given in Fig. 2), and the results are also reported in Table 1.

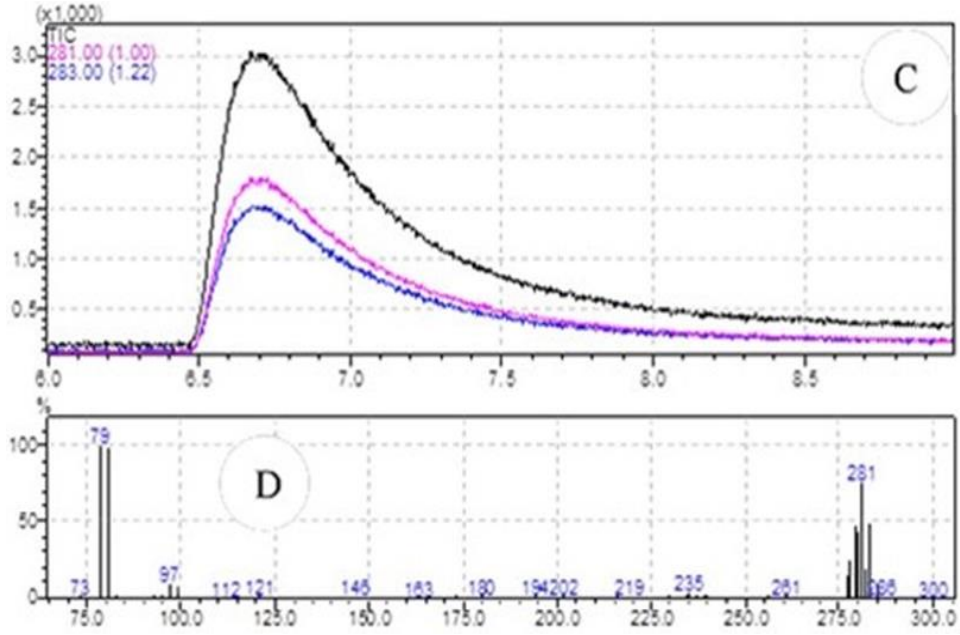


Figure 2. SIM (C) and Mass (D) Spectra of CRM IAEA 433 sample

Table 1. The correlation coefficient (R^2) of external calibration, method detection limit (MDL), method quantification limit (MQL), repeatability, reproducibility and recovery efficiency

Validated parameter of the analytical method for methyl mercury	The obtained value
- Correlation coefficient (R^2) of external calibration	> 0.99
- Method Detection Limit (MDL)	0.01 mg/kg (as Hg)
- Method Quantification Limit (MQL)	0.05 mg/kg (as Hg)
- Repeatability (% RSD_r)	3.79
- Reproducibility (% RSD_R)	4.13
- Recovery efficiency (%)	92 - 103

Based on the evaluation criteria of the analytical method validation published by the AOAC organization, the obtained results meet the requirements and the GC-MS method is completely adequate for the analysis of methyl mercury in the marine sediment sample.

The results of MeHg analysis in some sediment samples, which followed the studied procedure, are shown in Table 2.

Although there was the presence of methylmercury toxin in the surface sediments of the coastal zone at Dinh An estuary in Soc Trang province, where the mangrove is located, the total mercury content in general and the methylmercury content in particular still remained under the permitted limits according to Vietnam technical Regulation QCVN 43:2017/BTNMT on sediment quality as 0.7 mg/kg (total mercury) for saltwater and brackish water sediments.

Table 2. MeHg content in some marine sediment samples collected at coastal zone in Soc Trang province

Sample code	MeHg content calculated as Hg (µg/kg)	Total Hg content (µg/kg)
S3	24.3 ± 2.4	69.0 ± 5.8
S4	44.8 ± 3.9	240 ± 16.8
S7	25.9 ± 2.5	62.8 ± 5.4
S112	35.3 ± 3.0	170 ± 12.6
S124	28.9 ± 2.6	84.3 ± 6.9
S139	26.1 ± 2.5	63.1 ± 5.4

The product of this project is the procedure of analyzing methylmercury in marine sediment samples by using gas chromatography-mass spectrometry, with a determination limit of 0.01 mg/kg (calculated as Hg). The obtained study results are likely to form the basis for the next project with a broader investigation and assessment scale, in which the issue of technical cooperation with the IAEA may be included in the implementation criteria.

3- PHOTO ALBUM

A Wrap-up of VINATOM significant events in 2023

3.1. NUCLEAR TRAINING CENTER

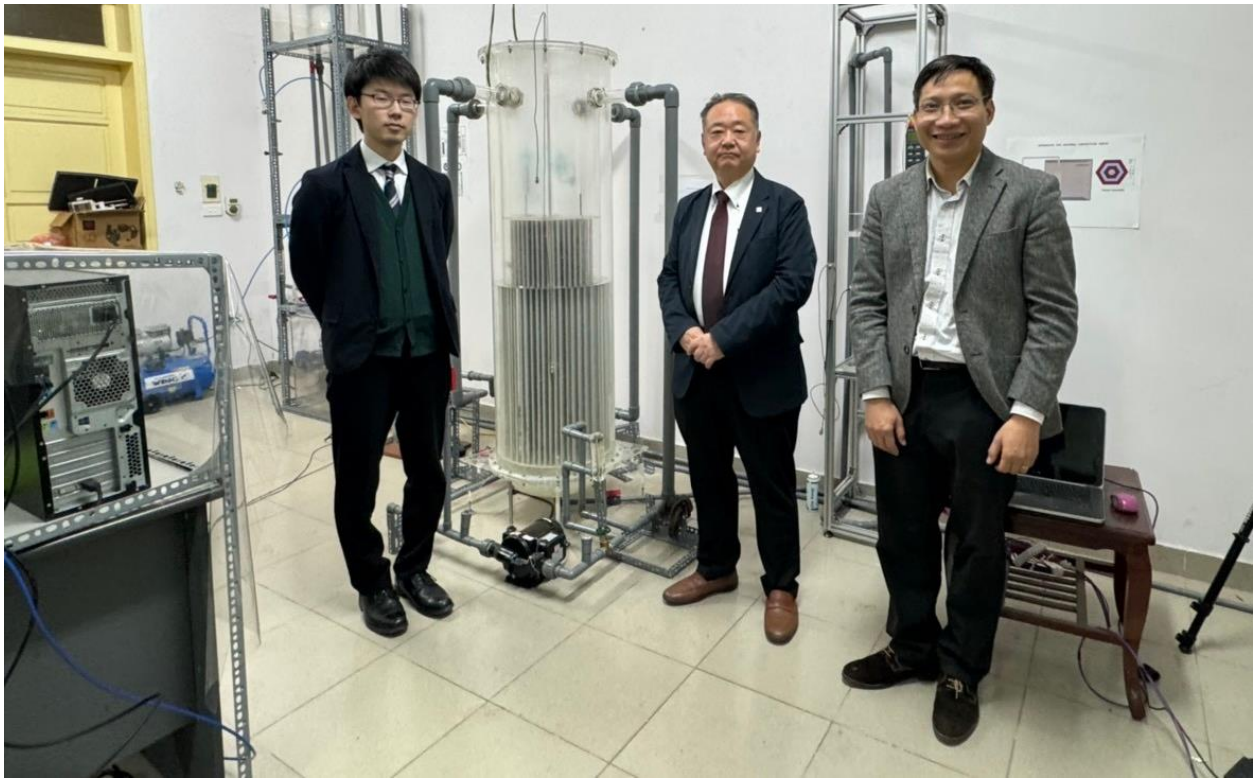
President of VINATOM awarded the PhD Degree to students

PhD candidate, Phonesavanh Lathdavong (Laos), successful defenseed his Dissertation

PhD candidate, Nguyen Kien Cuong, has successful defense his Dissertation

PhD candidate, Cao Van Hiep, has successful defense his Dissertation

Ceremony of Gratitude to Teachers and Awarding of Doctoral Degrees



TokyoTech's Delegation led Prof. Kikura visited the Nuclear Safety laboratory at NTC

The VINATOM's Committee for criteria evaluation of Professor candidate

Seminar for 2nd year PhD Student at VINATOM
Students have reported the research topics at the Seminar.

