VIETNAM ATOMIC ENERGY INSTITUTE

# 2020 ANNUAL REPORT

Science and Technics Publishing House

VIETNAM ATOMIC ENERGY INSTITUTE

# The ANNUAL REPORT for 2020



**Hanoi, November 2021**

The VINATOM Annual Report for 2020 has been prepared as an account of works carried out at VINATOM for the period 2020. Many results presented in the report have been obtained in collaboration with scientists from national and overseas universities and research institutions.

The ANNUAL REPORT for 2020

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# Preface

Despite the ongoing COVID-19 pandemic, the Annual Report 2020 of Vietnam Atomic Energy Institute is modified, completed and issued. This report aims to summarize the significant activities of the Institute during the period 1 January to 31 December 2020.

The first main part of this publication seeks to provide the status of the Institute and illustrative descriptions of the Institute's activities within the context of unprecedented difficulties in enduring and coping wih severe consequences of the pandemic. Refusing to step back, under the direction of the Board of Management, Vietnam Atomic Energy Institute has flexibly and determinedly made huge efforts to surpass certain obstacles and achieved proud results in terms 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 Economy
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 the Institute's 2020 remarkable events is added into this publication as a vivid description of what we have been through.

The pandemic will pass, but **sustainable values remain**. We sincerely thank those making great contribution and giving concern to the publication. We highly appreciate your continued trust, cooperation and support.

**The Editorial Board**

## CONTENTS

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ANSN | Asian Nuclear Safety Network |
| CANTI | Center for Application of Nuclear Techniques in Industry |
| CNT | Center for Nuclear Technique |
| Dr. | Doctor of philosophy |
| 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 Waste 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 |
| CNST | Research Center for Nuclear Science and Technology |
| R&D | Research and Development |
| SMR | Small modular reactor |
| TC | Technical cooperation |
| VAEA | Vietnam Atomic Energy Agency |
| VINAGAMMA | Research and Development Center for Radiation Technology |
| VINATOM | Vietnam Atomic Energy Institute |
| VND | Viet Nam Dong |

# 1- VINATOM 2020

## 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:

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

HEAD QUARTERS (3 functional units):

- Administration and Personnel
- Department of Planning and R&D Management
- Department of International Cooperation

RESEARCH AND DEVELOPMENT UNITS (9 units):

- Nuclear Research Institute
- Institute for Technology of Radioactive Waste and Rare Elements
- Institute for Nuclear Science and Technology
- Hanoi Irradiation Center
- Center for Nuclear Technique, Ho Chi Minh City
- Research and Development Center for Radiation Technology(*)
- Center for Application of Nuclear Techniques in Industry
- Center for Nondestructive Evaluation
- Nuclear Training Center

(*) 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 2020, VINATOM has 745 officials and contract staff members.

In terms of professional qualifications, there are 95 doctorates (including 02 professors and 08 associate professors), 196 masters, 372 people with bachelor's degrees and 82 people with intermediate and elementary education degrees. In other words, VINATOM has 15 senior researchers and equivalent, 77 principal researchers and equivalent, 523 researchers, engineers and equivalent, 25 technicians and equivalent, and more than 100 employees. This is shown in Figure 1.

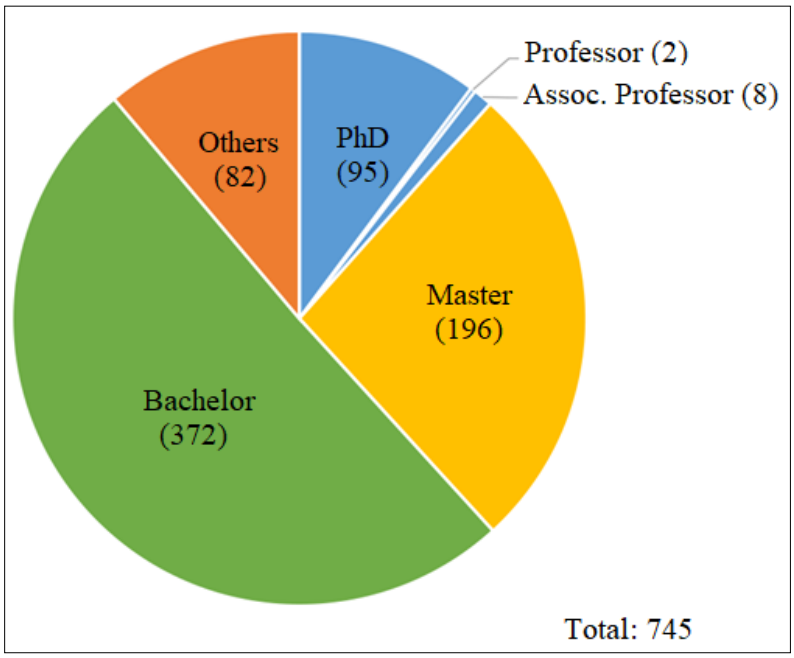


**Figure 1.** Academic levels of VINATOM's staff

### 1.2. INVESTMENT RESOURCES

In 2020, the budget VINATOM was funded by Ministry of Science and Technology was VND 154.803500 billion (excluding expenses of development investment and state-level science and technology projects) to carry out research activities.

### 1.3. HIGHLIGHTS OF RESEARCH, DEVELOPMENT AND APPLICATIONS

In 2020, VINATOM continued strengthening scientific research as well as promoting applications, production and services. In addition, the cooperation between the Institute and the enterprises kept being prioritized. Specifically, some outstanding results of research and service activities are highlighted as follows:

- The number of international publications by VINATOM continued to increase up to 91 (of which 68 articles have been published in ISI international journals with high Impact Factor), which showed an approximately 28% rise compared to that of 2019 (71 international publications, 57 ISI articles), and there were over 3 times as many publications as those of 2016. Figure 2 describes the number of internationally published articles continuously increasing in the period 2016 -2020. Many research works of the Institute's staff were published in prestigious international journals such as Physical Review Letters, Physics Letters B, Physical Review C, Physical Review D, Nuclear Physics A, Nuclear Science and Engineering, Nuclear Engineering and Design, Nuclear Engineering and Technology, Journal of Environmental Management, Polymer, …

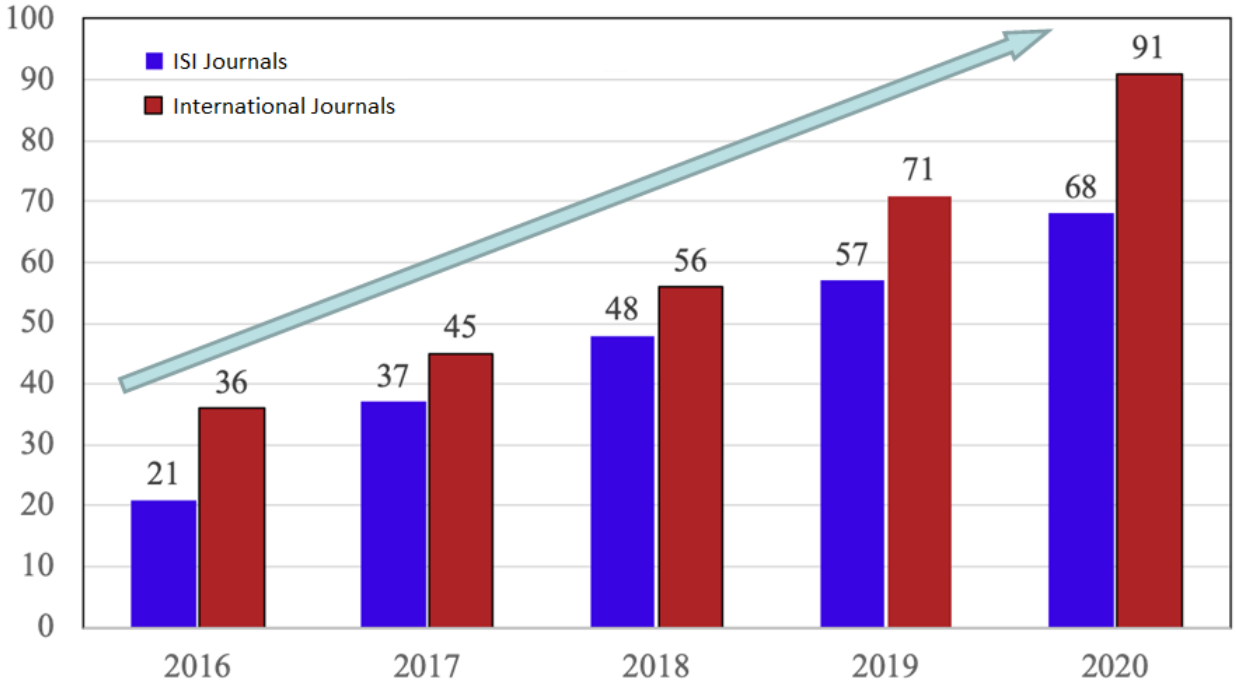


**Figure 2.** Overview of international publications and ISI articles in the last 5 years (2016-2020)

- The VINATOM revenue from service production of 2020 continued to climb compared to that of 2019 (continuously increasing throughout the 2016-2020 period), reaching an estimate of VND 319.86 billion, including the following fields: production of

radiopharmaceuticals, irradiation service, radiation safety service, non-destructive testing and evaluation, analysis service, environmental assessment, training etc. The revenues in different years from 2016 to 2020 are detailed in Figure 3.

- Producing radiopharmaceuticals in 2020 met the entire domestic demand for cancer diagnosis and treatment in the situation of the Covid-19 pandemic and impossibility to import pharmaceuticals from abroad (due to no flights). The Da Lat nuclear reactor in 2020 operated for nearly 4,300 hours, which shows an increase of 48% compared to 2019 (3 times as high as the average number of operation hours in the period 2010-2019) to produce radiopharmaceuticals to meet 80-100 % of the demand *(100% by the time of the second quarter).* VINATOM provided more than 1,300 Ci of radioactive isotopes, of which 977 Ci was produced by the Da Lat reactor (a double increase compared to that of 2015-2019) and 6.0 Ci was exported to Cambodia for its nuclear medicine facilities. To achieve this result, the operator team made great efforts in technical innovations, analysis and recalculation, and new processes of isotope production. This proves that Vietnam can completely master scientific, technical and technological issues to produce pharmaceuticals for domestic and export demand when a new research reactor is operated. In addition, the pharmaceutical production line at the Da Lat nuclear reactor has been upgraded (with self- funding) to obtain the GMP certificate of the Ministry of Health (June 2020) and the visa for radiopharmaceutical circulation for the first time, which replaces the previous license and the annual renewal procedure. Also, the result of continuous reactor operation to produce radiopharmaceuticals to meet the domestic demand is the best result ever, since its re-operation on March 20, 1984. Notably, the price of pharmaceuticals made by the Da Lat reactor is only about ¼ of that of imported drugs, which has truly been a good support for cancer patients.

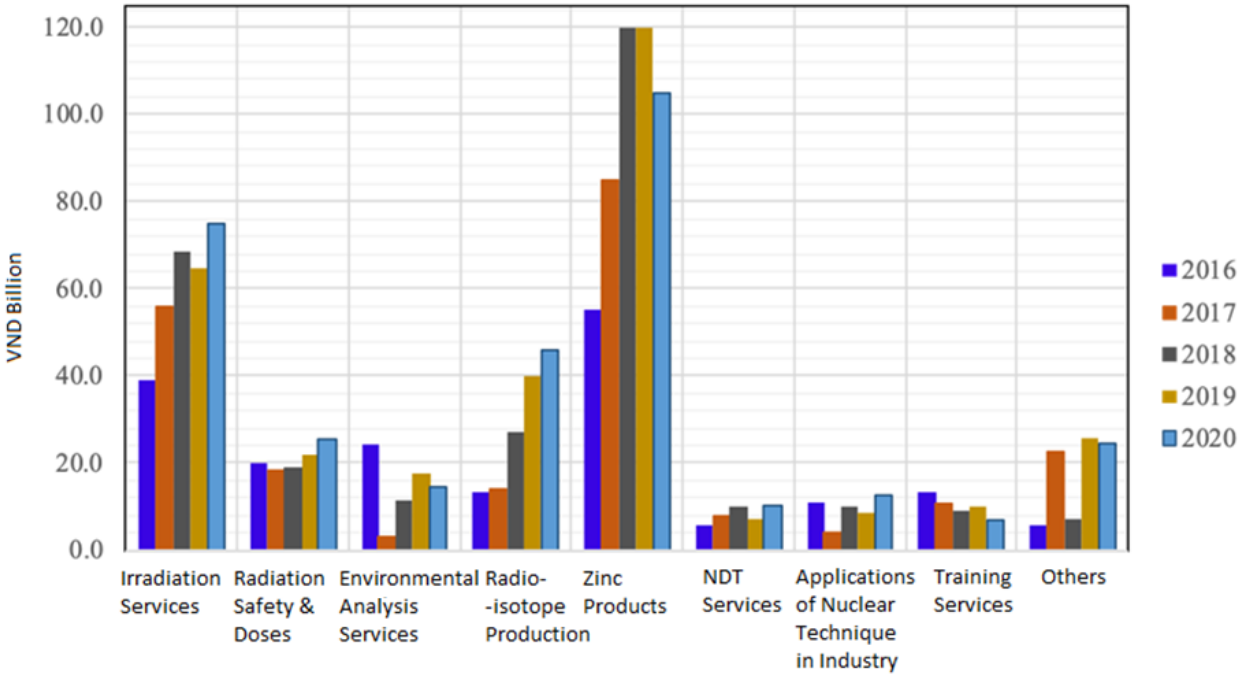


**Figure 3.** VINATOM Annual Revenue from production and services in 2016-2020

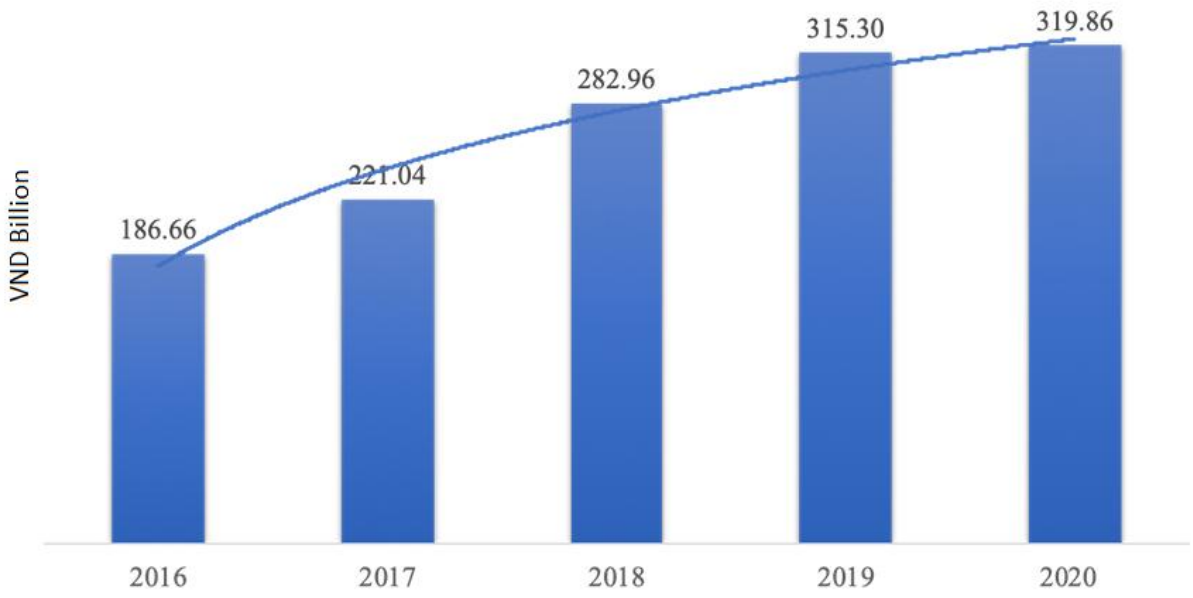


**Figure 4.** Total Annual Revenue from production and services in 2016-2020

- Use of irradiation as a quarantine treatment of export commodities continued to play an important role in 2020. Da Nang irradiation line kept being well operated for export. In particular, the two centers of VINATOM, Hanoi Irradiation Center and Research and Development Center for Radiation Technology, took action to support the country affected by the unprecedented epidemic: Free radiation of medical instruments and antibacterial masks, protective equipment; safe operation and increase of irradiation time of export products, contributing to foreign currency revenue for the country in the situation of international quarantine at some points of time.

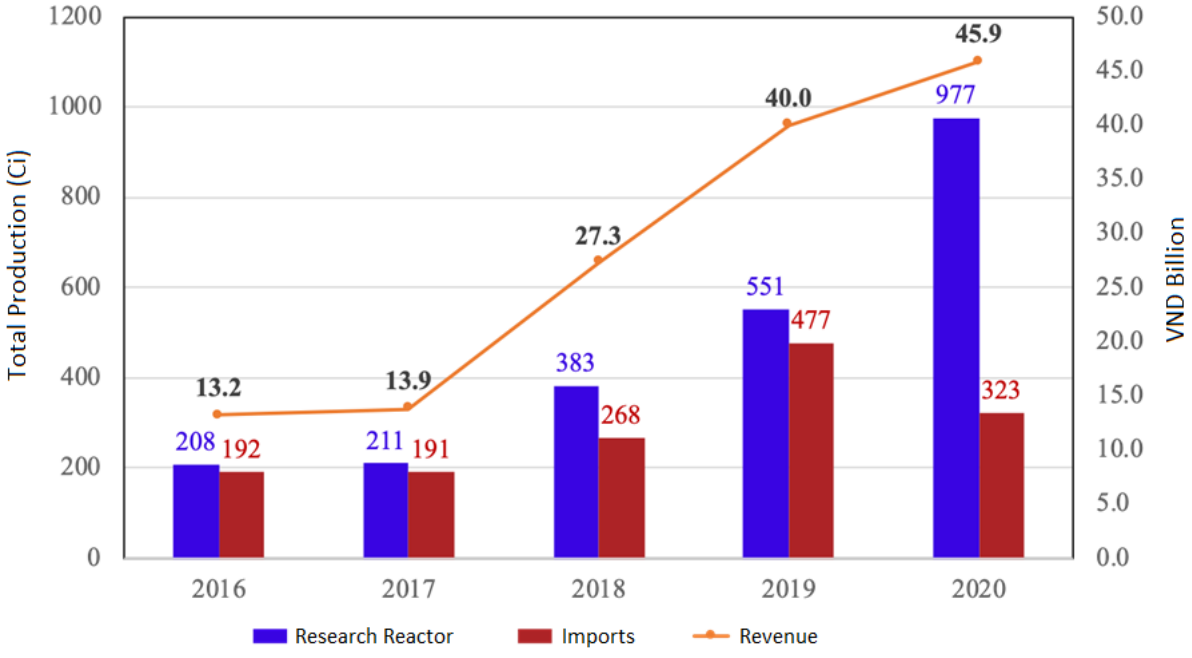


**Figure 5.** Annual Revenue from Radioisotopes Production

- VINATOM promoted the cooperation with India in the field of atomic energy and paid special attention to the purchase of Cobalt-60 sources for Vietnam from India. The two sides coordinated in using Indian military ships to successfully transport Cobalt-60 sources to Vietnam for the Institute.

- HIC upgraded the radiopharmaceutical production line and received GMP certificate from the Ministry of Health allowing the use of pharmaceutical FDG-18 for cancer diagnosis in the hospitals of Hanoi.

- By boosting the introduction of non-destructive evaluation into industrial facilities, the training and service sales continued growing in 2020. In this area, CANTI successfully deployed nuclear techniques and provided the service of investigation into carbon steel components in stainless steel welds of Nghi Son refinery and petrochemical plant construction project (Thanh Hoa). The incident of pipeline explosion happened while Nghi Son plant was in trial operation. The method and technique to figure out the cause had not been found even though some international partners had been hired. The plant is worth about 9 billion USD. If the operation were delayed for one month, it would have caused a loss of tens of millions of dollars. Fortunately, the service of CANTI could prevent this loss.

- The state-level projects under Program KC.05/16-20 were well implemented. These projects include important topics such as calculating radioactive release from Chinese nuclear power plant (hypothetical incident) in the air and marine environment; computational study to open a new research channel at the Da Lat reactor; successful manufacture of a Gamma chamber for Agricultural Genetics Institute, and producing new radiopharmaceuticals for cancer treatment.

- The applications of radiation technology products and rare earth microelements started to be deployed in organic agriculture (deployed in Quang Ninh, Thai Nguyen, Quang Ngai, Ca Mau), which has brought some positive results.

- CANTI won the international bid to implement the contract *"Supply of human resources, equipment, and tracers for condensate gas survey in the White Lion mine"* with the Cuu Long Joint Operating Company (CLJOC). This 2-year contract has been implemented since October 2020.

- Other production and service of the units under the Institute such as personal dose control and measurement, training and granting radiation safety certificates, standardization and inspection of equipment quality, testing and standardizing the dose of radiotherapy machines, sample analysis... were well implemented, which contributed to bringing the application of atomic energy to serve the country's socio-economic development.

- The project of the Research Center for Nuclear Science and Technology has been implemented on the basis of the Intergovernmental Agreement between Vietnam and the Russian Federation approved by the Prime Minister for investment policy in Decision No. 75 /QD-TTg dated November 19, 2018 and adjusted investment policy in Decision No. 36/QD-TTg dated May 15, 2020. Currently, CNST is in the stage of preparing the capital for the implementation of the Feasibility Study. The Center is expected to start its construction in 2022 and put into operation in 2026.

- The project of the National Environmental Radiation Monitoring and Warning Network continued developing. Up to now, the network has been gradually formed, installed, put into operation and managed by 11 stations in the North and North Central regions (including Mong Cai, Bai Chay, Lang Son, Hanoi, Hai Phong, Bach Long Vi Island (Hai Phong), Cao Bang, Lao Cai, Son La, Nghe An, Da Nang) and 01 Operation Center (in Hanoi) thanks to the projects of research capacity enhancement, the projects of equipment enhancement and products under Program KC.05, environmental projects, ministerial-level projects, and aid from international organizations. VINATOM initially built up a team of highly qualified and professional staff in the field of radiation monitoring and environmental impact assessment. Currently, VINATOM is working with Vietnam Agency of Radiation and Nuclear Safety on the project of equipping radiometric devices in gas and water environments funded by the European Union.

In order to achieve above successful results in such a challenging situation as 2020 due to the severe impact of the Covid-19 epidemic, all officials and employees of VINATOM have made great efforts to improve professional qualifications and implement actively the applications of nuclear and radioisotope techniques in different areas to serve the country's socio-economic development.

### 1.3.1. SCIENTIFIC RESEARCH

In 2020, VINATOM had 50 scientific research and technological development projects Regarding the National program of science and technology KC.05/16-20, 5 projects were accepted and expected to be accepted at the beginning of the first quarter of 2021 and 01 project was canceled. 23 ministerial-level projects of 2020 were implemented. Most of the 21 ministerial-level projects of 2019 were accepted in 2020. The others sent requests to extend the implementation time and were expected to be accepted in the following year.

#### 1.3.1.1. BASIC RESEARCH

**Nuclear Physics Research**

Basic research on nuclear physics in two directions of theoretical physics and experimental nuclear physics is carried out at Center for Nuclear Physics of INST. The studies focus on nuclear interaction and structure through microscopic reactions; moreover, the research on the low-energy nuclear reactions which is close to nuclear astrophysics, the physics of unstable nuclei, the nuclear reactions and nuclear data research on accelerators are expanded. In 2020, the Center obtained many new and important results which were published in 12 articles in international journals (including 11 articles in ISI journals), 04 articles in domestic journals, and 03 scientific conference reports.

The research team at NRI installed and used the first horizontal channel of Da Lat reactor in nuclear physics research, neutron scattering measurement and staff training. Also, it was used to perform the measurement of nuclear data, level schemes and structure of some unstable heavy nuclei (Sm-153, Dy-162 and Yb-172). The team successfully published 5 articles in ISI, 3 articles in Scopus and 6 articles in domestic journals.

**Research on Reactor Physics, Technology and Safety**

INST's research team focuses on the physics and engineering of research reactors, small modular reactors (SMR), and floating nuclear power stations (FNPS). The research topic on the technology and safety of FNPSs using SMRs focused on investigating the overview of their development and applicability in the world; studying the technology system of FNPSs using SMR; studying the the principles, standards, criteria and regulations on safety and security of FNPSs using SMRs; studying the physical characteristics and hydrothermal safety for SMRs used in FNPSs. This team published 15 international articles (11 ISI articles), 4 domestic articles and 16 domestic and international scientific conference reports.

NRI's the research team led by Assoc.Prof. Nguyen Nhi Dien conducted the research and calculation of neutron and hydrothermal characteristics, and analyzed the safety of a research reactor the Russian Federation recommended for RCNEST. This is a very important topic, serving the implementation and construction of RCNEST in the future. In 2020, the team published 01 ISI article. NRI is also carrying out two ministerial-level projects with the following objectives: (1) Research on management of the Da Lat reactor core area in order to improve the radioisotope yield and optimize the fuel efficiency; (2) Updating the plan for decontamination and dismantling of Da Lat reactor at the end of its service life. In the period 2016-2020, the implementation of research projects at all levels in this direction is useful in training a team of researcher to be more deeply expertise in research reactor technology, capable of calculating neutron and hydrothermal characteristics and safety analysis of research reactors, optimization of the core configuration design, optimal in-core fuel management, application of single crystal doped silicon irradiated. These works are to prepare for RCNEST, as well as ensure the safe operation of the Da Lat nuclear reactor. In 2020, the team published 1 ISI article.

### 1.3.1.2. HANDLING AND PROCESSING OF RADIOACTIVE ORES, NUCLEAR FUEL & RADIOACTIVE WASTE AND RARE EARTH MATERIALS

The research and development of beach sands processing technologies in the sustainable and environmentally friendly manners are being built and strengthened at ITRRE and CANTI. In 2020, VINATOM actively supported the development of research directions on processing technologies for ilmenite concentrates (containing titanium) to get $TiO_2$ pigment products and porous titanium/metallic titanium, for monazite concentrate to recover rare earth products, T h, U and by-products.... The research on ilmenite processing is currently gaining the interest and cooperation of a number of domestic research institutes and enterprises as a result of a large quantity of this kind of beach sand in our country, which can supply the high consumption demand from the domestic market and the exportation.

The research direction of radioactive waste treatment was still focused to develop the technology at ITRRE. The Institute intended to promote a teamwork of the study on highly effective adsorbents applied for radioactive wastewater and environmental treatment and continued the studies on NORM and TENORM management and treatment, as well as conducted the research to improve the waste treatment technology of ZOC factory.

In addition, ITRRE keeps maintaining the research on the nuclear fuel cycle, including radioactive ores processing technologies and nuclear fuel by the implementation of Institutional-level projects for staff training.

On the other hand, research and development of rare earth processing technology is a strong research direction at ITRRE. This Institute has the advantages in a good system of equipment, young and capable staff who masters research facilities and the technology of rare earth processing, especially the technology of solvent extraction for the separation and refining of rare earths. The Institute advocates promoting this research direction towards green and cleaner technology. The issues being researched in 2020 include ministerial-level projects *"Research on technological process for preparing metallic terbium from TbCl3 solution of the extraction process for rare-earth separation",* and *"Research on technological process for preparing metallic dysprosium from rare earth oxides by thermo-metal method";* state-level projects and projects in collaboration with other agencies *"Research on completing the technology of preparing Nd metal from $Nd_2O_3$ oxide by electrolysis in molten fluoride salt",* and *"Completing the technology, design and manufacture of production line for some rare earth elements Y, Gd, Tb and Dy with high purity by solvent extraction method".*

#### 1.3.1.3 TECHNICAL SUPPORT CAPACITY OF SAFETY, SECURITY AND ENVIRONMENTAL PROTECTION

VINATOM was responsible for the completion of studies on assessment of the possibility of radiation dispersion and impacts from China's Fangcheng and Xuong Giang nuclear power plants on Vietnam; completion of data sets of radionuclides in soil, main food, seawater samples collected at Co To island, and data sets on soil and air environmental radioactivity, population and food distribution in Northern region. In addition, NRI was also doing research on assessment of the radiation spread and dispersion in the marine environment from a nuclear power plant in case of an incident, to establish background radiation levels in the marine environment in the Gulf of Tonkin and manufacture the equipment for monitoring the radioactive contamination of Cs-134 and Cs-137 in sea water.

NTC conducted the research related to water and environment which is the contents of the Project under the Technical Cooperation Program 2020-2021 (TC VIE7006).

CNT, Ho Chi Minh City continued doing research on groundwater kinetics by isotope hydrology for water resource management in the Southern Delta.

VINATOM continued implementing the project of the National Environmental Radiation Monitoring and Warning Network. In order to standardize the monitoring data from the Network with many different monitoring equipment systems, recently the INST has integrated online radiological monitoring data sources and the processing procedures. As a result, the data is transferred and integrated and the database of environmental radioactivity is built in a unified format.

In addition, INST's research team is in charge of the project of monitoring and warning of environmental radiation from 2020 to 2022, synchronously monitoring the environmental radiation status in most of the major environmental objects at monitoring sites in order to determine the current state of environmental radiation, build a database on environmental

radiation to serve the state management of atomic energy, radiation and nuclear safety, ensure promptly detect abnormalities in radiation and assist in responding to radiation and nuclear incidents. Moreover, the Institute also conducted research using nuclear and isotope techniques to identify the origin and history of pollution in the coastal ecosystem of the Red River estuary, implemented the project of monitoring and analyzing environmental radiation and stable isotopes at some locations in Hanoi, Lang Son, Quang Ninh, Lao Cai, upstream of Red River, Nam Thi River, and Ky Cung River and dust pollution in Nghia Do, Hanoi, kept doing investigation, assessment, and development of data sets on environmental radiation background in the area which is likely to be affected soon by nuclear incidents outside the northern border to serve incident response of Phase 2.

### 1.3.1.4. APPLICATION OF NUCLEAR AND RADIATION TECHNOLOGY

The study on the application of nuclear and radiation technology in the production of isotopes and radiopharmaceuticals continues to be promoted and expanded. NRI was conducting research on preparation of $^{90}Y$ radioactive microsphere by the Da Lat nuclear reactor for the purpose of treatment of primary and metastatic liver cancer and studying the preparation of $^{32}P$-chromic phosphate. In 2020, the team published 2 ISI articles, 2 scopus articles and 1 domestic article. HIC already researched and mastered the synthesis process of radiopharmaceutical$^{18}F$-FDG.

INST has built and developed the capacity of research and apply the methods of physics, nuclear techniques and isotope techniques in a number of areas such as water resource assessment, hydrogeology, irrigation works, environmental pollution, food authenticity and traceability. The Institute completed the research on development of isotope techniques (C-13 and O-18) to support the identification of agricultural product origin (apples), successfully developed a method to analyze stable isotope composition of $\delta^{2}H$ and $\delta^{18}O$ in fresh apple juice and stable isotope composition of $\delta^{13}C$ in apple flesh and skin to assist in determining the geographical origin of imported apple products. Besides, the studies on evaluating the carbon storage capacity of agricultural soils were also being completed. Simultaneously, the research on the application of isotope techniques in assessing the connection between the flow and aquifers along the Red River from Son Tay to Hung Yen began to be implemented.

NDE Center was in the completion stage of research on application of non-destructive testing techniques to detect corrosion under insulation layer for some typical pipeline objects used in some oil refineries in Vietnam, and research on building up a quality system for training non-destructive testing technicians in accordance with international standards.

CANTI carried out the following studies: manufacturing and testing the system of induced magnetic devices to detect the leakage current through the hydroelectric dam and manufacturing the gamma measurement system with wireless data control and acquisition for industrial applications. Besides, the study on the application of the oil saturation determination method by natural indicators distributed in real oilfields, over 80% of the workload was done; however, due to the Covid-19 pandemic situation, the Kuwaiti side could not do the sampling and send the samples. As a result, the project was agreed to cancel by the competent authority. In the coming time, the Center will conduct the research on application of stable

isotope Deuterium and Oxy-18 techniques to investigate the characteristics of groundwater recharge on some areas of Long Khanh city; the research on the development of new tracking method combined with natural voltage measurement to locate leakage currents of water loss through dikes and dams; the study on manufacturing of mini-SPECT sample devices applied on mouse samples for medical research.

Additionally, CANTI carried out the studies on the method, design and manufacture of equipment for testing leakages in gas-lifted wells by tracking techniques; the study on establishing the procedure for analyzing ultra-low sensitivity Perfluorocarbon compounds (PFCs) for tracking applications in the oil and gas fields.

NRI did the research on development of techniques using a combination of radioisotopes and stable isotopes to study the source of nitrate or ammonium-based pollutants in the aquatic environment, using nuclear and isotope techniques to determine the origin of sediments and assess the history of sedimentation - erosion in the coastal area of Dinh An, using the trace and rare earth elements to characterize archeological materials at Cat Tien and Oc Eo - Ba The relic sites.

HIC carried out the studies on synthesis and application of Selenium nanoparticles by irradiation method to make shrimp feed supplements; research on making hydrogel materials from gelatin/carboxymethyl-chitin and gelatin/carboxymethyl-chitosan by irradiation to use them as growing media for stem cell (adipose tissue), developing the calculation software of 3D dose distribution for research and treatment of liver cancer using microspheres attached the radioisotope Y-90; research on treatment and decomposition of azo dyes from dyeing workshop wastewater by electron beam irradiation combined with biological treatment.

CNT, Ho Chi Minh City conducted the studies on the possibility of using electron beams to make ZSM5 zeolite materials with the properties of hazardous waste treatment and applications in industrial catalysis; research on age determination, origin and replenishment of aquifers in the Southwest region.

In terms of nuclear electronics, measurement, and control, NRI researched, successfully designed and manufactured the function block "neutron flux control" by DSP and FPGA techniques via the implementation of a project at ministry level. In 2020, the research team published 01 ISI article. Step by step, HIC mastered the cyclotron accelerator technology and successfully installed the ion source using PIG (Penning Ionization Gauges) technology for the KOTRON13 accelerator, and manufactured a number of radiation monitoring and warning devices for the national environmental radiation monitoringnetwork. The Center also mastered the ARM-Linux system used in the manufacture of nuclear electronic devices, researched and manufactured the device to measure high dose rate, such as measuring gamma dose rate of kGy/h.