The 13th Vietnam-Japan Research & HRD Forum on Nuclear Technology.
Scientist and specialist from Vietnam and Japan at FORUM

Collaboration for education and training with universities in nuclear field:
Students visited the research facility at Nuclear Training Center

3.2. RESEARCH AND DEVELOPMENT CENTER FOR RADIATION TECHNOLOGY

Appointment of VINAGAMMA's Deputy Director (Left: Dr. Tran Chi Thanh, President of VINATOM; Right: Newly-appointed Deputy Director of VINAGAMMA)

Scientific visit of Cambodia and Laos officials at VINAGAMMA

VINAGAMMA's researchers attending the 15th Vietnam National Cenference on Nuclear Science and Technology

The closing ceremony and conference of official –labour 2023

The symposium on studying and following President Ho Chi Minh's ideology, morality and style in 2023

Journey to Hung Kings Temple in Thu Duc District, Ho Chi Minh City

3.3. NON-DESTRUCTIVE EVALUATION CENTER

Signing ceremony of cooperation in implementing scientific and technical services between the Centre for Applications of Nuclear Technique in Industry (CANTI) and the Center for Non-Destructive Evaluation (NDE) with Oilfield Services Company (OFS)

The delegation of the Department of Standardization and Metrology (DSM), Laos scientific visit to the Non-Destructive Evaluation Center

Training course on Non-Destructive Testing methods level 1 for Department of Standardization and Metrology (DSM), Laos

Applying the NDT inspection program at Nghi Son 1 thermal power plant under ministry-level projects 2021-2023

Advisory Council for Evaluation and Acceptance of ministry-level projects 2022-2023: "Designing and fabricating a stationary magnetic particle testing system meets the requirements of the American Society for Testing and Materials (ASTM) standards"

A delegation of officials surveyed the current situation at the Da Lat nuclear research reactor under ministry-level projects 2023-2024

NDT training course at Son La Hydropower Company

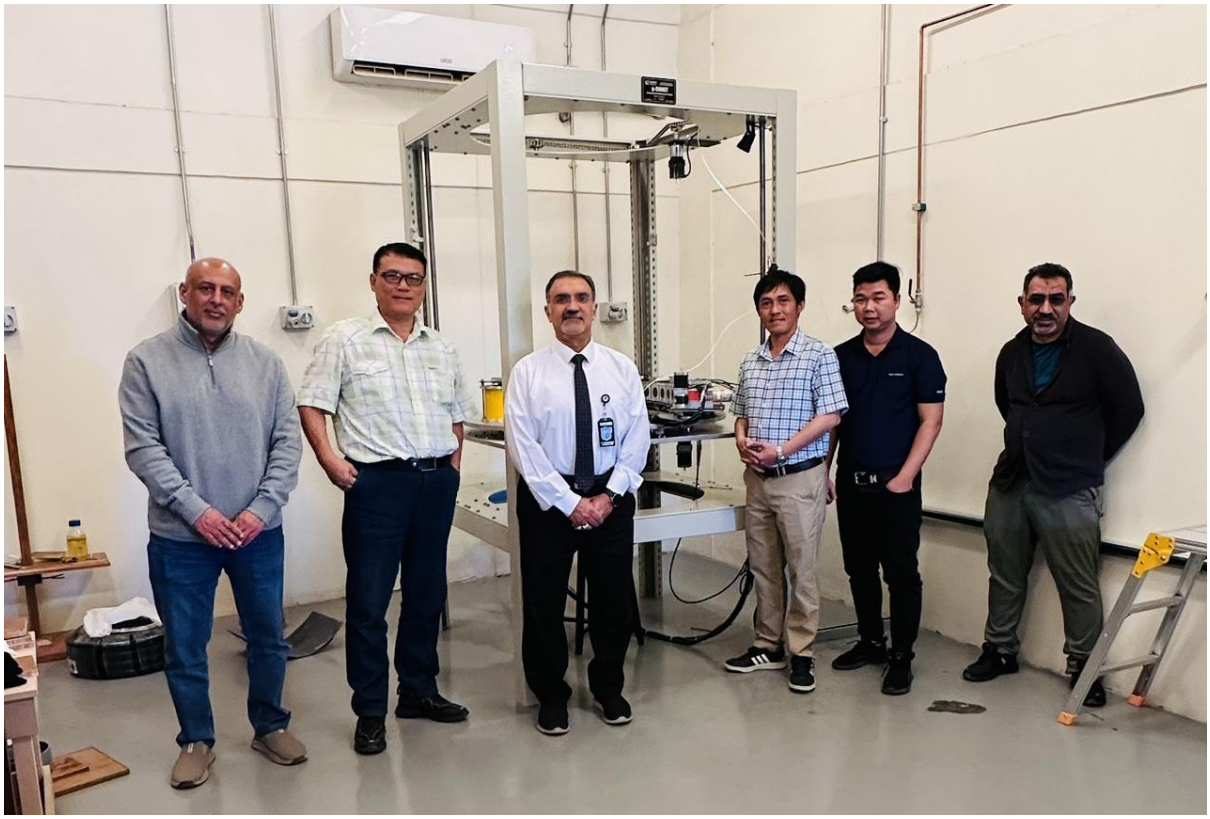
Students of Hanoi University of Science and Technology scientific visit at the Non-Destructive Evaluation Center

Radiation inspection of X-ray equipment in the industry

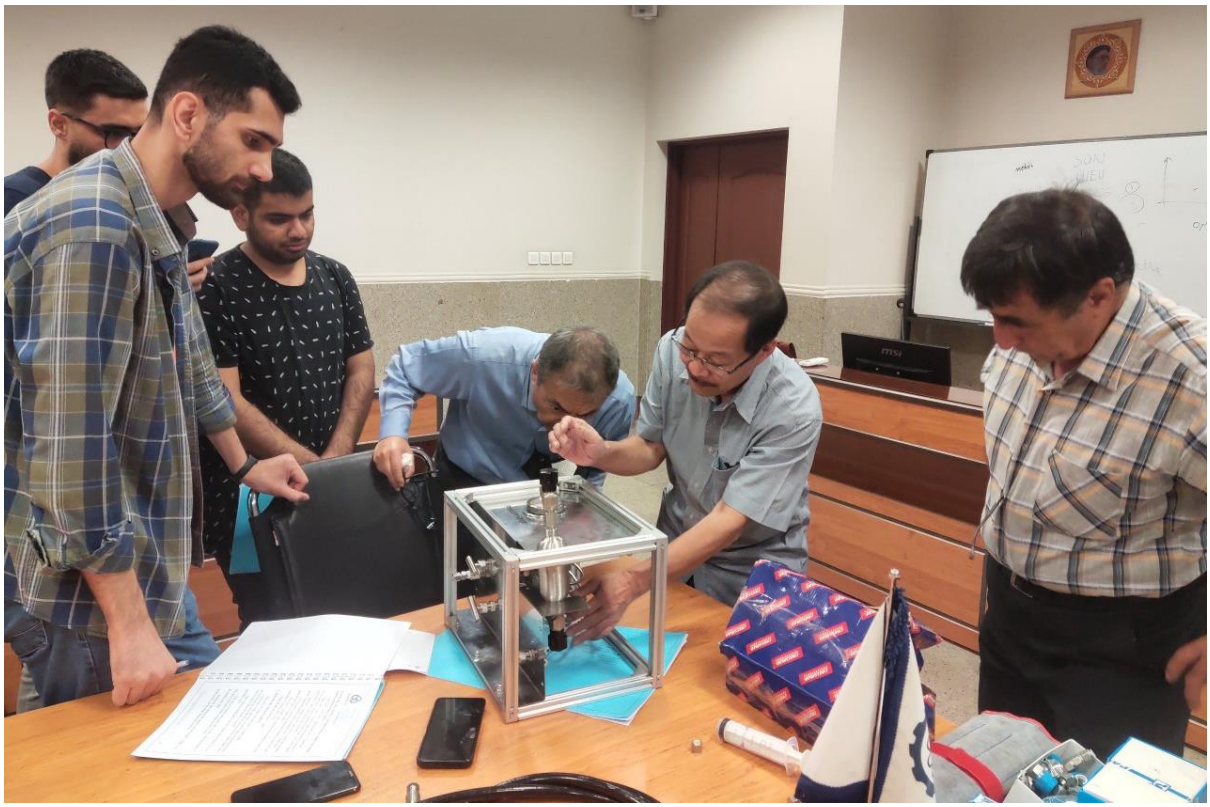
Deployment Non-Destructive Testing (NDT) service

3.4. CENTER FOR APPLICATION OF NUCLEAR TECHNIQUES IN INDUSTRY

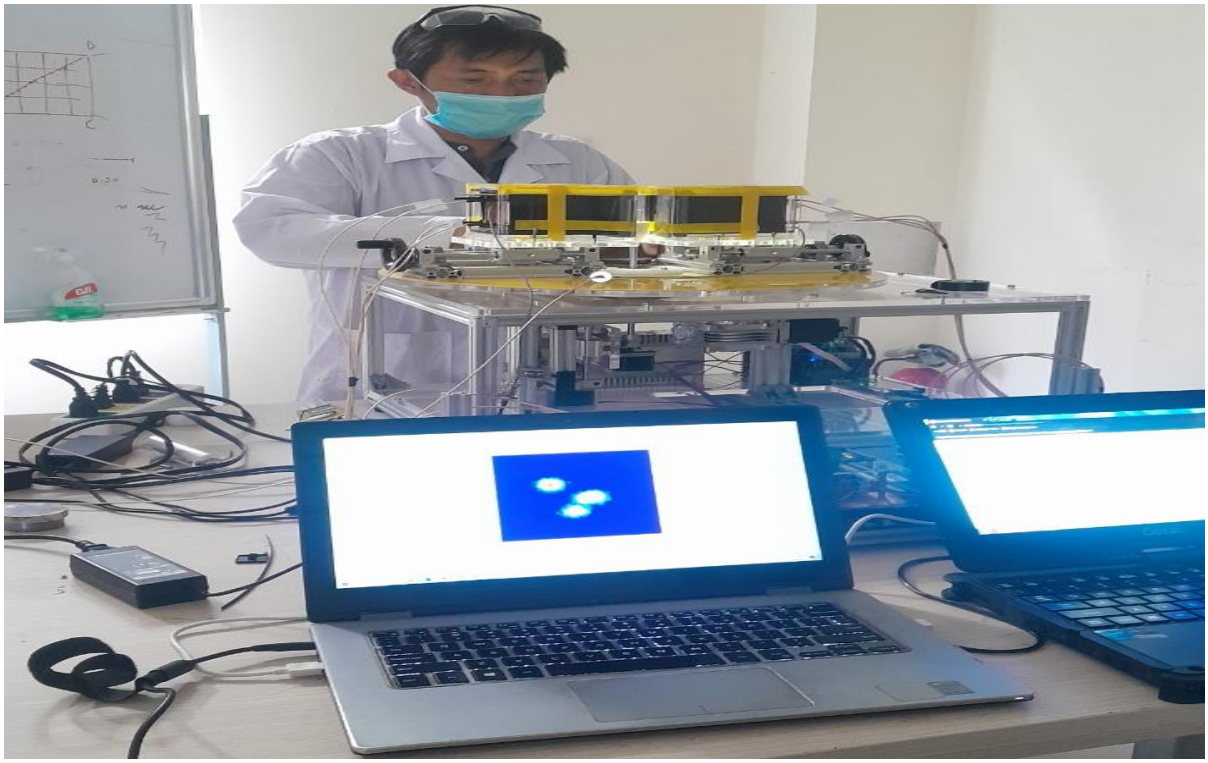
Application of the leak control method for gas-lift wells using the chemical tracer technique in the Bach Ho oil field.



Hand over the third generation industrial CT scanner to Kuwait end- user.



Title: A scientific discussion on the application of the interwell tracer method using gas tracers in oil reservoirs.



The first SPECT for small animals in Vietnam

Implementation of Flooded Member Inspection methodologies at the offshore drilling platform in Vietnam

3.5. INSTITUTE OF NUCLEAR SCIENCE AND TECHNOLOGY

The Institute for Nuclear Science and Technology organised the International Symposium on Physics of Unstable Nuclei 2023 (ISPUN23) in Phu Quoc (May 04-08, 2023).

The INST hosted the Regional Workshop on Requirements for the Safe Transport of Radioactive Material within the framework of the ANSN (2-6 October 2023)