### 1.3.1.5. SCIENTIFIC PUBLICATIONS

In 2020, the total number of publications by VINATOM in domestic and international journals and conferences was 244. Among 91 papers published in international journals (20 more than 2019), 68 articles were published in ISI journals *(See 4.1. in Appendices)*. In order to encourage scientific research in the Institute, VINATOM annually establishes a Council to

review and award the international publications' authors who deserve. In 2020, the Council considered and awarded A prize to 20 publications, B prize to 19 publications and C prize to 13 publications.

**Table 2.** Summary of scientific publications in the Institute

| Units | International journals | National journals | International conferences | National conferences | Total |
|---|---|---|---|---|---|
| Institute for Nuclear Science &Technology | 29 | 13 | 11 | 17 | **70** |
| Nuclear Research Institute | 28 | 29 | 3 | 08 | **68** |
| Institute for Technology of Radioactive Waste and Rare Elements | 5 | 9 | 1 | 11 | **26** |
| Center for Nuclear Technique, Ho Chi Minh City | 9 | 3 | 1 | 4 | **17** |
| Research and Development Center for Radiation Technology | 7 | 4 | 3 | 5 | **19** |
| Center for Application of Nuclear Techniques in Industry | 0 | 5 | 0 | 5 | **10** |
| Hanoi Irradiation Center | 4 | 4 | 1 | 5 | **14** |
| Center for Nondestructive Evaluation | 4 | 3 | 3 | 4 | **14** |
| Nuclear Training Center | 3 | 0 | 0 | 1 | **4** |
| Headquarters | 2 | 0 | 0 | 0 | **2** |

| Units | International journals | National journals | International conferences | National conferences | Total |
|---|---|---|---|---|---|
| **Total** | **91** | **70** | **23** | **60** | **244** |

### 1.3.2. SERVICE AND APPLICATIONS

The service and applications of VINATOM in 2020 were oriented towards **"Nuclear science and technology for socio-economic development"**. Here are some outstanding service implementation results:

- Nuclear Research Institute:

+ Radiopharmaceuticals and kits to domestic hospitals were prepared and supplied once a week. A total of about 1,365 Ci radioisotopes of all kinds were supplied, which was a growth of 32% compared to 2019. The revenue reached about VND 45.9 billion.

+ In terms of analysis and environmental services, about 3,000 samples of all kinds were carried out, directly serving the export of agricultural products and ensuring domestic food hygiene and safety, assessing and certifying VietGAP. The revenue reached VND 5.56 billion.

+ The services for radiation safety, personal dosimetry, calibration and testing of equipment for radiation facilities were still carried out. The total revenue reached VNS 4.95 billion.

- Institute of Nuclear Science and Technology:

+ The radiation safety services, personal dose control measurement, standardization and inspection of equipment quality, testing and standardization of radiation therapy machines, consultation of design, measurement, testing and assessment of radiation safety radiation brought the revenue of about VND 9.4 billion.

+ The contracts for analysis services: gamma activity, total alpha and beta measurement, radium measurement and determination of heavy metals in different samples brought revenue of more than VND 2.1 billion.

+ The service of training and granting radiation safety certificates: 35 classes, 1100 certificates brought the revenue of more than VND 1.7 billion.

- Institute for Technology of Radioactive Waste and Rare Elements:

+ The Center of Technology Implementation showed high determination in the zinc production, overcome many difficulties in production and business conditions and achieved the turnover of VND 105 billion.

+ The Institute continued to cooperate with VREC Company on consulting and technical support for the factory producing ZOC from Vietnam marine placer. The line of radioactive

waste treatment in ZOC factory was put into operation in Ba Ria - Vung Tau. The total revenue was VND 4,089 million.

- Center for Nuclear Technique, Ho Chi Minh City

+ The Center's implementation of applications and nuclear technical services obtained some encouraging results, such as: Service of analysis with revenue of over VND 1.3 billion, personal dosimeter services reaching over VND 1.1 billion and training services of about 0.9 billion VND.

- Research and Development Center for Radiation Technology (VINAGAMMA):

+ Irradiation service of food processing and sterilization for export and medical instrument sterilization achieved the revenue of about VND 55 billion, despite being affected by the adverse effects of the Covid-19 pandemic.

+ The service of producing silver Nano, Chitosan and antibacterial fabrics reached nearly VND 1.3 billion.

- Hanoi Irradiation Center:

+ The center's irradiation services include irradiation of exported fruits, irradiation for research, medicine, and irradiation of traditional medicines, brought about VND 11.5 billion. For the first time, the Center's irradiation facility was recognized by Australia to meet the standards for longan irradiation. The Center irradiated 18.4 tons of longan/ 86.2 tons of fruit.

+ The services related to the implementation of atomic energy application such as radiation safety training, radiation testing, etc. earned about VND 2.2 billion in revenue.

- Non-Destructive Evaluation Center :

+ Non-destructive testing service for factories and industrial facilities (eg Nghi Son Refinery and Petrochemical Plant; Mong Duong Thermal Power Plant; Son Dong Thermal Power Plant; Hai DuongThermal Power Plant) achieved the revenue of about 10 billion Dong.

+ The radiation safety service reached 3.5 billion VND.

+ The training service of non-destructive testing reached about 2.8 billion VND.

- Center for Application of Nuclear Technology in Industry:

+ The service of implementing the contract with Nghi Son refinery and petrochemical plant on detecting carbon steel in stainless steel welds brought about the revenue of about VND 6.9 billion.

+ Sample analysis service reached over 1.1 billion VND.

In summary, despite the difficult situation of the Covid-19 epidemic in 2020, which negatively affected other industries in Vietnam as well as in the world, VINATOM achieved good results in technical deployment, production and service and reached the estimated total revenue of VND 319.86 billion (the revenues of some units had not been yet reported in a timely manner). Compared to 2019, the revenue of 2020 went up. Although the production of zinc products declined due to the negative impacts of the Covid-19 pandemic, there was a gain

in the revenues of some other fields. VINATOM's main applications of technical services, production and business in 2020 include:

**Table 3.** Types of services and corresponding revenues

| **No** | **Services** | **Revenue (billion VND)** | |
|---|---|---|---|
| | | **2019** | **2020** |
| 1 | Irradiation | 64,6 | 75,0 |
| 2 | Radiation safety, dosimetry | 21,8 | 25,4 |
| 3 | Analysis services, environment | 17,6 | 14,5 |
| 4 | Radioisotope production | 40,0 | 45,9 |
| 5 | Producing zinc products | 120,0 | 105,0 |
| 6 | NDT | 7,2 | 10,3 |
| 7 | Application of nuclear techniques in industry | 8,5 | 12,4 |
| 8 | Training | 9,8 | 6,9 |
| 9 | Others | 25,8 | 24,4 |
| | **Total** | **315,3** | **319,86** |

In order to boost the deployment and application of nuclear techniques and radiation technology, VINATOM annually awarded the Institute's certificates of merit to the units and individuals with outstanding achievements in implementing tasks and promoting applications.

### 1.3.3. TRAINING AND DEVELOPMENT OF HUMAN RESOURCES

#### Doctoral Training

In terms of doctoral enrollment and training in 2020, 2 fresh PhD students were satisfied the entrance requirements of VINATOM. Their doctoral training majors were Atomic Physics and Analytical Chemistry.

The Institute completed and announced 4 frameworks of doctoral training programs for 4 specialized training disciplines, amended and supplemented and issued the Regulation on doctoral training of VINATOM.

The qualification of lecturers is constantly improving. In 2020, the State Council of Professor Titles conferred the title of Professor of Analytical Chemistry on Assoc.Prof.Dr. Nguyen Quoc Hien, a full-time lecturer of VINATOM.

Also, in 2020, the Institute has organized the review committees for essays, seminars, doctoral theses and defenses for 2 PhD students in Atomic Physics.

**Human Resources Development**

In 2020, VINATOM focused on grouping and developing the leading research teams to meet the assigned key tasks as well as the Institute's long-term development orientation by various training forms such as domestic and oversea training, training through cooperation with international atomic energy organizations, research institutes and universities. Apart from keeping and developing the core research teams such as: Nuclear Physics team; Physics, Nuclear technology and safety; Environmental radiation monitoring, Ionization standards and radiation safety; Nuclear engineering application, Research and manufacture, Equipment maintenance, Nuclear medicine, Biotechnology, Analytical chemistry... The researchers were trained to enhance their qualifications through the scientific research projects at all levels.

The Institute’s researchers also participated in postgraduate training at other institutions such as Institute of Physics, Hanoi University of Natural Sciences, Da Lat University, Ho Chi Minh City University of Natural Sciences, Hanoi University of Science and Technology.

The Institute facilitates incumbent and potential officials and cadres to participate in training courses on political theory, national security and defense, fostering and raising the ranks of civil servants, public employees and researchers, management knowledge at all levels.

**Specialized Training**

In 2020, the training courses were organized at Nuclear Research Institute for those monitoring and managing the projects of research reactor construction.

The training courses on "Manufacturing $^{18}$F-FDG radiopharmaceuticals" and "Operating the cyclotron accelerator KOTRON 13 MeV" were held for Da Nang hospital’s staff at Irradiation Center Hanoi.

Cooperating with Japan Atomic Energy Agency, the Institute successfully organized 2 online training courses on: (1) Radiation and nuclear incident response; (2) Reactor technology at Institute of Nuclear Science and Technology.

### 1.3.4. INTERNATIONAL COOPERATION

In 2020, the Covid-19 pandemic greatly affected the international cooperation activities of VINATOM. However, the Institute made efforts in maintaining international cooperation to support scientific research, technology implementation and training activities.

The Institute successfully organized more than 30 online international meetings and seminars with International Atomic Energy Agency (IAEA) and meetings within the framework of Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology for Asia and the Pacific (RCA) and the Forum for Nuclear Cooperation in Asia (FNCA) to maintain Vietnam's cooperation. VINATOM also maintained regular online meetings with the agencies of the Russian Federation to implement the Project of RCNEST.

15 staff members were nominated to attend seminars abroad and more than 100 were chosen to take part in online training courses to update knowledge and exchange research experiences in the field of renewable energy, radiation and nuclear safety, emergency response, counter-terrorism, nuclear security, etc.

In 2020, despite the Covid-19 pandemic, VINATOM kept close cooperation with the IAEA on TC programs, the Center for Cooperation with the IAEA on water and environment, National Data Center (NDC) under the framework of the Comprehensive Nuclear-Test-Ban Treaty (CTBTO), Asian Nuclear Safety Network (ANSN) in online forms. Nuclear Research Institute welcomed the IAEA's Nuclear Inspection Delegation and the Consulate General of the Russian Federation.

As the National Coordinating Body of RCA, VINATOM took responsibility of coordinating 16 IAEA/RCA (RAS) on-going projects in the areas of Health, Agriculture and Food, Industry, Environment, Radiation safety, 13 of which have been implemented by VINATOM. The Institute collaborated with the RCA National Coordinators to discuss many important contents about the objectives of the RCA program and the action plan to 2030, the initiative for the RCA program in the period of 2022-2030, carried out the socio-economic impact assessment of RCA projects on the occasion of RCA 50th Anniversary and developed the plans for the 50th RCA events that Vietnam will host in 2022. VINATOM was also responsible for leading a group of agricultural experts in the region to develop a regional cooperation strategy in the field of agriculture for the period 2024-2029, contributing to the goal of global sustainable development.

As the national focal point of FNCA, in 2020 VINATOM was in charge of coordinating 7 FNCA projects, 4 of which was under control of VINATOM. They focused on radiation technology application, Research reactor applications, radiation safety, radioactive waste management and climate change.

VINATOM still kept operations with its strategic partners, including the Russian Federation, Japan, the United States, India and other countries. Some details are listed below.

+ The Institute has cooperated with relevant agencies of the Russian Federation to implement the project of CNST.

+ The cooperation with Japan (JAEA, MEXT, and JINED) was carried on to organise online training courses for Vietnamese officials, including the course on nuclear technology in collaboration with Hanoi University of Science and Technology for about 30 students. In 2020, VINATOM signed a tripartite cooperation agreement with JINED and Hanoi University of

Science and Technology on organizing training courses on Nuclear Power Plant Technology for Vietnamese students.

+ With India's support, VINATOM managed to transfer Co-60 sources to Vietnam to serve the domestic irradiation needs.

+ NTC cooperated with University of Newcastle, University of Nottingham, United Kingdom on the application of isotope techniques in the study of the water environment of the Red and Mekong Deltas. In addition, the Center had cooperation with Institute of Soil Physics and Rural Water Management (SoPhy) of BOKU University, Austria in the framework of the Protocol "Application of isotope techniques in the study of hydrological processes in the Red River and tributaries".

+ NRI completed the aid project of the Pacific Northwest National Laboratory (USA) on "Supplying alternative materials and components for the security control system at Nuclear Research Institute".

+ VINATOM discussed with the Taiwan Nuclear Energy Research Institute to sign the memorandum of cooperation in the field of Radiation Medicine.

The international cooperation activities in 2020 of VINATOM met the needs and tasks in order to support scientific research activities and deploy nuclear technology applications for socio-economic development, which contributed to the implementation of the project of RCNEST.

### 1.3.5. INFORMATION & COMMUNICATION, SCIENTIFIC CONFERENCES

The publication of the followings was completed by VINATOM in 2020:

+ 4 issues of Journal of Nuclear Science and Technology (printed and online versions)

+ Nuclear Science and Technology Information (online version)

+ Annual reports for 2019 (printed version collecting scientific research reports of VINATOM's projects at the Institutional and Ministerial levels in 2019)

In order to build and develop a database for the Institute's electronic library, important printed science and technology documents were converted into computer files and transferred into the e-library, a platform for search, research and training activities.

The Institute's Web Portal in Vietnamese and English versions 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.

The 6th Nuclear Science and Technology Conference for young researchers was successfully organised.

### 1.3.6. SERVING STATE MANAGEMENT IN THE FIELD OF ATOMIC ENERGY

*Summary of 15-year implementation of the Strategy on atomic energy application for peaceful purposes up to 2020 and the Master Plan on development and application of atomic energy in the period of 2021-2030, with the vision up to 2050*

VINATOM closely coordinated with Vietnam Atomic Energy Agency in writing the report summarising the 15 years of implementation of the Strategy on atomic energy application for peaceful purposes up to 2020. In the report, the Institute summarised the status and the results of the schemes, projects and planning related to the Strategy, including the Scheme "Strengthening the capacities of research - implementation and technical support for the development of atomic energy applications, ensuring safety and security" (Decision No. 265/QD-TTg dated March 5, 2012 of the Prime Minister), with the focus on building the program of scientific research and technological development in the field of atomic energy and boosting the development of VINATOM In addition, the Institute summarised the status and results of implementing the Project of Research Center of Nuclear Science and Technology (Decision No. 75/QD-TTg dated November 19, 2018) and the Planning of the National network of environmental radiation monitoring and warning (Decision No. 1636/QD-TTg dated August 31, 2010).

Moreover, VINATOM and VAEA worked closely together to develop the Master Plan on development and application of atomic energy for the period 2021 - 2030, with the vision to 2050, as a basis for the leaders of the Ministry of Science and Technology to consider and submit to the Prime Minister for approval. Furthermore, the Institute drafted the planning for development of nuclear science and technology potentials, human resource development, and ensuring safety and security, which is one of 6 components of the master plan on development and application of atomic energy in the period of 2021 - 2030, with the vision to 2050.

The Institute along with the Agency made the description of the plan for training human resources for state management, research - deployment and technical support for the development of atomic energy applications in the 2021-2025 period.

*Technical support for radiation and nuclear safety*

VINATOM paid attention to supervising the activity of ensuring radiation and nuclear safety at its units using radioactive sources, radiation and nuclear equipment. The plan to collect radioactive sources that pose a risk to the safety and security from other facilities was built by Head Quarters, INST and NRI. In general, all units of VINATOM made attempts to comply with the law on ensuring nuclear and radiation safety, nuclear security, radioactive source security and nuclear inspection such as: reporting on storage, transportation and use of radioactive sources and radiation equipment, renewing the permits of conducting radiation tasks, organising training courses on radiation safety and providing medical examinations for employees, occupational radiation dose monitoring, carrying out the calibration and verification of radiation measuring devices and radiation equipment, checking and counting the radioactive sources. The results of occupational radiation dose monitoring showed that no radiation employees were overexposed. There was no loss of radioactive sources and radiation equipment. However, the inspection on radiation safety at the units also showed that there

were still shortcomings and limitations that required them to overcome and continuously improve the radiation and nuclear safety according to the regulations.

In 2020, VINATOM issued the Regulations on radiation and nuclear safety, nuclear security, security of radioactive sources and nuclear inspection. The Regulations are the basis for more unified and effective management of radiation and nuclear safety, nuclear security, radioactive source security and nuclear inspection throughout the Institute.

In addition, VINATOM cooperated with VAEA in researching and developing drafts of legal documents on radiation and nuclear safety for the new research reactor.

The Institute researched and commented on IAEA's draft on nuclear safety standards for research reactors, participated in the Regional Workshop on Self-Assessment of Incident Response Information Management Systems organised by IAEA. Also, the Institute gave comments on the draft of the 3rd national report on the implementing the obligations of the General Convention on Safety in the Management of Spent Fuel and Safety in the Management of Radioactive Waste.