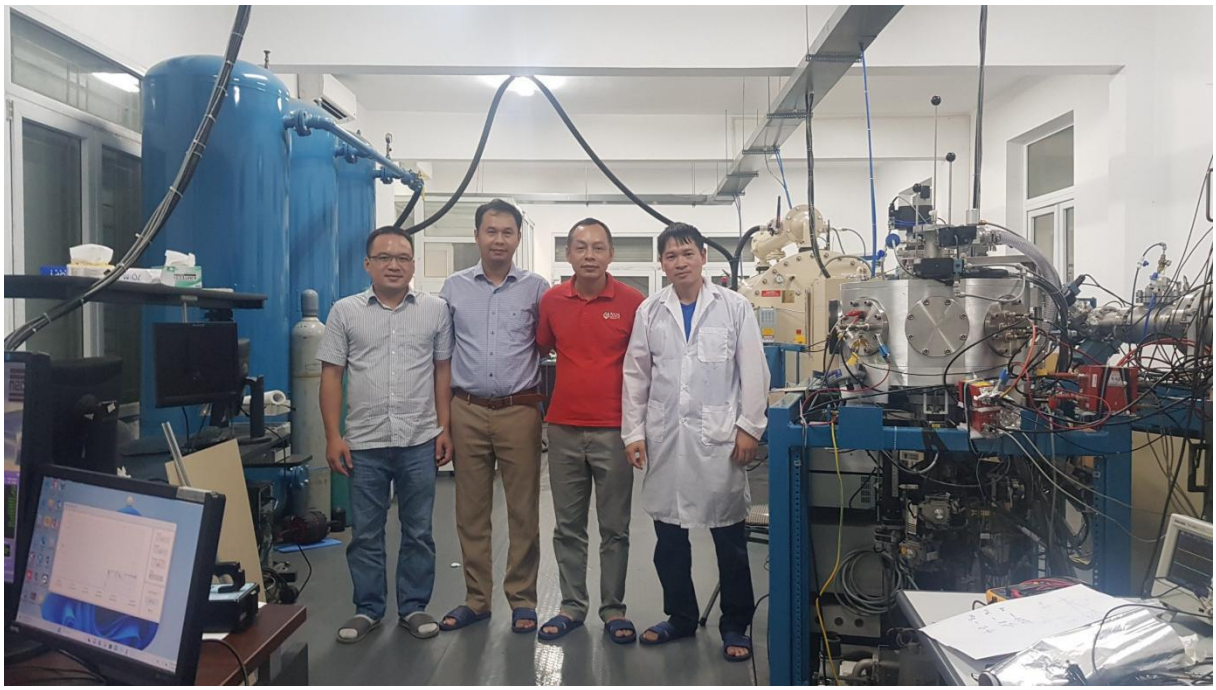
The INST hosted the Workshop on Current Studies on Improving Water Resources Management Using Environment Isotopes Tracers under the IAEA technical cooperation project RAS7040 (20-23 November 2023)

The INST hosted Training Course on Environmental Radioactivity Monitoring (NUTEC)

The INST hosted the Kick-off Meeting of the Project "Sustainable Management and Reuse of Waste Containing Radioactive Residues - Naturally Occurring Radioactive Material (NORM) from Titanium Industry in Vietnam" (18 Sept. 2023)

Maintenance of air sampling system at the Mong Cai radiation monitoring station

Sampling water sample and measuring dose rate at Son La radiation monitoring station

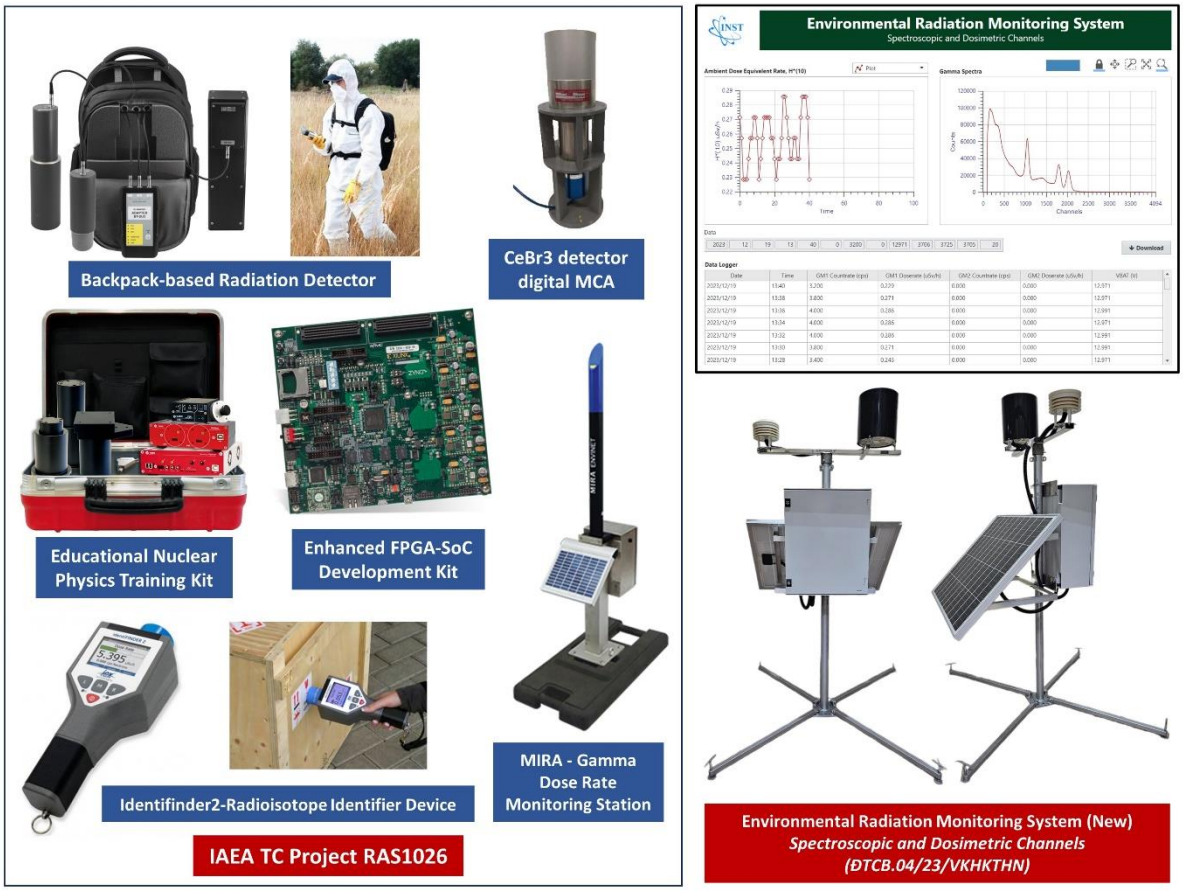


VINATOM and VNU-HUS research team, and the experimental setup at the Pelletron Accelerator Laboratory, Hanoi University of Science.

IAEA experts visit the laboratory: Project information: Monitoring the Marine Environment for Enhanced Understanding of the Abundance and Impact of Marine Plastic Pollution RAS 7038.

Field sampling for microplastic monitoring: Project information: Research to develop a method for separation and identification of microplastic in the coastal environment using nuclear techniques and related techniques (ĐTCB.01/23/VKHKTHN)

Dr. Pham Nhu Viet Ha at the International Symposium on the Development of Floating Nuclear Power Plants- Benefits and Challenges, Vienna, Austria, 11st Nov, 2023



Equipment provided by the IAEA under the IAEA TC Project RAS1026 and equipment designed and fabricated by the INST under the Project coded ĐTCB.04/23/VKHKTHN7.

3.6. INSTITUTE FOR TECHNOLOGY OF RADIOACTIVE AND RARE ELEMENTS

Signing ceremony of cooperation agreement between Institute for Technology of Radioactive and Rare Elements (ITRRE) - Korea Institute of Geoscience and Mineral Resources (KIGAM)

Working with POSCO INTERNATIONAL VIETNAM CO., LTD. (POSCO)

Workshop on Rare Earth Research and Development in Vietnam: Prospects for cooperation

Working with President of Korea Institute of Geoscience and Mineral Resources (KIGAM)

The ITRRE survey team worked at Ho Chi Minh City Oncology Hospital

The survey team worked at Toan Phat Company

ITRRE researchers participated in the Vietnam Rare Earth Science Conference: Current status of mining, processing technology and prospects

ITRRE researchers participated in a workshop on Uranium in Argentina

An ITRRE researcher joined International Workshop On Enhanced Management Of NORM Activities, Particilarly NORM residue, Indonesia

An ITRRE researcher joined 2023 FNCA Workshop, Malaysia

Technical Support For Radiation And Nuclear Incident Response

Regional Workshop On Requirements For The Safe Transport Of Radioactive Waste

Launch Workshop For The Project "Sustainable Management And Reuse Of Naturally Occurring Radioactive Materials (NORM) Residue Waste From The Titanium Industry In Vietnam

Conference On Disseminating Knowledge And Laws Regarding Counter-Terrorism In The Field Of Science And Technology

Operating separatedly RE extraction systems at Phung campus

Temporary radioactive waste storage at Phung campus

3.7. NUCLEAR RESEARCH INSTITUTE

The DNRI working with the IAEA's expert Delegation (INVAP Company) under TC Project VIE1010

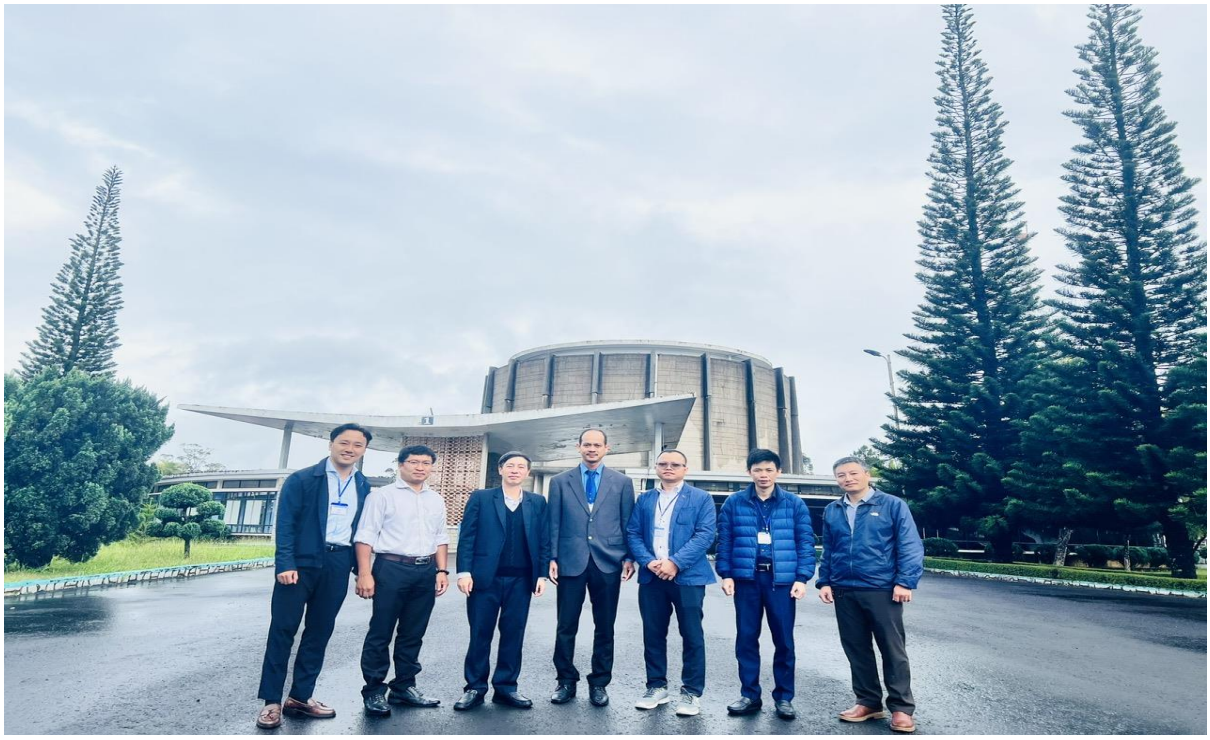
MOU signing ceremony on research cooperation in the field of nuclear physics with the High Energy Physics Center, Kyungpook National University, Korea at DNRI

Group photo on the occasion of the visit of the Russian Ambassador to Vietnam to Dalat Nuclear Research Institute

The DNRI coordinated with the US National Nuclear Security Administration (NNSA) to organize the workshop on the Site Security Plan Development

The DNRI coordinated with the IAEA to organize the Regional Training Course under the project RAS/5/091

The DNRI coordinated with the JAEA to organize the Follow-up Training Course on Reactor Engineering



Scientific visit of the Cambodian Ministry of Mines and Energy'officials at DNRI

DNRI/JAEA Follow-up Training Course on Nuclear and Radiological Emergency Prepareness

Dr. Tran Chi Thanh, the President of Vinatom gave an award to Dr. Pham Thanh Minh, Director of the Center for Research and Production of Radioisotopes, who is the author of a patent in 2023

3.8. CENTER FOR NUCLEAR TECHNIQUES

CNT and Nguyen Tat Thanh University signed a cooperation agreement on three main activities including: undergraduate training, postgraduate training and scientific research cooperation.

Dr. Tran Chi Thanh, VINATOM's President handed over the Decision to appoint Deputy Director of CNT and gave flowers to congratulate Ms. Tran Thi Bich Lien.

3.9. HANOI IRRADIATION CENTER

ME-RAS/5087-2023 Final Project Review Meeting by HIC

3.10. HEADQUARTERS

Deputy Prime Minister of the Russian Federation visited VINATOM

Signing ceremony of MoU between VINATOM and Janus Capital

Signing ceremony of contract package: Development of Feasibility study report and Dossier for site approval, Project of Center for nuclear science and technology

Signing ceremony of contract package: Development of Feasibility study report and Dossier for site approval, Project of Center for nuclear science and technology

Vietnam Conference on Nuclear Science and Technology by VINATOM, held in Nha Trang, Khanh Hoa province, Vietnam

Participants in Vietnam Conference on Nuclear Science and Technology by VINATOM, held in Nha Trang, Khanh Hoa province, Vietnam