## 1.4. INVESTMENT PROJECTS, EQUIPMENT ENHANCEMENT PROJECTS, MINOR CONSTRUCTION AND MAJOR REPAIR PROJECTS IN 2020

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

### 1.4.1. RESEARCH CENTER OF NUCLEAR SCIENCE AND TECHNOLOGY

The project to build CNST is implemented on the basis of the Intergovernmental Agreement between the Socialist Republic of Vietnam and the Russian Federation, signed on November 21, 2011, on cooperation in building CNST in the territory of the Socialist Republic of Vietnam. The main objective of the project is to build a nuclear science and technology research center, of which main component is a research reactor in Dong Nai, with the capacity of 10 MWt on the area of about 100 hectares, to enhance the national potential of nuclear science and technology, contribute to the socio-economic development and replace the Da Lat nuclear reactor that is about to expire.

The project's investment policy was approved by the Prime Minister in Decision No. 75/QD-TTg dated November 19, 2018. The adjustment of investment policy was issued in Decision No. 36/QD-TTg dated May 15, 2020. Here are some main points related to the project:

**Implementation period:** 2018-2026;

**Capital source:** Credit of the Russian Federation and Vietnam;

**Investors:** Ministry of Science and Technology;

**Implementing units:** Project Management Board - PMU (established by the Ministry);

**Coordinating units:** Vietnam Atomic Energy Institute, Vietnam Agency of Radiation and Nuclear Safety and other related units under the Ministry.

**Implementation status:** In August 2020, the Prime Minister agreed to allow the contractor selection under a special form in Article 26 of the Bidding Law for bidding packages for preparation of Feasibility Study Report - FS and FS appraisal. The contractor selection procedure consists of 8 steps. Up to 2020, the 3rd step was ongoing. To continue implementing the 4th step, the PMU coordinated with the other units to select the contractor who is responsible for implementing the bidding package to prepare the FS and the portfolio of the project location, to submit to the Ministry of Science and Technology for approval of the investment project (according to the Law on Public Investment in 2019, the Law on Construction 2014, the Ministry of Science and Technology is in charge of investment approval).

### 1.4.2. NATIONAL MEASUREMENT STANDARDS IN THE FIELD OF IONIZING RADIATION DOSIMETRY MEASUREMENT FOR THE PERIOD 2015-2020

In 2020, the project moved ahead with the coordination with the contractor of Minerals Import-Export JSC. and the Supervision Consultant of the contract implementation of the package No. 1: Purchasing the equipment under the project, including two equipment systems, namely the precise irradiation system of multi-gamma-source and the precise irradiation system of X-ray in accordance with the bidding law and the national regulations. The equipment has been handed over at the Institute's Division of measurement standards Level II since July 2020. However, due to the complicated Covid-19 pandemic, it is impossible for the technical experts from the US to arrive in Vietnam for machine installation. Thus, the project was delayed, leading to the extension of time in contract implementation to 2021.

### 1.4.3. CONSTRUCTION OF THE BUILDING OF THE TECHNICAL SUPPORT FACILITY TO ENSURE SAFETY, SECURITY AND ENVIRONMENTAL PROTECTION FOR NUCLEAR POWER DEVELOPMENT

In 2020, the construction drawing design was completed and the construction estimate was approved. Construction work was actively implemented. The pile, foundation, basement and steel-reinforced concrete formwork of 7 floors were finished. Steel-reinforced concrete of the 8th floor was expected to be done by December 31, 2020. The bidding packages for Supervision Consultant and Project Management were carried out as planned.

### 1.4.4. EQUIPMENT ENHANCEMENT PROJECTS

CANTI's equipment enhancement projects of 2019 was accepted in 2020. The project includes the automatic low-level background alpha/beta counting system, the Cobalt-60 radioactive source, the double-beam UV-Vis measuring device and the geoelectrical measurement system.

In terms of the project of adding Cobalt-60 source for research and application of radiation technology in 2020-2021 of HIC, the process of selecting a contractor was carried out. It is expected that in the fourth quarter of 2021, loading 200 kCi of Cobalt-60 source will be finished.

VINAGAMMA completed the project of designing, manufacturing and installing SVST/Co60-B irradiator control system, putting the equipment into operation on January 30,

2020. The project of purchasing 300 kCi of Cobalt-60 source to ensure and increase the source activity for two Cobalt-60 irradiators was ongoing.

The project of capacity building for laboratory of research and application of nuclear technology in health was approved under Decision No. 1417/QD-BKHCN dated May 26, 2020 of the Ministry of Science and Technology. INST carried out the procedures for appointing the contractor with the appraisal unit and the consultancy unit for the bidding documents, evaluated the tender documents for the equipment package and selected the contractor for the package of equipment procurement. However, in the process of developing the bidding documents for the equipment procurement package, INST applied for unit adjustment of one piece of equipment, and time adjustment of the contractor selection for the equipment bidding package in the 4th quarter of 2020. It took Ministry of Science and Technology a certain time for appraisal and decision of adjustment approval. Therefore, the project progress was delayed at that point. The bidding documents of the equipment procurement package was posted later on the national bidding network in the form of online public bidding. The next stage of the project was urgently done in December, 2020 and 2021.

The project on strengthening research capacity for laboratories of the IAEA-VINATOM Cooperation Center in 2021-2022, with a total proposed budget of VND 50 billion, was been submitted to Ministry of Science and Technology by VINATOM and was in the appraisal stage.

### 1.4.5. MINOR CONSTRUCTION AND MAJOR REPAIR PROJECTS IN 2020

The projects of renovation, repair and anti-degradation of VINATOM's headquarters and Institute for Technology of Radioactive Waste and Rare Elements were completed in December 2020.

The project of construction and restoration of fences and garages of INST was approved according to Decision No. 80/QD-VNLNT dated March 13, 2020 of VINATOM. The project objective was site clearance for the construction of the overpass at the intersection of Hoang Quoc Viet - Nguyen Van Huyen, Hanoi. The project was finished and put into use in the second quarter of 2020.

# 2- RESEARCH REPORTS 2020

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

# STUDIES TO EFFECTIVELY AND ECONOMICALLY USE FUEL AND ENHANCE RADIOISOTOPE PRODUCTION CAPABILITY OF THE DALAT NUCLEAR RESEARCH REACTOR

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**Project information:**

- **Project name: Studies to effectively and economically use fuel and enhance radioisotope production capability of the Dalat Nuclear Research Reactor**
- **Code: DTCB.10/19/VNCHN**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan 2019-Dec 2020)**
- **Contact mail: cuongnk.re@dnri.vn**
- **Published papers related to the project:**

1. Nguyen Kien Cuong, Huynh Ton Nghiem, Pham Quang Huy, Tran Quoc Duong, Vo Doan Hai Dang, and Bui Van Cuong, Calculation Results for Enhancing Ability of I-131 Radioisotope Production Using Tellurium Dioxide Target on the Dalat Nuclear Research Reactor, Nuclear Science and Technology, Volume (9), No. 3 (2019), pp.9-20. DOI: https://doi.org/10.53747/jnst.v9i3.39
2. Nguyen Kien Cuong, Le Vinh Vinh, Huynh Ton Nghiem, Luong Ba Vien, and Nguyen Nhi Dien, Steady-state thermal-hydraulic analysis of the LEU-fueled Dalat Nuclear Research Reactor, *Science and Technology of Nuclear Installation*, Volume 2021, Article ID 6673162.

The objective of the project is to carry out calculation studies to effectively use low enriched uranium (LEU) VVR-M2 fuel of the DNRR by refueling process at the end of the cycle of 92 LEU fuel assemblies (FAs) configuration and planning a refueling strategy for using existed 10 fresh LEU FAs. The fuel loading configurations of the DNRR were determined by using fuel loading pattern optimization code with combining of simulated annealing optimization algorithm [1] and 2-dimension, triangle map diffusion code. The main requirements of the calculation process are to determine fuel loading patterns that must satisfy with the operating limit conditions [2], increase the fuel burn-up, extend the operation time, and improve the ability of radioisotope production. The enhancement of the radioisotope production was also researched, tested, and implemented with the requirements of meeting operational safety and increasing I-131 radioisotope produced on the DNRR from 5 to 15% with 130 hours of reactor operation. Design calculation of lead container containing irradiated $TeO_2$ targets

aluminum containers was also performed. The requirements of radiation safety and ensuring maximum loading capacity of the crane in the reactor hall were satisfied too.

In the project framework, main research methods applied included experiments to measure neutron flux and spectrum at the neutron trap, wet channel 1-4 or two new irradiation channels using neutron activation method, and theoretical calculation computer codes about neutronics, thermal hydraulics, and safety analysis. In the design calculation of the lead container, the measured data of gamma dose rate at the container surface for each operation cycle was used to compare with calculation results. The computer codes were used in the project including MCNP6 code [3] with ENDF/B7.1 [4] data library for neutronics calculation, MCNP-REBUS system code [5] for fuel depletion calculation, ORIGEN2.1 code [6] for activity calculation and photon spectrum with 18 energy groups. In thermal-hydraulics analysis, the PLTEMP4.2 code [7] was used for safety analysis, and the RELAP5 code [8] was applied. In addition, the PIJ code (SRAC2006 system code [9]) was used to create group constants for optimization code applying simulated annealing algorithm and solving the 2–dimensional diffusion equation.

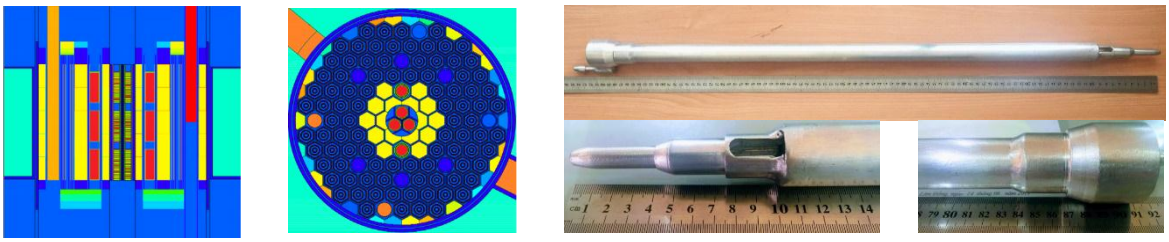

**Figure 1.** Calculation model of the reactor core with two new additional irradiation channels and a new irradiation channel

All computer codes using in the project were validated through design calculation of LEU core with 92 FAs and 12 beryllium rods located around neutron trap. The design calculation of new additional irradiation channels as well as all determined fuel loading patterns is based on the operating limit conditions denoted in the safety analysis report for the DNRR, such as maximum fuel cladding temperature (under $103^0$C), minimum Onset Nucleate Boiling Ratio (1,4) and Departure from Nucleate Boiling Ratio (1,5).

In the calculation to effectively use LEU fuel for the DNRR along with the determination of the fuel loading patterns strategy, the optimization code was applied together with the evaluation process by using MCNP6 code. Three core configurations loaded with 2, 4 or 6 FAs to replace beryllium rods around the neutron trap were identified through the calculated results. In the safety aspect, three core configurations were met safety requirements related to fuel cladding temperature and operational conditions. However, thermal neutron fluxes at the neutron trap for I-131 radioisotope production were reduced from 4.7 to 11.7% and 18.2%, respectively. For using fuel strategy, two core configurations were calculated in detail when replacing 4 or 6 FAs to 4 or 6 beryllium rods near neutron trap and then adding 6 or 4 FAs to fully replace all 10 beryllium rods. The calculation results showed that the total operation time for 2 options from 14,000 to 17,400 hours when using all 10 fresh LEU FAs with the nominal operation power of 500 kW. At present, the fuel loading pattern will be carried out in each step

with 2 FAs adding until the core configuration can be reached to 98 LEU FAs. And then the option of adding 4 fresh LEU FAs to replace the 4 highest burn-up FAs will be carried out. Maybe in 2023, 26 fresh LEU FAs will be bought and then 30 new LEU FAs will be remained for refueling at least 5 times by replacing 6 highest burnt FAs with the 6 fresh FAs. So the fuel loading strategy will be changed and the operation time of the DNRR will be extended until 2035 to serve the main objectives of research, training, radioisotope production as well as other applications.

The determination of loading patterns for using 10 fresh FAs strategy was implemented with 3 steps to add 6 fresh FAs to replace 6 beryllium rods until to reach core configuration with 98 LEU FAs and then adding the last 4 fresh FAs to replace 4 highest burn-up FAs. By such loading patterns, it will be possible to exploit the reactor effectively and the thermal neutron fluxes at irradiation positions will not be much changed suddenly. Furthermore, the necessary researches will be implemented such as changing the dimension of the irradiation targets container, adding more beryllium blocks inside the neutron trap to keep stable neutron flux and negative gradient of neutron flux will not so high when 10 beryllium rods replaced with 10 LEU burnt FAs. The optimization for fuel loading computer code was developed but having limitations when applying to find the best core configuration because all FAs will be shuffled inside the core. This means, the research and application of optimization algorithms are only for academic study but difficult to apply in practice.

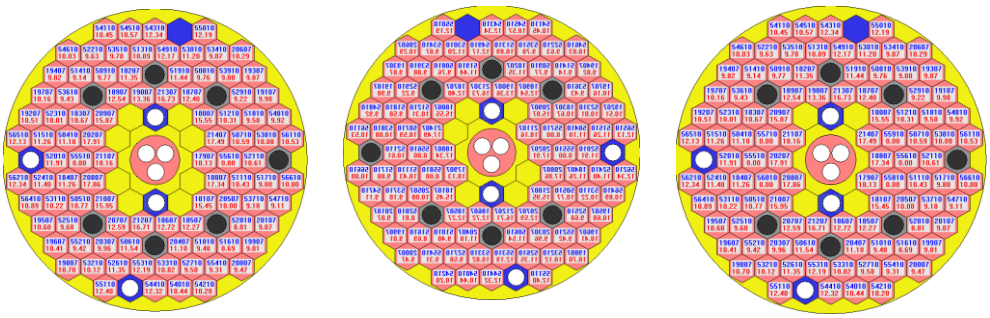

**Figure 2.** Core configuration when loading 2, 4 and 6 fresh FAs

With low operation power and neutron flux, the calculation to enhance radioisotope production on the DNRR is mainly dependent on the ability to increase the total mass of the $TeO_2$ targets inside the reactor core. The theoretical calculation was performed through examination of the existed irradiation channels currently and then creating 2 new irradiation channels to replace 2 beryllium rods at cells 5-6 and 9-6. The loading capacity of the $TeO_2$ targets in the reactor core was increased from 9 containers (each container has 220 g $TeO_2$) to 15 containers when having 2 new irradiation channels. Besides that, many options for enhancing radioisotope production were investigated, and after testing thought operation of 130 hours then reducing to 100 hours with rotating irradiation target containers in the core, the radiation production of I-131 was much higher than those when using only the neutron trap before. The testing of the new irradiation container having 24 cm long with $TeO_2$ target was also done but it was still difficult in case of loading 3 containers following axial direction, the top container will have the lowest thermal neutron flux. Therefore, the research will be continuous

for finding a reasonable solution for effectively using thermal neutron flux by the height of 60 cm as of the active core.

Design calculation for the lead container was conducted by taking into account of ensuring the radiation safety and maximum loading capacity of the crane in the reactor hall. The calculation results of the current lead container were directly compared with the measured data. The designed lead container has less than 650 kg in weight with 3 ways for carrying out: additional shielding to the old container, and construction of the new containers with 3 or 6 holes to keep irradiated targets containers. Due to the irradiation time of the target containers inside the reactor core was more than 400 hours with a cooling time of more than 2 days at each operation cycle of 100 hours, the gamma dose rate at the surface of the lead container is now not too high compared to that of the old container used in the previous procedure when the operation time of 130 hours with the cooling time of 10 hours. Currently, the maximum surface dose rate of the lead container with the irradiated target containers was only about 600 to 650 Sv/h compared to about 1800 Sv/h to 2000 Sv/h in the past.

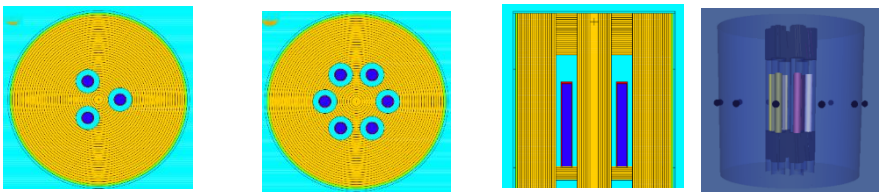

**Figure 3.** The calculation model for new lead containers with 3 and 6 holes

The next research direction will be focused on continuing the research to enhance the radioisotope production on the DNRR by re-designing the irradiation target container, adding more beryllium blocks at the neutron trap to reinforce the neutron slowing down material and reduce the decrease of thermal neutron flux when 10 beryllium rods will be replaced with 10 burnt LEU FAs. In addition, problems related to optimization for refueling should be developed to creating more options for finding optimal fuel loading patterns. The experiment of measuring fuel burn-up of LEU fuel type VVR-M2 should be done by gamma scanning or reactivity methods to get information about burn-up distribution as well as validation for burn-up computer code.

The results from the project were very important for reference in the process of refueling, extending operation time of the reactor with using fuel strategy, ensuring the ability to exploit and meeting the safety operation requirements. The optimal theory was applied in refueling but only having academy study but difficult to apply in practice because the huge of FAs will be shuffled in the reactor core to finding the best core with the highest excess reactivity and lowest radial power peaking factor. However, calculation results of fuel loading patterns are a very good reference to choose the most reasonable configuration in both to meet safety operation and effective utilization. The option to increase radioisotope production with different operation times and rotating irradiation target containers gave positive results and now the DNRR can supply more than 100 Ci I-131 each month. The design calculation of the lead container was also performed with taking into account of ensuring radiation safety as well as accordance with the crane capacity inside the reactor hall.