4- APPENDICES

4.1. LIST OF VINATOM'S INTERNATIONAL SCIENTIFIC PUBLICATIONS IN 2023

No	Name of publications	Authors	Journals
1	Level structures of ^{56,58}Ca cast doubt on a doubly magic ^{60}Ca	S Chen,…, L.X. Chung et al.	Physics Letters B Volume 843, 10 August 2023, 138025 Online ISSN: 1873-2445 Linking ISSN: 0370-2693
2	Extended $p_{3/2}$ Neutron Orbital and The N=32 Shell Closure in ^{52}Ca	M Enciu,…, L.X. Chung et al.	Physical Review Letters Print ISSN: 0031-9007 Online ISSN: 1079-7114
3	Southwestern boundary of the island of inversion: First study of low-lying bound excited states in ^{59}V and ^{61}V	Z Elekes,…, L.X. Chung et al.	Physical Review C Online ISSN: 1089-490X Print ISSN: 0556-2813
4	Measurement of neutron capture cross sections for the ^{174}Yb(n,γ)^{175}Yb reaction at thermal and epithermal energies	Nguyen Thi Hien, Nguyen Van Do,Guinyun Kim, Haladhara Naik, Pham Duc Khue.	Radiation Physics and Chemistry Volume 205, April 2023, 110738 Print ISSN: 0969-806X Online ISSN: 1879-0895
5	Application of data assimilation in searching better lattice-physics parameters of fuel assembly	Nguyen Huu Tiep, Kyung-Doo Kim, Hae-Yong Jeong, Nguyen Ngoc Anh, and Nguyen Xuan Mung.	Nuclear Engineering and Design Volume 411, September 2023, 112415 Print ISSN: 0029-5493 Online ISSN: 1872-759X
6	Stable isotope signatures of deuterium, oxygen 18, and carbon 13 (δ^2H, δ^{18}O, δ^{13}C) in imported apples available in the markets of Vietnam	Ha Lan Anh, Dang Duc Nhan, Tran Minh Quynh.	Food Chemistry: X Volume 17, 30 March 2023, 100576 Online ISSN: 2590-1575
7	Trace element characterization and source identification of particulate matter of different sizes in Hanoi, Vietnam	Quang Tran Vuong, Vuong Thu Bac, Phan Quang Thang, Min-Kyu Park, Sung-Deuk Choi.	Urban Climate Volume 48, March 2023, 101408 Online ISSN: 2212-0955
8	A multi-detector comparison to determine convergence of measured relative output factors for small field dosimetry	Do Duc Chi, Tran Ngoc Toan, Robin Hill.	Physical and Engineering Sciences in Medicine (2023) Electronic ISSN: 2662-4737 Print ISSN: 2662-4729
9	Natural cellulose fiber-derived	Hoang Giang Nguyen,	Langmuir 2023

	photothermal aerogel for efficient and sustainable solar desalination	Thi An Hang Nguyen, Danh Bich Do, Xuan Nui Pham, Tuan Hong Nguyen, Ha Lien Thi Nghiem, Minh Viet Nguyen, and Tien Thanh Pham.	Print Edition ISSN: 0743-7463 Web Edition ISSN: 1520-5827
10	Stream analysis for a sub-catchment of Red River (Vietnam) using isotopic technique and recursive digital filter method	Vo Thi Anh, Ha Lan Anh, Mai Dinh Kien, Vu Hoai, Dang Duc Nhan, U. Saravana Kumar.	Journal of Hydro-environment Research Volume 52, January 2024, Pages 1-16 Online ISSN: 1876-4444 Print ISSN: 1570-6443
11	Temporal trends of sediment accumulation in the Xuan Thuy Natural Wetland Reserve (Ba Lat coastal area of the Red River, Vietnam) and implications for future coastal wetland development	Bui Dac Dung, Duong Duc Thang, Doan Thuy Hau, Nguyen Huyen Trang, Le Dinh Cuong, Nguyen Van Khanh, Duong Van Thang, Pham Tuan Nam, Vuong Thu Bac, Nguyen Thi Thu Ha	Wetlands Ecology and Management Volume 31, Pages 419–433 (2023) Print ISSN: 0923-4861 Electronic ISSN: 1572-9834
12	Radiological Hazard Assessment of High-Level Natural Radionuclides in Surface Sediments Along Red River, Vietnam	Van-Hao Duong, Duc-Thang Duong, Loat Van Bui, Thanh Tien Kim, Hue Minh Bui, Trong Dinh Tran, Trinh Trong Phan & Thanh-Duong Nguyen.	Archives of Environmental Contamination and Toxicology Volume 85, Pages 302–313 (2023) Print ISSN: 0090-4341 Electronic ISSN: 1432-0703
13	Adsorption behavior of cationic surfactant onto aluminum hydroxide nanoparticles and application in lindane removal	Thi Hang Nguyen, Thi Thuy Linh Nguyen, Truong Chinh Nguyen, Thuy Hau Doan, Quang Huong Le, Quang Minh Bui, Thanh Son Le, Tien Duc Pham.	Materials Today Communications Volume 34, March 2023, 105266 Online ISSN: 2352-4928
14	Distribution and characteristics of 137Cs in surface soil in the middle of Laos	The-Nghia Nguyen, Van-Loat Bui, Van-Hao Duong, Somsavath Leuangtakoun, Huu-Duc Hoang, Duc-Thang	Journal of Radioanalytical and Nuclear Chemistry Volume 332, Pages 3661-3673 (2023) Print ISSN: 0236-5731

		Duong, Ngoc-Thiem Le, Dinh Khai Nguyen, Dinh-Khoa Tran & Hoai-Nam Tran	Electronic ISSN: 1588-2780
15	Experiences from the ARGOS user group nuclear emergency exercise	Blake Orr, Agnieszka Hac-Heimburg , Naeem Ul Hasan Syed, Anna Maria Blixt Buhr, Laura Ribeiro, Lauren Bergman, Robert Ryan, Adam Jaroszek, Geraldine Ow, Bui Dac Dung, Jan Pehrsson.	Journal of Environmental Radioactivity Volume 270, December 2023, 107298 Online ISSN: 1879-1700 Print ISSN: 0265-931X
16	Nano selenium–alginate edible coating extends hydroponic strawberry shelf life and provides selenium fortification as a micro-nutrient	Tran Thu Hong*, Le Xuan Cuong, Tran Thi Ngoc Mai, Nguyen Ngoc Thuy Trang, Pham Bao Ngoc, Duong Vu	Food Bioscience Online ISSN: 2212-4306 Print ISSN: 2212-4292
17	Safety assessment, radioiodination and preclinical evaluation of antinuclear antibody as novel medication for prostate cancer in mouse xenograft model	Thu Minh Chau Nguyen, Lu Duc Chinh Hoang, Nguyen Thi Khanh Giang, Nguyen Thi Ngoc, Quang Chien Nguyen, Nguyen Thanh Binh, Đang Ho Hong Quang, Bui Van Cuong, Pham Thanh Minh, Nguyen Thi Thu*	Scientific Reports ISSN: 2045-2322 (online)
18	Preparation of water-soluble chitosan oligosaccharides by oxidative hydrolysis of chitosan powder with hydrogen peroxide	Nguyen Trong Hoanh Phong, Nghiem Anh Tuan Le, Phuoc Tho Tran, Duy Du Bui*, Quoc Hien Nguyen	Heliyon Volume 9, Issue 9, 2023 ISSN 2405-8440 (online)
19	Thermal neutron capture cross-section and resonance integral measurements of 186W(n,γ)187W reaction using the thermal column neutron source at the Dalat research reactor	Trinh T. Tu Anh, Pham Ngoc Son*, Nguyễn Bich Thuy, Cao Đong Vu	Annals of Nuclear Energy Volume 194, 15 December 2023 Print ISSN: 0306-4549 Online ISSN: 1873-2100
20	Comparison of the radioprotective effects of the	Pham Ngoc Duy, Thi-Huynh-Nga Nguyen, Vu	Journal of Microencapsulation Print ISSN: 0265-2048

	liposomal forms of five natural radioprotectants in alleviating the adverse effects of ionizing irradiation on human lymphocytes and skin cells in radiotherapy	Ngoc Bich Đao, Tran Thi Ngoc Mai, Pham Bao Ngoc, Hoang-Sinh Le, Kim-Hai Vo, Le Xuan Cuong, Le-Bao-Ha Tran, Nguyen Minh Hiep*	Online ISSN: 1464-5246
21	Improved micropropagation efficiency of purple artichoke (CynarascolymusL.) plantlet	Le Van Thuc, Hoang Thanh Tung*, Hoang Dac Khai, Nguyen Thi Nhu Mai, Do Manh Cuong, Vu Quoc Luan, Le The Bien, Hoang Thi Nhu Phuong, Nguyen Ba Nam, Bui Van The Vinh, Duong Tan Nhut*	South African Journal of Botany 160 ISSN: 0254-6299 eISSN: 1727-9321
22	Degradation of Triazole Fungicides by Plant Growth-Promoting Bacteria from Contaminated Agricultural Soil	Luong Thi Tham, Nguyen Thi Hong Tham, Nguyen Tien Đat, Le Van Toan, Thi Hong Trang Pham, Thanh-Tam Ho*, and Ngoc-Loi Nguyen*	Journal of Microbiology and Biotechnology eISSN 1738-8872 pISSN 1017-7825
23	Possibility of nanostructured lipid carriers encapsulating astaxanthin from Haematococcus pluvialis to alleviate skin injury in radiotherapy	Vu Ngoc Bich Đao, Pham Ngoc Duy, Tran Thi Ngoc Mai, Pham Xuan Hai, Dai-Nghiep Ngo*, Nguyen Minh Hiep*	International Journal of Radiation Biology Print ISSN: 0955-3002 Online ISSN: 1362-3095
24	Antifungal activity of essential oil-encapsulated lipid nanoemulsions against Neopestalotiopsis rosae causing leaf spot on strawberry	Tran Thi Ngoc Mai, Vu Ngoc Bich Đao, Nguyen Minh Hiep *	Journal of Plant Diseases and Protection 130 ISSN: 1861-3829 eISSN: 1861-3837
25	A Digital Controller for Reactivity Monitoring and Power Control	Vo Van Tai, Nguyen Van Kien, Le Va Diep, Phan Quoc Minh, Phan La Son, Nguyen Huy Bach, Nguyen Nhi Dien*	Hindawi Science and Technology of Nuclear Installations Volume 2023 ISSN: 1687-6075 eISSN: 1687-6083
26	Assessment of environmental gamma dose in air in Ho Chi	Tran Đinh Khoa*, Le Nhu Sieu, Nguyen Van	Journal of Radioanalytical and Nuclear Chemistry

	Minh city, Vietnam	Phu, Vuong Thi Thu Hang, Nguyen Đinh Tung, Nguyen Van Phuc, Le Thi Minh Tuyen, Nguyen Tong Thanh Hong, Phan Van Toan, Nguyen Thi Thanh Nga, Pham Đang Quyet, Tran Hoai Nam*	ISSN: 0236-5731
27	Baseline micronucleus frequencies and 60Co cytokinesis-block micronucleus assay dose-response curve for biodosimetry in Vietnam	Pham Ngoc Duy*, Tran Thanh Mai, Donovan Anderson, Che Quang Tuan, Pham Ho Thuat Khoa	Radiation Protection Dosimetry ISSN: 0144-8420 eISSN: 1742-3406
28	An Open-Source Software for Calculating 1D Gamma Index in Radiation Therapy	Duong Thanh Tai*, Hiba Omer*, Le Cuong Quoc, Nguyen Xuan Hai, Van Minh Truong, Abdelmoneim Suleiman*, Essam Mattar, Hind Toufig, N. Tamam, David A. Bradley	Journal of King Saud University - Science Volume 35, Issue 10, 2023 ISSN: 1018-3647 eISSN: 2213-686X
29	RENEB Inter-Laboratory Comparison 2021: Inter-Assay Comparison of Eight Dosimetry Assays	Michael Abend*, Pham Ngoc Duy, Tran Thanh Mai	Radiation Research ISSN: 0033-7587
30	RENEB Inter-Laboratory Comparison 2021: The Dicentric Chromosome Assay	D. Endesfelder, U. Oestreicher*, Pham Ngoc Duy, Tran Thanh Mai	Radiation Research ISSN: 0033-7587
31	RENEB Inter-Laboratory Comparison 2021: The Cytokinesis-Block Micronucleus Assay	A Vral*, Pham Ngoc Duy, Tran Thanh Mai	Radiation Research ISSN: 0033-7587
32	First measurement of differential cross sections and photon beam asymmetries for photoproduction of the f0(980) meson decaying into π0π0 at Eγ < 2.4 GeV	N. Muramatsu*, Trần Hải Nam, et al.	Physical Review C Print ISSN: 2469-9985 Online ISSN: 2469-9993
33	Dosimetric and radiobiological	Duong Thanh Tai*,	Frontiers in Oncology

	comparison between conventional and hypofractional breast treatment plans using the Halcyon system	Luong Tien Phat, Nguyen Ngoc Anh*, Huynh Van Tran Sang, Tran Minh Loc, Nguyen Xuan Hai, Peter A. Sandwall, David Bradley and James C. L. Chow	ISSN/eISSN: 2234-943X
34	Assessment of the distribution and ecological risks of heavy metals in coastal sediments in Vietnam's Mong Cai area	Bui Thi Thanh Loan*, Dang Hoai Nhon*, Nguyen Dac Ve, Nguyen Thi Mai Luu, Le Nhu Sieu, Nguyen Thi Huong Lan, et al	Environmental Monitoring and Assessment ISSN: 0167-6369 eISSN: 1573-2959
35	Investigation of prompt γ-ray neutron activation spectrometer at the Dalat research reactor using Geant4 simulation	Chau Thanh Tai*, Tran Thien Thanh, Pham Ngoc Son, Chau Van Tao	Radiation Physics and Chemistry ISSN: 0969-806X
36	A study on the impact of pulse shaping parameters on zero-crossing method performance for neutron/gamma discrimination	P. V. Chuan, L. V. Tung, N. N. Hai, T. H. Duy, N. T. Phuc, Mai Xuan Phong, Nguyen Xuan Hai, N. N. Anh*	IEEE Transactions on Nuclear Science ISSN: 0018-9499 eISSN: 1558-1578
37	Study of proton and deuteron pickup reactions (d,3He), (d,4He) with 8He and 10Be radioactive beams at ACCULINNA-2 fragment separator	Mai Quynh Anh, et al.	Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms Online ISSN: 1872-9584 Print ISSN: 0168-583X
38	Extraction of 99Mo hot atoms made by a neutron capture method from α-MoO3 to water	N. M. Quach*, M. C. Ngo , Y. Yang, Nguyễn Thanh Bình, et al.	Journal of Radioanalytical and Nuclear Chemistry ISSN: 0236-5731

4.2. LISTS OF INTERNATIONAL PROJECTS 2023

4.2.1 - LIST OF VIE PROJECTS 2023
(Implemented by VINATOM)

Code	Project Title	Start Year	Finish Year	Budget (Euro)	Field code	Project Counterpart
VIE1010	Promoting the Reactor Safety Development Programme — Phase III	2020	2023	210,000	Tran Chi Thanh	VINATOM
VIE7006	Assessing Flow Regimes and River Biogeochemistry of Lower Red River in an Integrated Manner Using Isotope Techniques	2020	2023	150,885	Trinh Anh Duc	NTC