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[9] Keisuke OKUMURA, Teruhico KUGO, Kunio KANEKO and Keichiro TSUCHIHASHI, *SRAC2006: A Comprehensive Neutronics Calculation Systems*, JAEA, Japan, Febuary 2007.

# DEVELOPMENT OF A SIMULATOR FOR THE DALAT NUCLEAR RESEARCH REACTOR

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**Project information:**

- **Project name: Development of a simulator for the Dalat Nuclear Research Reactor**
- **Code: DTCB. 03/18/TTHN**
- **Managerial level: Ministry**
- **Implementation time: 36 months (Jan 2018 - Dec 2020)**
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- **Published papers related to the project:**

1. Cao Thanh Long, Truong Hoang Tuan, Huynh Dong Phuong, Nguyen Hoang Nhat Khang, Ho Manh Dung; Verification of a real-time interactive transient simulator for Dalat Nuclear Research Reactor; Nuclear Science and Technology (NST), Vol 10(4), 2020, 7p. DOI: https://doi.org/10.53747/jnst.v10i4.10
2. Truong Hoang Tuan, Cao Thanh Long, Huynh Dong Phuong, Ho Manh Dung; Development of a Real-time Simulation RELAP/SUNDIALS Code for Dalat Nuclear Research Reactor; the 22nd IEEE NPSS Real Time Conference, held virtually, October 2020, 8p.

Nuclear reactor simulation systems play an important role in operator training, research on safety analysis, thermal-hydraulic, automatic control, and protection system design. In addition to full scope simulators describing the entire real systems, basic principle simulators have also been designed and developed for educational purposes. Numerous scientific, educational and training organizations in the world have developed basic principle simulators for nuclear research reactor studies. Ricardo Pinto de Carvalho and Jos□Rubens Maiorino built a simulation system for Brazil's IEA-R1 nuclear research reactor in 2006, which allows simulation in real-time of start-up, power maneuver, and shutdown. The Korea Atomic Energy Research Institute (KAERI) developed a real-time simulation system for High-flux Advanced Neutron Application Reactor (HANARO) in Korea and Jordan Research and Training Reactor (JRTR) in Jordan for operator training in 2014. They also studied to construct a web-based nuclear reactor simulator using the best-estimate nuclear system analysis code RELAP5 as the core program and LabVIEW for the real-time interactive interface in 2007. In Vietnam,

there are many activities of learning and utilizing nuclear reactor simulators for research and educational purposes. However, these simulators are mainly for commercial nuclear power plants and sponsored by other countries such as the real-time OPR 1000 core simulator (Dalat University) and the VVER-1200 nuclear power plant simulator (Nuclear Training Center - VINATOM). As a result, the development of a simulation system for Dalat Nuclear Research Reactor (DNRR) is an essential role in supporting the operational training and educating students. Furthermore, it also retains valuable knowledge and experience gained from research and operating activities on DNRR. The development of the first real-time transient simulator for DNRR (in short DalatSim) in Vietnam was researched and performed at the Center for Nuclear Technologies. This simulator allows users to simulate operating procedures in normal conditions and several hypothetical transient accidents of DNRR including Reactivity Insertion Accident (RIA), Loss of Coolant Accident (LOCA), Loss of Flow Accident (LOFA).

DalatSim consists of two main modules: the physics core module and the driver module. These modules exchange necessary data interactively to form a complete simulation program. The functions and data transfer are displayed in Figure 1.

- The physics core module solves neutron kinetics and thermal-hydraulic problems for each time step required by the driver module for both steady-state and transient processes of DNRR. Consequently, it provides the required parameters for the driver module for control and display functions of DalatSim. The module was developed based on RELAP5/MOD3.3 code. A bug occurs inside the embedded point reactor kinetics module of RELAP5/MOD3.3 resulting in nonphysical reactor power curves when applying small calculation time steps. To solve that problem, the embedded module was replaced with SUNDIALS solver. The coupled code RELAP/SUNDIALS has been verified with benchmarks for point kinetics equations and proven to produce up to nine-decimal-place accurate results.

- The driver module is responsible for controlling the execution of DalatSim and comprises two main modules: the control module, and the human-machine interface (HMI) module. The control module simulates the reactor control and protection system of DNRR. The module was designed based on the logic circuit of the actual control and protection system. The HMI module, which was designed to be as identical as possible to the real control panel of DNRR, includes graphical interfaces that help users to interact with DalatSim (Fig. 2). Besides, an auxiliary “realism” module is required to prepare and process input data for the physics core, retrieve and display the calculation data from the physics core module to the HMI module in real-time, simulate the actual three monitoring channels of DNRR, etc.

The Hypertext Transfer Protocol (HTTP) was used to exchange parameters/data between the physics core and the driver module. The driver module, as a client, sends requests for necessary control or display parameters to the physics core. On the other hand, the physics core, as a server, will return the required calculated parameters for further simulation performance.

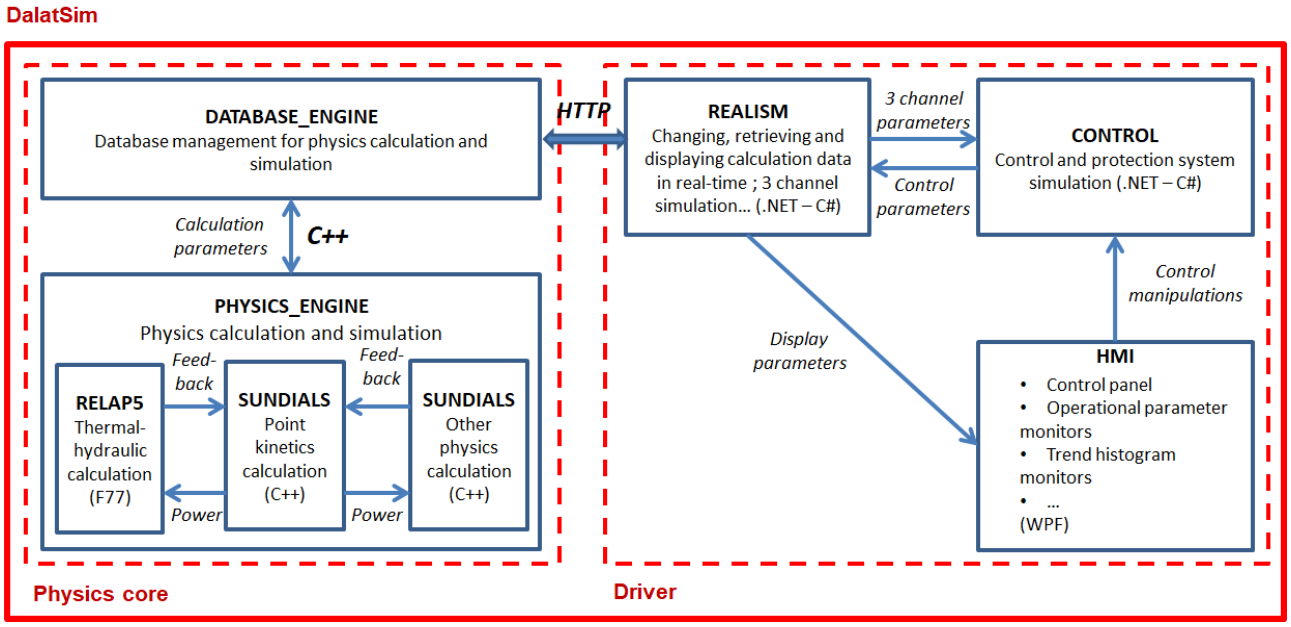


**Figure 1.** Design diagram of DalatSim

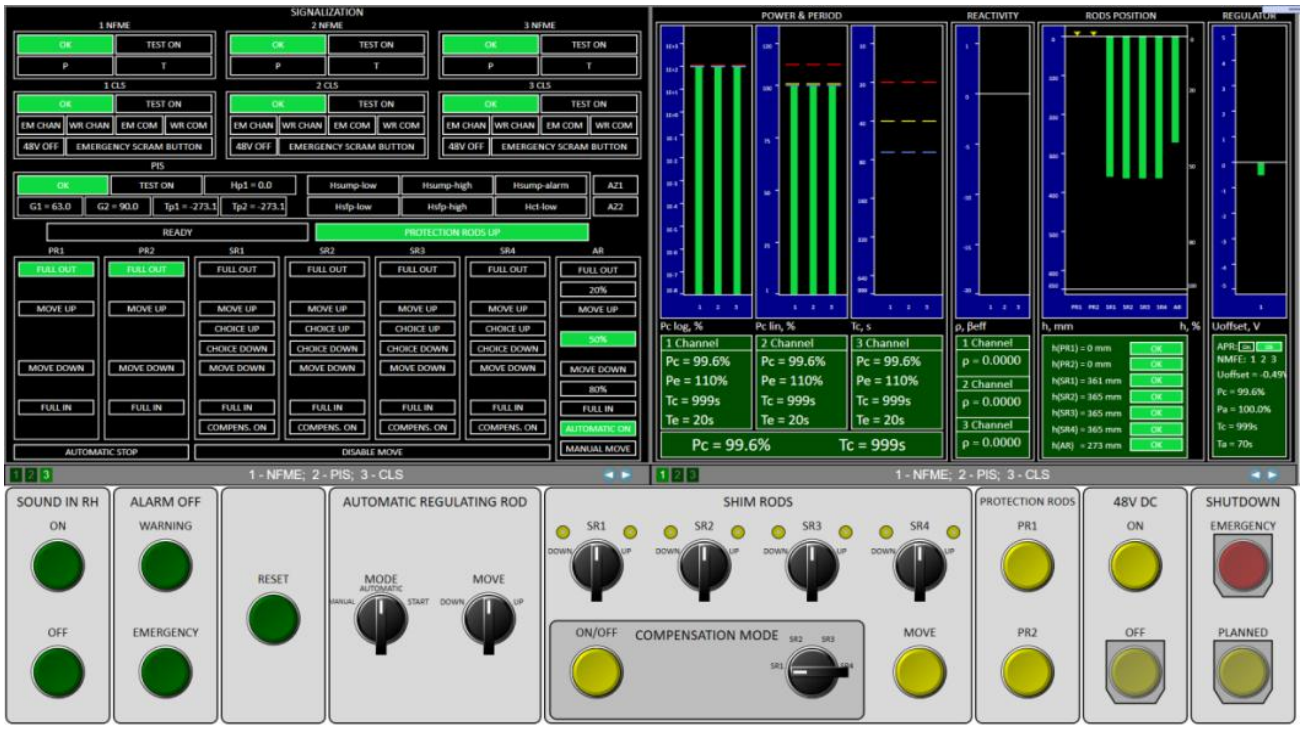


**Figure 2.** Part of HMI module of DalatSim

To evaluate the capability and fidelity of DalatSim, the verification was performed by simulating a start-up process of DNRR. The start-up process includes changing the reactor from subcritical to critical state; raising the reactor power to required levels of 0.5%, 50%, 80%, and finally 100% of nominal power (500 kW). All operations during the simulation were carried out according to the start-up procedure for DNRR.

The comparison shows that the time to reach each required power level and the waiting duration at power levels of 50%, 80% of nominal power depend on the operator's experience.

In reality, operators operated the reactor with a higher reactor period for safety purposes, which leads to a longer time to reach the desired power levels compared with our simulation as shown in Figure 3. In our simulation, the simulator was manipulated with a lower reactor period but still higher than 70 seconds, which complies with the start-up procedure for DNRR. Figure 3 also shows that the reactor power curves are not identical but their shapes are similar. Therefore, the real-time simulation of a start-up process of DNRR can be achieved with DalatSim. The simulator can automatically maintain the reactor power at each required power level as expected as illustrated clearly in Figure 3.

The verification result shows that the computational capability of DalatSim can meet the requirement of real-time transient simulation of DNRR. The verification also emphasizes that DalatSim can be a suitable tool to support effectively basic operator training and nuclear education for trainees from VINATOM subsidiary units as well as local university students. Moreover, the research to build this simulator is a meaningful contribution to the development of nuclear research reactor modeling and simulation capabilities in Vietnam in the future.

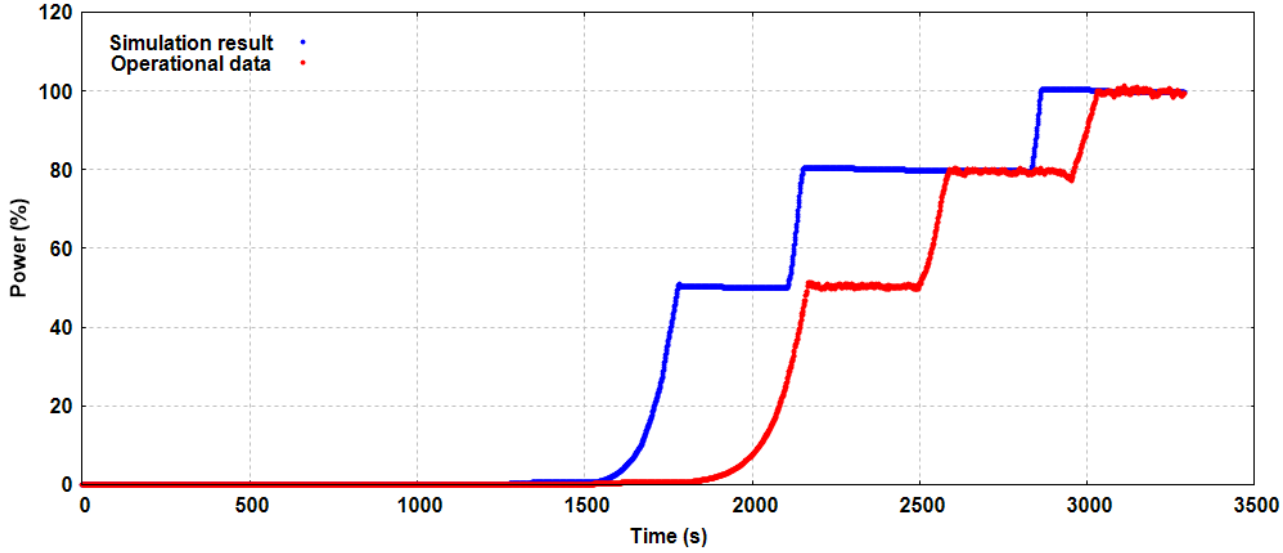


**Figure 3.** The comparison between simulation result and operational data of reactor power

To optimize the performance of DalatSim, the installed computers should meet the minimum system requirements shown in below table.

**Table 1.** Minimum system requirements for DalatSim

| | |
|---|---|
| Central Processing Unit (CPU) | Intel core i7-8700, frequency of 4.0 Hz |
| Operating system | Windows 10 |
| Random Access Memory (RAM) | 16 GB |

| | |
|---|---|
| Storage space | 1 GB |
| Graphics Processing Unit (GPU) | NVIDIA GeForce GTX 1060 6GB |
| Monitors | 2 monitors, 16:9 aspect ratio, resolution of 1920x1080 |

Future work will involve developing the 3D nodal neutronics model of DalatSim's physics core to enhance its fidelity and accuracy. The number of current simulation exercises is limited, thus it should be increased in the future. Besides, additional calculation data displaying, exporting features should be included to further facilitate the user's simulation analysis.

# NEUTRONICS ANALYSIS OF THE DALAT NUCLEAR RESEARCH REACTOR WITH THE PARCS AND SERPENT CODES

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**Project information:**

- **Project name: Study on kinetics and reactivity initiated accidents (RIAs) of the Dalat Nuclear Research Reactor (DNRR) loaded with low enriched uranium (LEU) fuel using PARCS**
- **Code: DTCB.06/18/VKHKTHN**
- **Managerial level: Ministry**
- **Implementation time: 30 months (Jan 2018 - June 2020)**
- **Contact email: hapnv0915@gmail.com**
- **Published papers related to the project:**

1. Viet-Phu Tran, Kien-Cuong Nguyen, Donny Hartanto, Hoai-Nam Tran, Vinh Thanh Tran, Van-Khanh Hoang, Pham Nhu Viet Ha, "Development of a PARCS/Serpent Model for Neutronics Analysis of the Dalat Nuclear Research Reactor," Nuclear Science and Techniques, ISSN: 1001-8042, accepted for publication (2020).
2. Nguyen Kien Cuong, Nguyen Thi Dung, Tran Viet Phu, Nguyen Huu Tiep, Pham Nhu Viet Ha, "Modeling of the Dalat Nuclear Research Reactor (DNRR) with the Serpent 2 Monte Carlo Code," Nuclear Science and Technology, ISSN 1810-5408, Vol.9, No. 3 (2019), pp. 21-29.
3. Tran Viet Phu, Nguyen Thi Dung, Nguyen Kien Cuong, Nguyen Huu Tiep, Pham Nhu Viet Ha, "Modeling and Group Constants Generation of the Dalat Nuclear Research Reactor using Serpent 2 and MCNP6," The IAEA Technical Meeting on Computational Benchmarks for Research Reactor Fuel Burnup and Activation Code, IAEA, Vienna, Austria, 02-06 September 2019.

4. Nguyen Thi Dung, Nguyen Kien Cuong, Tran Viet Phu, Nguyen Huu Tiep, Pham Nhu Viet Ha, “Modeling of the Dalat Nuclear Research Reactor with the Serpent 2 Monte Carlo Code,” The 13th Vietnam Conference on Nuclear Science and Technology (VINANST13), Ha Long, Viet Nam, 07-09 August 2019.
5. Ta Duy Long, Nguyen Hoang Tu, Nguyen Thi Dung, “Preliminary Study on Modeling the Dalat Nuclear Research Reactor and Generating the Multi-Group Cross-Section for Three Dimensional Reactor Kinetics Calculations,” The 5th Nuclear Science and Technology Conference for Young Researchers, Hanoi, Viet Nam, 03-04 October 2018.

In this study, neutronics analysis of a research reactor type TRIGA Mark-II loaded with the Russian VVR-M2 fuel (called the Dalat Nuclear Research Reactor or DNRR) was performed using the PARCS and Serpent 2 codes (hereinafter called PARCS/Serpent or PARCS) in relation to the reference Serpent, RELAP5 and measured results. The comparative results are expected to reveal the applicability of PARCS/Serpent for further steady-state and transient analyses of the DNRR aimed at updating the safety analysis report of the DNRR for its operation extension in the coming years.

The FDM (Finite Difference Method) solver of PARCS was selected for the DNRR full-core two-group diffusion calculations. The full-scale DNRR model with Serpent 2 was proposed to generate the homogenized few-group cross-sections for full-core diffusion calculations with PARCS and to verify the PARCS/Serpent results at steady states. Furthermore, the effective point kinetics parameters of the DNRR calculated by Serpent that are needed for transient calculations with PARCS were compared against the measured ones. It is noted that the full-scale modeling of the DNRR with Serpent could eliminate the need of neutron leakage correction for small reactor cores and allows the use of the out-scatter approximation for calculations of the diffusion coefficients for the DNRR. To ensure the accurate solution of the FDM solver of PARCS when the highly absorbing material $B_4C$ is present in the active core, the supercell model with Serpent in which the absorption part of a shim or safety rod was homogenized with the surrounding fuel bundles was proposed to generate the homogenized cross-sections of the shim/safety rods and the neighboring fuel bundles when these control rods are inserted in the active core.

For transient calculations with PARCS in standalone mode, the TH (thermal-hydraulic) card of PARCS for the PWR (pressurized water reactor) reactor type was applied herein. However, the default parameters in this TH card for PWRs do not match the TH parameters of the DNRR. Similar issue was also reported for the LVR-15 research reactor (A. Dambrosio et al., Neutronic analysis of the LVR-15 research reactor using the PARCS code. Ann. Nucl. Energy 117, 145-154 (2018)). To enable this TH card work for the DNRR, a major modification was made to this card: the inlet coolant temperature was set to 130°C. The inlet coolant temperature of 130°C is unrealistic for the DNRR as the real value is ~32°C. However, if the inlet coolant temperature was set to a value below 130°C, the convergence could not be reached for transient calculations with PARCS. For that reason, this approximation allows to

perform transient analyses of the DNRR with PARCS in comparison to the simulation results obtained by RELAP5 and the measured results from neutronic viewpoint.

Good agreement was found between the keff, core power distributions and control rod worths obtained with PARCS and Serpent at steady statesas well as between the effective kinetics parameters calculated by Serpent and the experimental results attained in this study.

The simulation results obtained with PARCS (this study) and RELAP5 (L.B. Vien et al., Design analyses for full core conversion of the Dalat Nuclear Research Reactor. Nucl. Sci. Tech., ISSN 1810-5408, 4 (1), 10-25 (2014)) for a scenario of uncontrolled withdrawal of the shim rod ShR1 from the DNRR core are illustrated in Figures 1 and 2, respectively. In this scenario, it is assumed that the withdrawal speed for ShR1 was 3.4 mm/s and the transient started from the full power (FP) condition of the DNRR. In addition, the transient scenarios when (1) raising the power of the DNRR from 80% to 100% FP and (2) introducing a small positive reactivity (<10 cents) into the DNRR was also analyzed using PARCS/Serpent in relation to the experimental results obtained in this work.

Comparing Figures 1 and 2 shows that, for a fast transient with the overpower setting value of 110% FP, the time at which the power reached 110% FP simulated using PARCS and RELAP5 were found both around 3.4 s. However, if a fast period scram signal appeared instead of the overpower scram signal at 110% FP (i.e., the reactor scram appeared at 15.03 s in this case), the difference in the power values predicted by PARCS and RELAP5 at 15.03 s became considerable. Such discrepancy can be explained by (1) the difference in simulating the TH feedbacks in the PARCS and RELAP5 models for the DNRR and (2) the different kinetics models used in PARCS (3D kinetics) and RELAP5 (point kinetics) for the DNRR.

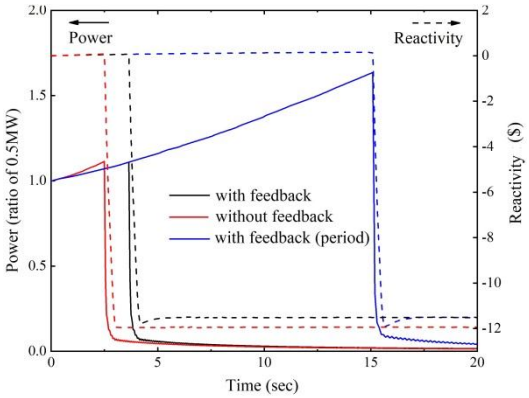


**Figure 1.** Simulation of the uncontrolled withdrawal of ShR1 with PARCS

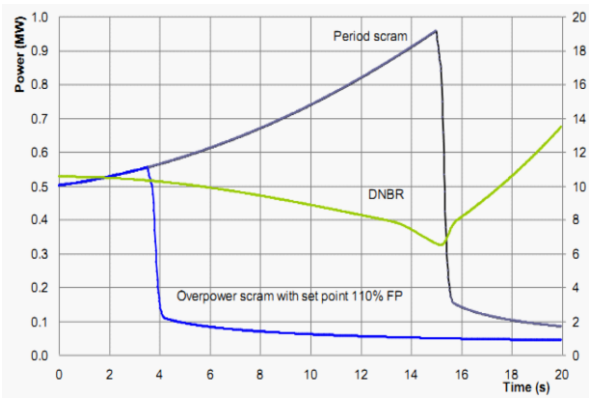


**Figure 2.** Simulation of the uncontrolled withdrawal of ShR1 with RELAP5

Besides, the capability of PARCS in simulating transients of the DNRR was also demonstrated, from neutronic viewpoint, for the case of raising power from 80% to 100% FP. However, the comparison between PARCS and RELAP5 for a longer transient as mentioned above (e.g., initiating a fast period scram signal instead of the overpower scram signal at 110% FP) as well as between PARCS and the measured results for the case of introducing a small positive reactivity into the DNRR showed that the approximation of the TH feedbacks used in

the PARCS/Serpent model for the DNRR should be significantly improved for accurate transient calculations of the DNRR.

Consequently, the results indicate the applicability of the PARCS/Serpent model proposed here for further steady-state and transient analyses of the DNRR. In addition, the cross-section homogenization approach based on the full-scale DNRR model with Serpent and the supercell model developed has the flexible capability of analyzing the full-range of operating states of the DNRR thanks to the automated burnup sequence for cross-section homogenization of Serpent. It is also noteworthy that another flexibility of the PARCS/Serpent model for the DNRR is that it can be directly coupled with the U.S. NRC thermal hydraulics system code TRACE or RELAP5 for 3D coupled neutron kinetics/thermal hydraulics calculations of the DNRR. In future work, the PARCS/Serpent model for the DNRR is being planned to be further improved as well as validated against experimental data during reactor startup, and thereafter applied to transient and safety analyses of the DNRR.

# STUDY ON FUEL DESIGN FOR THE LONG-LIFE CORE OF ACPR50S NUCLEAR REACTOR

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**Project information:**

- **Project name: Studying and designing of fuel for long-life core in China's ACPR50S nuclear reactor**
- **Code: CS/20/04-04**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020 - Dec 2020)**
- **Contact email: hvkhanh21@gmail.com**
- **Published papers related to the project:**

1. Hoang Van Khanh et al., Neutronic analysis of fuel design for the long-life core in a pressurized water reactor. Nuclear Science and Technology. DOI: https://doi.org/10.53747/jnst.v11i1.127
2. Hoang Van Khanh, Tran Vinh Thanh, Cao Dinh Hung, Pham Nhu Viet Ha. Neutronic analysis of fuel design for the long-life core in a pressurized water reactor. Conference on Nuclear Science and Technology for Young Researchers in Atomic energy area.

Small Modular Reactors (SMR) and their applications are receiving more attention from the nuclear community. One of the applications is the use in floating nuclear power stations, however, floating nuclear power stations are potentially at risk and requires higher level of safety. In addition to the combination of active and passive safety systems, the use of accident tolerant fuel (ATF) by improving or replacing fuel ceramic materials and use other fuel cladding materials has been studied in order to improve the safety. As a result, the operators will has more time to respond to events, that could result in the release of fuel material and fission products. The project focuses on studying and designing a fuel with high burn-up for the ACPR50S reactor - the type of reactor expected to be installed on China's floating nuclear power stations.

Calculations of the project were performed using the SRAC2006 code. This is a program to calculate neutron transport using deterministic methods. The calculation includes: (1) neutronic characteristics of the ACPR50S reactor fuel; (2) effect of the enrichment and pitch-to-diameter ratio (P/D) the fuel cell on fuel rods and fuel assemblies using fuel types as $UO_2$, UNO, UNSi and SiC fuel cladding; (3) neutronic characteristics when using burnable-poison to reduce the reactivity of fuel rods or fuel assemblies.

Calculation results are showed in Table 1 and Table 2. The characteristic values for the fuel cell using different fuel types and the P/D ratio are shown in Table 1. Increasing fuel enrichment leads to the increase of burnup and $k_{inf}$ values at the beginning of the fuel cycle (BOC). It can be seen that fuel with enrichment greater than 15 wt%. and with the pitch-to-diameter ratio P/D = 1.27 can be used in designing fuel with a high burnup.

**Table 1.** Fuel cell characteristics versus P/D and $U_{235}$ enrichment

| Enrichment | Max. burnup, [GWd/t] | | | P/D for burnup ≥ 100 GWd/t | | | k-inf at BOC, [-] | | |
|---|---|---|---|---|---|---|---|---|---|
| [wt. %] | UNO | UNSi | $UO_2$ | UNO | UNSi | $UO_2$ | UNO | UNSi | $UO_2$ |
| 4.45 | -- | -- | 30.0 | -- | -- | -- | -- | -- | 1.3950 |
| 5.00 | 40.0 | 40.0 | 40.0 | -- | -- | -- | -- | -- | -- |
| 10.00 | 80.0 | 82.5 | 80.0 | -- | -- | -- | -- | -- | -- |
| 15.00 | > 120 | > 120 | > 120 | 1.25-1.95 | 1.35-1.95 | 1.25-1.85 | 1.5224-1.6984 | 1.5693-1.6984 | 1.5368-1.6959 |
| 17.50 | > 120 | > 120 | -- | 1.15-1.95 | 1.15-2.05 | -- | 1.4789-1.7151 | 1.4779-1.7156 | -- |
| 20.00 | > 120 | > 120 | > 120 | 1.15-2.05 | 1.25-2.05 | 1.15-1.95 | 1.4977-1.7268 | 1.5474-1.7267 | 1.5062-1.7265 |

Table 2 shows the calculation results for $UO_2$, UNO fuel with the enrichment of 15 wt%. and UNSi with enrichment of 17.5% wt. in which Erbium is used as a burnable poison to reduce the excess reactivity value. The results show that for $UO_2$ fuel 15% wt. and UNSi 17.5% wt. the burnup poison addition is from 1.5% to 2.5%, and for UNO fuels the burnup poison addition for 1.5%, the fuel can achieve the target of 100 GWd/tHM.

**Table 2**. Fuel cell and fuel assembly characteristics for various fuel compositions

| | 15 wt. % - UO2 | | | | 15 wt. % - UNO | | | | 17.5 wt. % - UNSi | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Er2O3 | k-inf at BOC | | Max. burnup | PPF | k-inf at BOC | | Max. burnup | PPF | k-inf at BOC | | Max. burnup, | PPF |
| | Fuel cell | FA | [GWd/t] | | Fuel cell | FA | [GWd/t] | | Fuel cell | FA | [GWd/t] | |
| 0.0 | 1.5568 | 1.5805 | -- | -- | 1.5394 | 1.5639 | -- | -- | 1.5419 | 1.5653 | -- | -- |
| 0.5 | 1.4770 | 1.5015 | -- | -- | 1.4693 | 1.4939 | -- | -- | 1.4847 | 1.5076 | -- | -- |
| 1.0 | 1.4145 | 1.4389 | -- | -- | 1.4138 | 1.4380 | -- | -- | 1.4387 | 1.4607 | -- | -- |
| 1.5 | 1.3631 | 1.3870 | 100.0 | 1.090 | 1.3678 | 1.3912 | 100.0 | 1.090 | 1.4001 | 1.4212 | 110.0 | 1.091 |
| 2.0 | 1.3194 | 1.3426 | 100.0 | 1.090 | 1.3285 | 1.3511 | 97.5 | 1.091 | 1.3668 | 1.3870 | 110.0 | 1.091 |
| 2.5 | 1.2814 | 1.3038 | 100.0 | 1.091 | 1.2941 | 1.3159 | 97.5 | 1.092 | 1.3375 | 1.3568 | 110.0 | 1.091 |
| 3.0 | 1.2478 | 1.2694 | 97.5 | 1.091 | 1.2636 | 1.2845 | 95.0 | 1.092 | 1.3112 | 1.3296 | -- | -- |
| 3.5 | 1.2175 | 1.2382 | 97.5 | 1.092 | 1.2360 | 1.2560 | 92.5 | 1.092 | 1.2873 | 1.3048 | -- | -- |
| 4.0 | 1.1899 | 1.2098 | 95.0 | 1.092 | 1.2108 | 1.2300 | 95.0 | 1.092 | 1.2653 | 1.2821 | -- | -- |
| 4.5 | 1.1645 | -- | -- | -- | 1.1875 | -- | -- | -- | 1.2449 | -- | -- | -- |
| 5.0 | 1.1410 | -- | -- | -- | 1.1659 | -- | -- | -- | 1.2259 | -- | -- | -- |
| 5.5 | 1.1191 | -- | -- | -- | 1.1456 | -- | -- | -- | 1.2080 | -- | -- | -- |
| 6.0 | 1.0984 | -- | -- | -- | 1.1266 | -- | -- | -- | 1.1911 | -- | -- | -- |
| 6.5 | 1.0790 | -- | -- | -- | 1.1085 | -- | -- | -- | 1.1750 | -- | -- | -- |
| 7.0 | 1.0605 | -- | -- | -- | 1.0914 | -- | -- | -- | 1.1596 | -- | -- | -- |
| 7.5 | 1.0430 | -- | -- | -- | 1.0751 | -- | -- | -- | 1.1449 | -- | -- | -- |
| 8.0 | 1.0263 | -- | -- | -- | 1.0594 | -- | -- | -- | 1.1308 | -- | -- | -- |

Thus, it is possible to design the fuel to achieve burnup of 100GWd/tHM without compromising the safety parameters by using $UO_2$, UNO fuel with 15% wt., UNSi, 17.5% wt; 1.5 to 2.5 % of Erbium as burnable poison addition; P/D ratio = 1.27 and using SiC as fuel cladding.

The project provided knowledge about the ACPR50S reactor as well as the neutronic characteristics of the ACPR50S reactor fuel. The project has studied and designed fuel with high burnup of 100GWd/tHM for the ACPR50S reactor. In the future study, this preliminary study would be refined and extended including full-core coupled neutronic-thermal-hydraulic analysis, stability analysis, transients, and accidents analysis.

# STUDY AND CALCULATION ON THE APPLICABILITY OF IN-VESSEL MELT RETENTION STRATEGY FOR VVER1000

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**Project information:**

- **Project name: Study and calculation on the applicability of In-Vessel melt Retention strategy for VVER1000**
- **Code: DTCB.04/18/TTNTC**
- **Managerial level: Ministry**
- **Implementation time: 30 months (January 2018- June 2020)**
- **Contact email: longdoanmanh28@gmail.com**
- **Paper published in related to the project:**

1. Doan Manh Long, 2018, "Study on IVR strategy for VVER1000/V320 reactor in case of SBO accident," The 5th Conference on Nuclear Science and Technology for Young Researchers, Ha Noi.
2. Doan Manh Long et al., 2019 "Evaluation on In-Vessel melt Retention for VVVER1000 reactor under SBO accident," The 13th Vietnam Conference on Nuclear Science and Technology, Ha Long, August 7-9.
3. Doan Manh Long et al., 2019 "A study on safety margin of In-Vessel melt Retention for VVER1000 reactor," 18th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-18), Portland, USA, August 18-23.
4. Doan Manh Long et al., 2020 "Analysis of in-vessel accident progression in VVER1000 NPP during SBO accident with external reactor vessel cooling method," Nuclear Science and Technology, Vol.10, No.2(2020), pp.01-14. DOI: https://doi.org/10.53747/jnst.v10i2.32
5. Doan Manh Long et al., 2020 "An analysis of In-Vessel Melt Retention strategy for VVER-1000 considering the effect of torospherical lower head vessel," Journal of Nuclear Engineering and Design 371 (2021) 110972.