4.2.2. LIST OF INT AND NON-RCA PROJECT 2022
(Implemented by VINATOM)

Code	Project Title	Start Year	Finish year	Budget (Euro)	Field code	Project Counterpart
INT9186	Sustaining Cradle-to-Grave Control of Radioactive Sources - Phase II	2020	2024	1,653,718.75	Hoang Nhuan	ITRRE
INT9186	Sustaining Cradle-to-Grave Control of Radioactive Sources - Phase II	2020	2024	1,653,718.75	Tran The Dinh	ITRRE
INT2022	Supporting Capacity Building in Member States for Uranium Production and Safety of Naturally Occurring Radioactive Material Residue Management	2020	2024	400,050.00	Cao Dong Vu	NRI
RAS1026	Strengthening Nuclear Instrumentation Capacity in the Areas of Nuclear Sciences and Applications	2020	2023	620.442,00	Nguyen Duc Tuan	INST
RAS7038	Monitoring the Marine Environment for Enhanced Understanding of the Abundance and Impact of	2022	2025	892.800,00	Ha Lan Anh	INST

	Marine Plastic Pollution					
RAS1027	Improving the Utilization of Nuclear Techniques for Cultural Heritage Characterization, Consolidation, and Preservation	2022	2025	270.900,00	Tran Quang Thien	NRI
RAS1030	Using Radioisotope Techniques and Computational Fluid Dynamics Simulation for Troubleshooting and Optimizing of Industrial Processes	2022	2025	419.250,00	Dang Nguyen The Duy	CANTI
RAS9094	Enhancing Nuclear Emergency Preparedness and Response in the Member States of the Association of Southeast Asian Nations	2022	2025	1,286,670	Pham Quang Huy	NRI

4.2.3 - LIST OF FNCA PROJECTS 2023

(Participated by VINATOM and other Vietnam organizations)

Field	Project Title	Project Coordinator
Research Reactor Utilization Development	Research Reactor Network	**Dr. Pham Thanh Minh** Director, Center for Research and Production of Radioisotope, Nuclear Research Institute (NRI) Vietnam Atomic Energy Institute (VINATOM)
	Neutron Activation Analysis	**Dr. Tran Tuan Anh** Head, Department of Nuclear Technique and Isotope Applications Research Nuclear Research Institute (NRI)) Vietnam Atomic Energy Institute (VINATOM)
Radiation Utilization Development (Agricultural/ Healthcare /Industrial/ Environmental Utilization)	Mutation Breeding	**Dr. Le Duc Thao** Deputy General Director Agricultural Genetics Institute (AGI) Ministry of Agriculture and Rural Development (MARD)
	Radiation Oncology	**Dr. Nguyen Cong Hoang** Head of General Radiation Oncology Department National Cancer Hospital (K Hospital)
	Radiation Processing and Polymer Modification for Agricultural, Environmental and Medical Applications Project	**Dr. Nguyen Ngoc Duy** Head of Research and Development Department, Research and Development Center for Radiation Technology (VINAGAMMA), Vietnam Atomic Energy Institute (VINATOM)
	Radiocarbon-based approach to evaluating the CO_2 emission from forest soils in Asia	**Mr. Phan Quang Trung** Deputy Head, Department of Nuclear Technique and Isotope Applications Research Nuclear Research Institute (NRI) Vietnam Atomic Energy Institute (VINATOM)
	Combating Food Fraud using Nuclear Technology	**Dr. Nguyen Thi Hong Thinh** Head of the Department of Planning and International Cooperation Institute for Nuclear Science and Technology (INST) Vietnam Atomic Energy Institute (VINATOM)

Nuclear Safety Strengthening	Radiation Safety and Radioactive Waste Management	**Mr. Nguyen Thanh Thuy** Deputy Head Radioactive Waste Management Center Institute for Technology of Radioactive and Rare Elements (ITRRE) Vietnam Atomic Energy Institute (VINATOM)
Nuclear Infrastructure Strengthening	Nuclear Security and Safeguard	**Ms. Bui Thi Thuy Anh** Director, International Cooperation Division Vietnam Agency for Radiation and Nuclear Safety (VARANS)

4.2.4 - LIST OF RAS PROJECTS 2023

(Participated by VINATOM and other Vietnam organizations)

Code	Title	Year of approval	Budget (EUR)	Project Type	Project Coordinators
RAS1028	Improving the Quality Management Practices in Radiation Processing Facilities for Better Performance and Applications (RCA)	2022	641,150	RCA	**Dr. Tran Minh Quynh** Hanoi Irradiation Center, VINATOM
RAS1029	Enhancing Regional Capabilities in Advanced Non-Destructive Testing Techniques for Improved Safety and Inspection Performance in Industries (RCA)	2019	660,625	RCA	**Mr. Nguyen The Man** Non-Destructive Evaluation Center, VINATOM
RAS5087	Promoting Food Irradiation by Electron Beam and X Ray Technology to Enhance Food Safety, Security and Trade (RCA)	2020	300,300	RCA	**Dr. Tran Minh Quynh** Hanoi Irradiation Center, VINATOM
RAS5088	Enhancing Crop Productivity and Quality through Mutation by Speed Breeding (RCA)	2021	425,250	RCA	**Dr. Le Duc Thao** Agricultural Genetics Institute

					(AGI)
RAS5091	Assessing and Mitigating Agro-Contaminants to Improve Water Quality and Soil Productivity in Catchments Using Integrated Isotopic Approaches	2022	541,800	RCA	**Ms. Nguyen Thi Hương Lan** Nuclear Research Institute, VINATOM
RAS6096	Empowering Regional Collaboration among Radiotherapy Professionals through Online Clinical Networks (RCA)	2020	201,000	RCA	**Dr. Bui Quang Bieu** Central Military Hospital 108
RAS6097	Enhancing Capacity and Capability for the Production of Cyclotron-Based Radiopharmaceuticals (RCA)	2020	445,200	RCA	**Mr Nguyen Quang Anh** Hanoi Irradiation Center, VINATOM
RAS6098	Standardizing Radiotherapy in Palliative Care (RCA)	2022	416,050	RCA	**Dr. Nguyen Cong Hoang** National Cancer Hospital
RAS6100	Strengthening Clinical Application of Hypofractionated Radiotherapy (RCA)	2022	490,000	RCA	**Dr. Bui Quang Bieu** Central Military Hospital 108
RAS6101	Improving the Quality and Safety of Radiation Medicine through Medical Physicist Education and Training (RCA)	2022	617,000	RCA	**Dr. Tran Ngoc Toan** Vietnam Atomic Energy Institute (VINATOM)
RAS7035	Enhancing Regional Capability for the	2020	404,225	RCA	**Mr. Nguyen Kien Chinh**

	Effective Management of Ground Water Resources Using Isotopic Techniques (RCA)				Center for Nuclear Techniques, VINATOM
RAS7037	Enhancing Wetland Management and Sustainable Conservation Planning (RCA)	2020	390,075	RCA	**Dr. Tran Thi Nhu Trang** Nguyen Tat Thanh University
RAS7040	Improving Water Resources Management Practices by Enhancing the Regional Collaboration in Environmental Isotope Analysis and Applications (RCA)	2022	630,775	RCA	**Dr. Dang Duc Nhan** Institute for Nuclear Science & Technology, VINATOM
RAS9092	Strengthening the Capacity to Respond to Radiological Emergencies of Category II and III Facilities (RCA)	2020	324,450	RCA	**Mr. Pham Hung Thai** Nuclear Research Institute, VINATOM

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