The content of this project is a next step from the results of institutional level project in 2017 [**1**], in order to take a step into in-depth research on nuclear safety analysis, especially is on severe accident. The project focused on evaluation the applicability of In-Vessel melt Retention through External Reactor Vessel Cooling (shortly called IVR) for VVER1000 reactor in case of the Large Break Loss of Coolant Accident (LBLOCA) simultaneously happening with

Station Black-Out (SBO) accident, shortly called LBLOCA accident. The simulation and calculation tools included the severe accident MELCOR 1.8.6 code, the computational ANSYS Fluent program and an analytical MIVR model. The MIVR (Modified IVR) was developed from the originally analytical IVR model which was firstly proposed by Prof. Theofanous and his colleagues [**2**], with the aim of adoption for a two-layer molten pool bounded by a semi-elliptical lower head like the shape of VVER1000 lower head vessel (Figure 1).

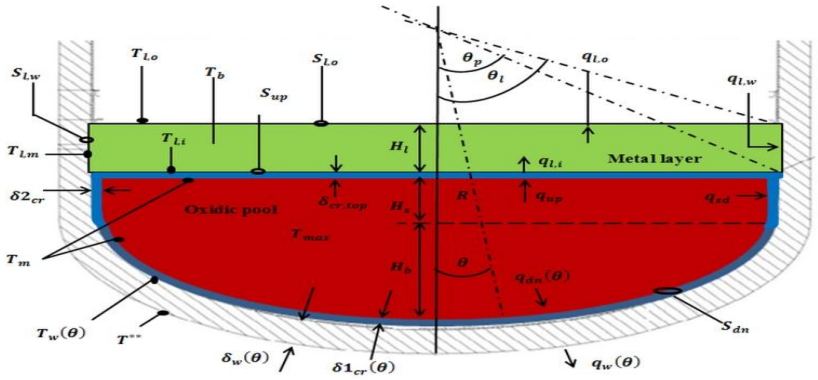


**Figure 1.** Demonstration of a molten pool in elliptic-shaped lower plenum of VVER1000 reactor vessel

In this calculation, the MELCOR 1.8.6 code was used to analyze the VVER1000 in-vessel severe accident progression with the aim of providing initial parameters of debris bed configuration, which can be established in VVER1000 lower plenum during the LBLOCA consequence, for calculation of ANSYS Fluent and MIVR model. The ANSYS Fluent calculation was an intermediate step in order to determine the time when the debris bed completely melted and formed a molten pool. The MIVR model was applied to predict the heat load imposed into VVER1000 lower head vessel the molten pool.

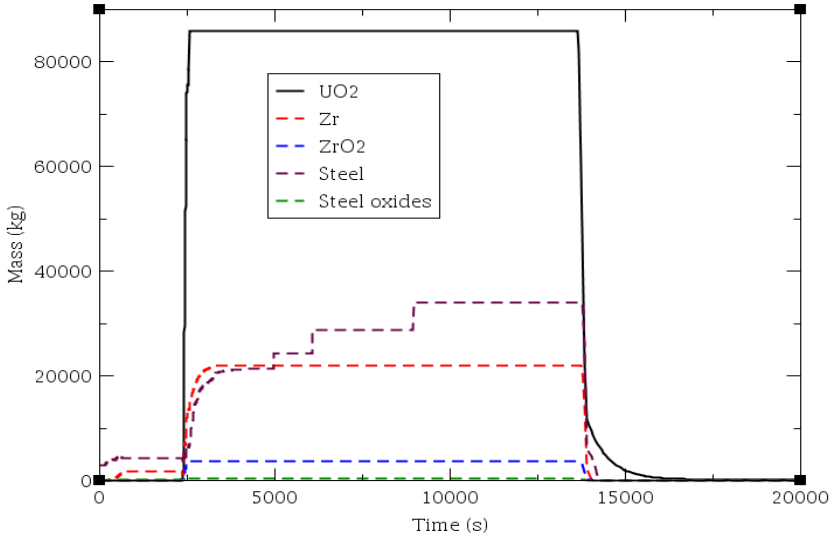


**Figure 2.** The evolution of debris in VVER1000 lower plenum during LBLOCA1 scenario

The results obtained from MELCOR calculation showed the damage of reactor core early happened at 134 seconds since initiation of the accident even water still existed in here. The

additional water supplied into reactor vessel from four hydro-accumulators were not enough to maintain water volume in there, and the reactor core totally dried out at 2000 seconds. As a result, the core debris early appeared in VVER1000 lower plenum at 2400 seconds. The evolution of core debris in VVER1000 lower plenum is showed in figure 2. The failure time of bottom part of core barrel was a reference point to quantify the configuration of core debris bed establishing in VVER1000 lower plenum. The calculation of MELCOR 1.8.6 indicated the failure of bottom part of core barrel occurred at 5000 seconds. An assumption was made for the configuration of core debris is the stratification has been occurred with a complete molten metallic layer above a solid oxide bed. The configuration has been called LBLOCA configuration since then and its information is presented in table 1. The decay power was assumed to be located entirely in oxide bed.

**Table 1.** The parameters of geometry of LBLOCA molten pool configuration

| Material | Mass (kg) | Density ($kg/m^3$) | Volume ($m^3$) | Height (m) | Volumetric heat density ($MW/m^3$) |
|---|---|---|---|---|---|
| Oxide | 89940 | 7560 | 11.9 | 0.965 (elliptic part)<br>0.362 (cylindrical part) | 2.46 |
| Metal | 46000 | 6500 | 7.08 | 0.52 | 0 |

The calculation of ANSYS Fluent was performed with the aim of determining the time when the LBLOCA configuration was completely molten. The assumption for initial state of stratified debris bed was: the metallic layer was totally melted with temperature of 1800$^o$K; and the oxide bed was at solid state with temperature of 2000 $^o$K. The emissivity of the top surface of metallic layer was taken as 0.45. For lower head wall, the thermo-physical properties was resembled the metallic layer except the conductivity coefficient was taken as 32 W/m.K. The solidification and liquidation temperature of metallic layer and oxide bed are 1700/1750 $^o$K and 2700/2750 $^o$K respectively.

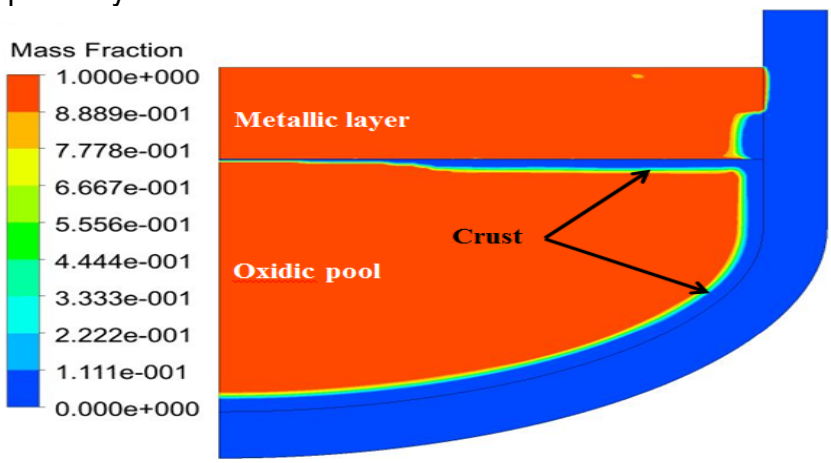


**Figure 3.** Demonstrate the meshing scheme and physical state of SBO configuration

The calculation from ANSYS Fluent showed the oxide bed was totally liquidated at 2000 seconds since stratification and 7000 seconds since initiation of the accident. Figure 3 presents the physical state of LBLOCA configuration at 7000 seconds. The oxide pool and metal layer are at liquid state with displaying color of red, and the lower head vessel wall and the crust surrounding the pool are at solid state with the blue color.

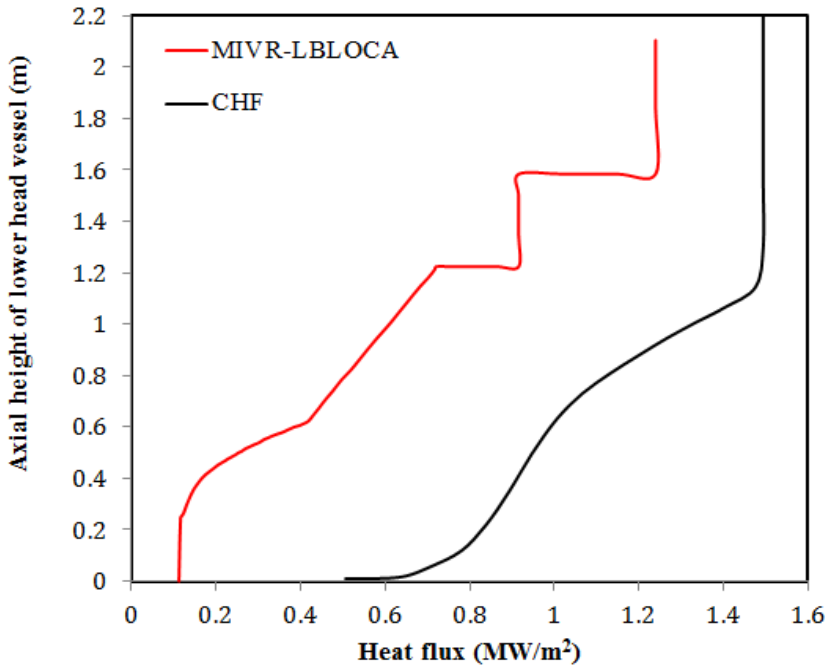


**Figure 4.** Prediction of MIVR model on heat flux distribution on VVER1000 external vessel caused by LBOCA pool and the CHF

The calculation of MIVR model started from 7000 seconds since initiation of the accident, at which the debris bed was completely molten as predicted by ANSYS Fluent calculation. At that time, the decay heat power decreased to 26.5 MW and the corresponding power density was 2.23 MW/m$^3$. The prediction of heat flux distribution on VVER1000 external lower head vessel at 7000 seconds imposed by LBLOCA molten pool is shown in figure 4 which indicates the heat flux distribution is increased along the external surface of lower head wall and the heat peak value is 1.24 MW/m$^2$ – as a result of focusing effect caused by metallic layer. The CHF is also presented in figure 4 which points out the heat flux imposed by LBLOCA pool is smaller than the CHF. Therefore, in term of thermal load, the IVR strategy could protect VVER1000 lower head vessel from failure. However, the gap between the heat peak value of 1.24 MW/m$^2$ and the CHF maximum value of 1.49 MW/m$^2$ is small, and unlikely secures the success of the IVR strategy in term of probabilistic study.

The heat flux distribution on VVER1000 external surface of lower head wall predicted by MIVR model was compared to the results presented in the report of the European Joint Research Center (JRC) [3] which were obtained from calculation tools as ASTEC v2.1 and SOCRAT/B1 of Kurchatov Institute, ASTEC v2.1beta of IVS Institute and ANSYS CFX of JRC.

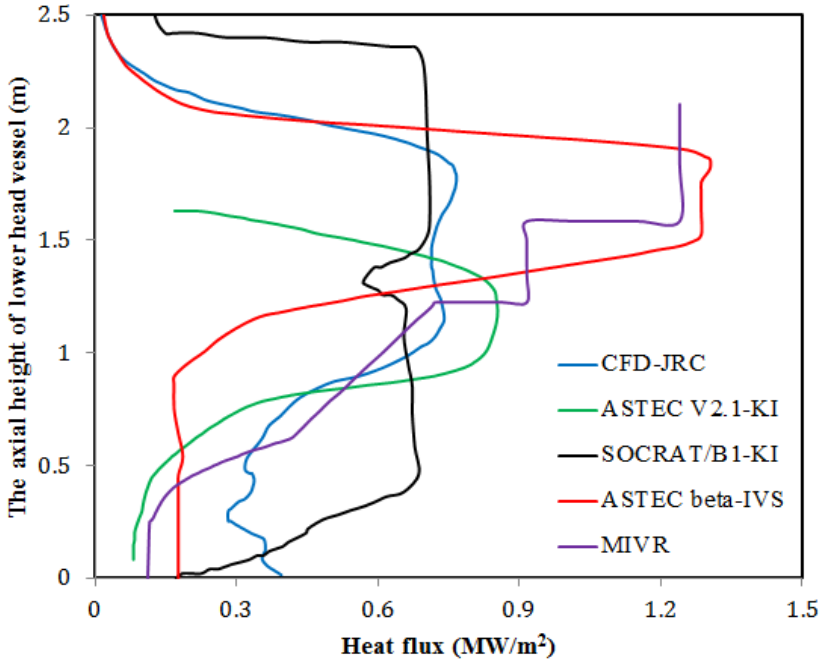


**Figure 5.** The maximum heat fluxes distribution along external surface of VER1000 lower head vessel predicted by different tools

The comparison on the maximum of heat flux distribution on external surface of VVER1000 lower head vessel obtained from calculations is shown in figure 5. All results predicted the heat flux increased along the external surface of VVER1000 lower head wall, however, there were significant differences in heat flux profiles. The heat flux profiles predicted by SOCRAT/B1 - KI and CFD-JRC were the lowest and quite identical with flat profiles. The heat peaks could be extracted from predictions of SOCRAT/B1 - KI and CFD-JRC are 0.7 and 0.74 MW/m$^2$, respectively. Calculation by ASTEC V2.1 (KI) clearly showed the heat peak which was 0.85 MW/m$^2$. The predictions of MIVR and ASTEC beta were highest with the peaks of 1.24 and 1.3 MW/m$^2$ respectively. The figure 5 also indicates the heat peak locations on external surface of VVER1000 lower head vessel predicted by different calculations are different.

The difference in predictions of calculation tools mainly come from the difference in the methodology and solving method for heat transfer of molten pool, and the problem was also mentioned in the report of JRC [3]. Therefore, it is necessary to perform experimentally study activities on thermal dynamics of molten pool with the real material and full-scale geometry like VVER1000 lower head vessel.

The MIVR results of heat flux distribution on external surface of VVER1000 lower head vessel imposed by LBLOCA configuration, which was established during the accident LBLCOA scenarios, was lower than the critical heat flux (CHF). Therefore, in term of thermal load, the IVR strategy could protect the VVER1000 lower head wall from failure. However, the predictions of MIVR model indicated the gap between the heat peak induced by metallic layer and maximum of CHF was small, therefore, the success of the IVR strategy could not be secured. Thus, there is a need for additional studies on probabilistic risk assessment (PRA) to get the complete evaluation of the success of IVR strategy for VVER1000 reactor.

The results of the project will be a significant step for research team on nuclear safety analysis of Vietnam Atomic Energy Institute, and it is a basis for the team to carry out further studies on severe accidents, which occur in a nuclear power plant.

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[2] T. G. Theofanous et al.,"*In-vessel coolability and retention of a core melt*," DOE/ID-10460 VOLUME 1&2, October 1996.

[3] SANGIORGI Marco et al., "*In-Vessel Melt Retention (IVMR) Analysis of a VVER-1000 NPP*," JRC Technical Report, European Commission, 2016.

# STUDY ON TECHNOLOGY AND SAFETY OF FLOATING NUCLEAR POWER PLANT USING SMALL MODULAR REACTOR

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**Project information:**

- **Project name: Study on technology and safety of floating nuclear power plant using small modular reactor**
- **Code: DTCB.02/19/VKHKTHN**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan 2019 - Dec 2020)**
- **Contact email: tvietphu@gmail.com**
- **Published papers related to the project:**

1. Van Khanh Hoang, Viet Phu Tran, Van Thin Dinh, Hoai Nam Tran, ‘‘Conceptual design of a small-pressurized water reactor using the AP1000 fuel assembly design”, Nuclear Science and Technology, Vol.9, No. 2 (2019), pp. 25-30. DOI: https://doi.org/10.53747/jnst.v9i2.49
2. Van Khanh Hoang, Tran Vinh Thanh, Thanh Mai Vu, Hoai Nam Tran, ‘‘Conceptual design of a small-pressurized water reactor using the AP1000 fuel assembly design”, The 13th Vietnam Conference on Nuclear Science and Technology (VINANST13), Ha Long, Viet Nam, 07-09 August 2019.
3. Phạm Tuan Nam, Vo Thi Huong, ‘‘Investigation of natural circulation in primary system of NUSCALE-SMR by using RELAP5”, The 6th Nuclear Science and Technology Conference for Young Researchers, Hanoi, Viet Nam, 08-09 October 2020.

Recently, small modular reactors (SMR) and floating nuclear power plants (FNPP) are being researched and developed in many countries. The advantages of these technologies are the low initial investment, high safety, and flexibility in construction, operation, and application. In addition, China is also developing many SMR technologies for both land-based and sea-based such as ACP100, ACPR50S, DHR400, HTR-PM ..., and planning to bring FNPPs to

disputed waters like the East Sea. As a result, the study on SMR and FNPP technologies has both economic and political significance for Vietnam which contributes to the solution of power shortages and power supply for islands. In addition, understanding Chinese technologies helps us to prepare for the situations in the East Sea in the future.

In this project, an overview of the SMR and FNPP technologies was carried out. Several reactors of FNPP developed based on land-based versions of reactors (ACPR50S of china) or the versions in icebreakers (KLT-40S and RITM-200 of Russia) to save the time of applying for licensing because of their proven technologies. In addition, there are new SMRs that are being researched and are in the process of licensing by the US, namely NuScale and OFNP-300. It can see that these technologies have been improved from the traditional PWR with many proven technologies, and in combination with advanced safety technologies. Therefore, it can hasten the process of researching, licensing, and then constructing and operating.

In the case of FNPP, the safety and security issues also need to be concerned with more aspects due to its characteristics of operating in sea, movable, and sovereignty issues. Therefore, the design of FNPPs shas to consider the effect of waves on thermal-hydraulic characteristics and the safety of the reactor. In addition, the integrated design feature of SMR and the sea-based feature of FNPP will prevent problems such as Large break LOCA or core melting. Regarding the security of FNPP, the coordination of many nations is necessary to ensure the security and safety of the FNPP in the international sea. At the same time, safety and security risks can have consequences that affect the international environment, so the security issue needs to be explored in more detail.

Regarding the legal regulations for FNPP, international legal documents of the IAEA have not been fully and systematically developed because FNPPs are new and unpopular technology. Currently, the IAEA is still mainly based on The Physical Protection of the Nuclear Material and Nuclear Facilities - CPPNM. In addition, the International Maritime Organization (IMO) promulgated the international standards for the transportation of dangerous goods according to the International Maritime Safety Convention. The IAEA also published a publication describing the legal and institutional issues in the case of implementation of FNPP in the countries that are not the origin. In the case of Vietnam, documents related to the safety and security of SMR and FNPP have not been issued. However, because of complicated situations in the East Sea and neighboring countries, the development of relevant legal documents is very necessary. The formulation and promulgation of these documents need to refer to two the documents of the countries that developed SMR and FNPP technologies such as Russia, the US, and China. At the same time, it is also necessary to base on the existing documents of the IAEA, IMO as well as the help of the IAEA experts and countries mentioned above.

In addition to exploring the overview of SMR and FNPP, the project has also preliminarily performed the calculation of the neutronic characteristics and safety analysis of these technologies in order to build capacity for technology research and calculation. Evolutionary simulated annealing (ESA) method is applied to design a small 200 MWt reactor core. The core design is based on a reference ACPR50S reactor deployed in a floating nuclear power plant. The core consists of 37 typical 17x17 PWR fuel assemblies with three different U-235

enrichments of 4.45, 3.40, and 2.35 wt%. Core loading pattern (LP) has been optimized for obtaining the cycle length of 900 effective full power days while minimizing the average U-235 enrichment and the radial power peaking factor. The optimization process was performed by coupling the ESA method with the COREBN module of the SRAC2006 system code. Figure 1 shows the optimal core LP of the small 200 MWt reactor selected from the ten independent runs of the optimization process. The relative radial power distribution at the beginning of the cycle shows that the PPF of 1.377 appears near the core central at the assembly with the enrichment of 3.40 wt%. Figure 2 shows the change of $k_{eff}$ and PPF during the burnup. The PPF is decreased during the EFPDs, and the $k_{eff}$ is unity at about 900 days. The optimal core can be applied to perform safety analysis and source terms calculation for FNPP using SMP in future studies.


**Figure 1.** Optimal loading pattern and relative power distribution of the small reactor core.

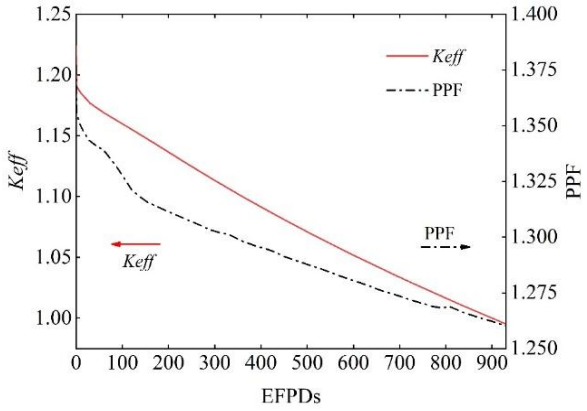


**Figure 2**. Evolution of the $k_{eff}$ and PPF of the optimal core as functions of burnup.

Thermal-hydraulic calculations have been performed for the NuScale reactor because this technology has almost all data for the modeling in the final safety analysis reports (FSAR). Simultaneously, this is the first time we model a reactor using natural circulation. Therefore, it is good to improve the capability of our research staff. Firstly, the steady-state was simulated by RELAP5. The results showed a good agreement with the FSAR, i.e. the difference of important parameters ranged from 0.0 to 5.9%. After verifying with steady-state calculations, the RELAP5 was used to simulate the rod ejection accident of the NuScale. Figure 3 and Figure 4 show that RELAP5 can simulate the accident well qualitatively. Quantitatively, the simulation results are consistent with the FSAR at the early stage of the accident. The difference of parameters of coolant mass flow rate parameters in the primary loop and the average temperature of the coolant in the core is less than 10%. However, at the later stage, the difference is greater. The cause can come from different calculation tools (NRELAP and RELAP5) and the limitation of information of the passive residual heat system. Therefore, it is necessary to have more researches on this problem.

# DESIGN AND FABRICATION OF A NEUTRON FLUX MONITORING EQUIPMENT OF DALAT NUCLEAR REACTOR CONTROL SYSTEM

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**Project information:**

- **Project name: Design and fabrication of a neutron flux monitoring equipment of Dalat nuclear reactor control system**
- **Code: DTCB.08/19/VNCHN**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan/2019-Dec/2020)**
- **Contact email: taivnchn@gmail.com**
- **Published papers related to the project:**

1. Vo Van Tai, Trinh Dinh Hai, Nguyen Van Kien, Le Van Diep, Inspection and evaluation of digital instrument and control system of the Dalat nuclear research reactor, Proceedings of the 13th Vietnam Conference on Nuclear Science and Technology (VINANST-13), Ha Long, Vietnam, 2019, p.87-88 (in Vietnamese).
2. Vo Van Tai, Nguyen Van Kien, Nguyen Nhi Dien, Trinh Dinh Hai, Le Van Diep, Design of a FPGA-based controller for power and period measurement in the start range of Dalat Nuclear Research Reactor. Accepted on Nuclear Science and Technology, VAES and VINATOM. DOI: https://doi.org/10.53747/jnst.v10i3.7
3. Vo Van Tai, Nguyen Van Kien, Nguyen Nhi Dien, Trinh Dinh Hai, Phan La Son, Design of a neutron flux measurement channel using the ionization chamber KNK-3 at the Dalat Nuclear Research Reactor. Accepted on Nuclear Science and Technology, VAES and VINATOM.

This report summarizes the results of the design and fabrication of the neutron flux monitoring equipment (NFME) as shown in Figure.1a, which is based on a high-speed field-programmable gate array (FPGA) and digital signal processing (DSP) using moving average (MA) filters, for Dalat research reactor control system named ASUZ-14R. The testing is performed both by pulse-generated simulator PGT-17R and by real neutron signals from the reactor. Technical characteristics of this module are equivalent to those of the BPM-107R1 module of ASUZ-14R.

The reactor power of a nuclear reactor follows the exponential function as shown in Figure. 1b. Where P(t) is transient reactor power at time $t$, $P_0$ is initial reactor power at time $t_0$.

The time interval that takes for the reactor power changed by a factor of e (e = 2.718) is called the reactor period T, t is the time during the reactor transient.

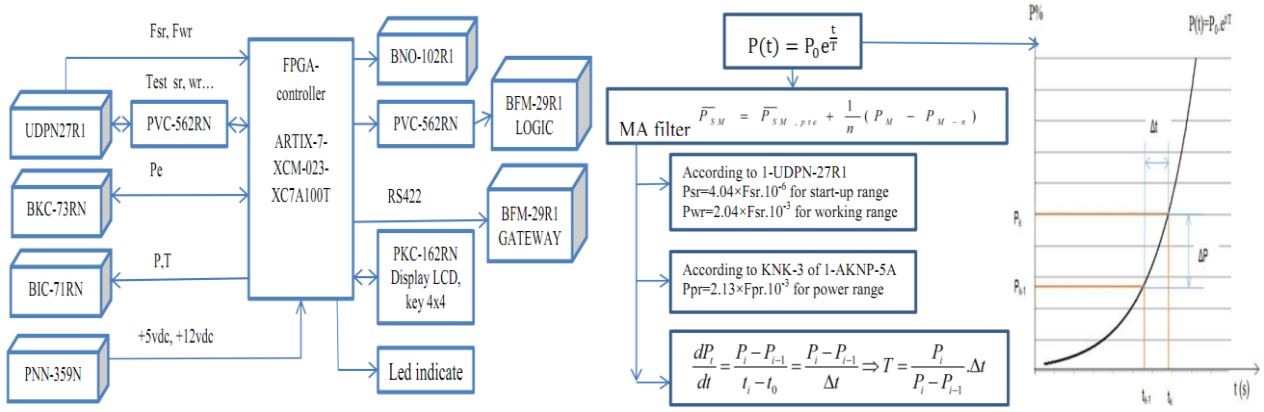



**Figure. 1.** Function diagram of NFME unit
(a) and theory of calculating the reactor power and period (b).

FPGA-controller is NFME controller, PVC-562RN is signals isolation, PKC-162RN is monitoring sub-module, PNN-359RN is the power supply, BKC-73RN is NFME preset value, BIC-71RN is NFME digital display. In the case of the Dalat nuclear research reactor (DNRR), the output frequency from the amplifier or the converter is proportional to the reactor power. These signals are filtered by MA filters and used for calculating the reactor power and period by FPGA-controller.

**Testing of the NFME module on the DNRR using the ionization chamber KNK-3**

The KNK-3 is Boron-lined CIC type, operated in the current mode and used to the power range (PR) of the analog control system AKNP-5A of DNRR. The output current of the KNK-3 is proportional to the neutron flux density. Then, that current is converted to frequency Fpr which is accessed to the NFME and BPM-107R1 modules. In this experiment, the BPM-107R1 module is NFME controller of the ASUZ-14R complex, and the designed NFME module is called FPGA-PR control module due to the KNK-3 is used for the power range only.

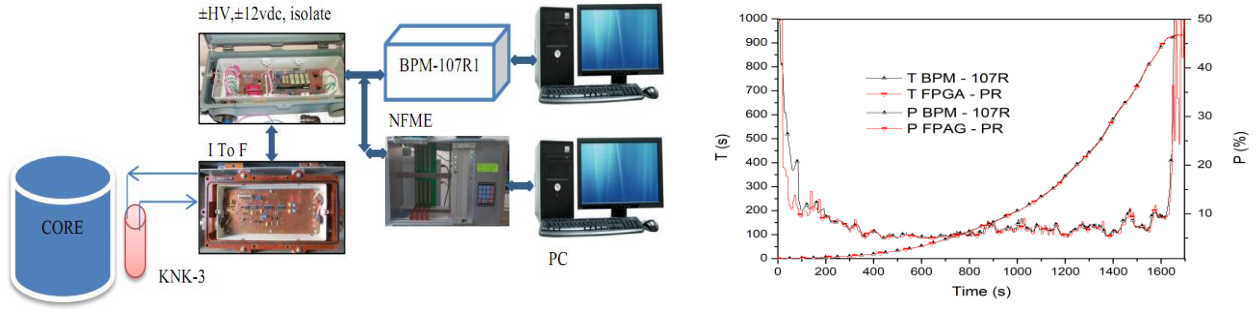



**Figure 2.** Testing NFME unit using KNK-3 (a) and results from testing (b)

The output pulse signals of the I to F converter is accessed to both the BPM-107R and FPGA-PR modules through a digital buffer. The values of reactor power and period are logged by the computer through serial interfaces RS-422. In this experiment, the reactor is only

operated up to 50% $P_{nominal}$. The reactor power and period values are shown in Fig. 2b, which were measured from 0.5 to 50% $P_{nominal}$.

**Testing of the NFME module on the DNRR using the UDPN-27R1 unit of ASUZ-14R complex**

The UDPN-27R1 is a neutron detection device that consists of the pulse amplifier BPH-61R, the conversion unit BPH-63R and auxiliary unit BH-150R2. The BPM-107R1 is the NFME controller and the BFM-29R1 is a logical processing unit of the ASUZ-14R complex. The FPGA-controller has been developed to measure reactor power and period based on DSP principle, using a Xilinx FPGA Artix-7 and MA filtering techniques. The principle schema for testing the NFME using UDPN-27R1 unit is shown in Figure. 3.

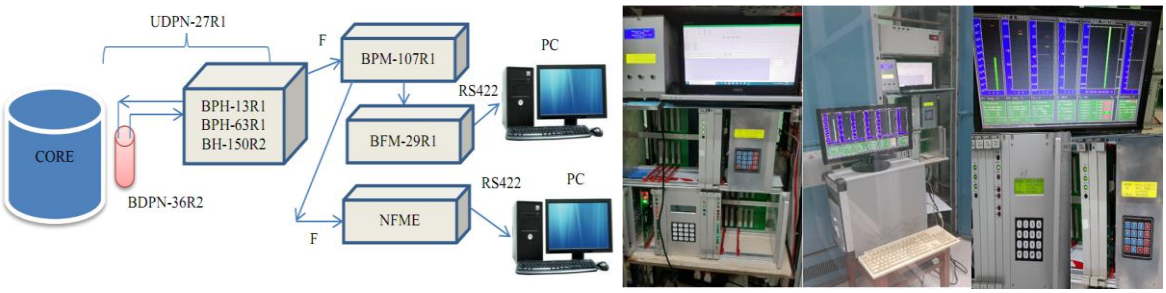
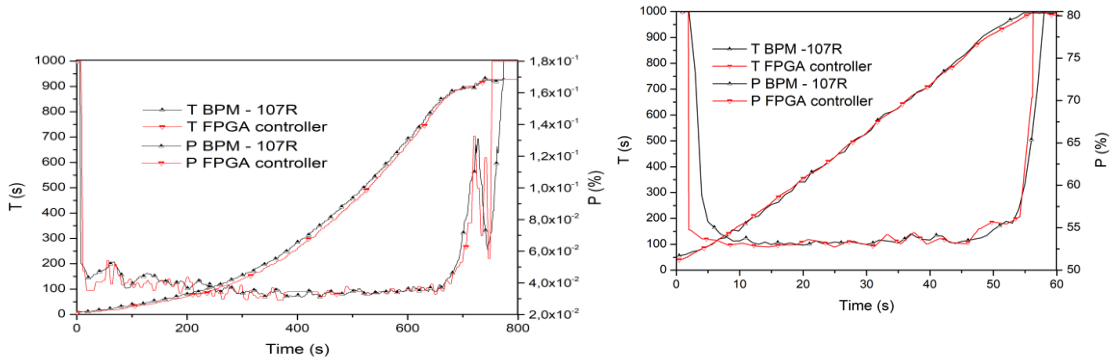



**Figure. 3.** Principle schema for testing the NFME module using UDPN-27R1 unit.




a) In the start-up range b) In the working range

**Figure. 4.** Typical results of testing the NFME module using UDPN-27R1 unit.

The combined experiment using the UDPN-27R1 unit of the ASUZ-14R complex to measure the reactor power and period in the startup range from $10^{-5}$ to $5\times10^{-1}$% $P_{nominal}$ and the working range from 0.5 to 100% $P_{nominal}$ of the DNRR is performed. The results of the reactor power and period measurements by the FPGA-controller and BPM-107R1 show that both the controllers have almost the same values as shown in Figure. 4. The comparison results also show that the designed NFME fully meets the requirements on the accuracy of the reactor power and period parameters.

**Time constant of generating emergency protection signals by reactor power and period**

The fast response ability of a NFME controller for emergencies to stop chain reactions is one of the important parameters of a control protection system (CPS) in the nuclear reactor.

The pulse generator PGT-17R was used for checking the time constant for the generation of the actuation preset values by reactor power and period of the BPM-107R1 and FPGA-controller modules. This response time is measured by the oscilloscope TBS1202B of TEKTRONIX.

**Table 1.** Time for producing period emergency signals of BPM-107R1 and FPGA-controller modules.

| Reactor power (% Pn) | Frequency (Hz) | Response time of BPM-107R1 unit (sec) | | Response time of FPGA-controller unit (sec) | |
|---|---|---|---|---|---|
| | | Simulation at T = 10 (sec) | Simulation at T = 20 (sec) | Simulation at T = 10 (sec) | Simulation at T = 20 (sec) |
| $2.5\times10^{-3}$ | 618 | 9.3± 0.1 | 32.2± 0.1 | 10.7 ± 0.1 | 22.3 ± 0.1 |
| $1\times10^{-2}$ | 2 474 | 5.1± 0.1 | 9.2± 0.1 | 6.6 ± 0.1 | 12.9 ± 0.1 |
| 0.1 | 24 752 | 3.3± 0.1 | 6.9± 0.1 | 2.8 ± 0.1 | 5.2 ± 0.1 |
| 0.2 | 100 | 10.3 ± 0.1 | 27.0 ± 0.1 | 9.7 ± 0.1 | 23.8 ± 0.1 |
| 1 | 469 | 5.1 ± 0.1 | 9.3 ± 0.1 | 5.2 ± 0.1 | 9.4 ± 0.1 |
| 5 | 2347 | 3.7 ± 0.1 | 7.2 ± 0.1 | 3.8 ± 0.1 | 5.4 ± 0.1 |
| 70 | 32864 | 3.3 ± 0.1 | 6.7 ± 0.1 | 3.2 ± 0.1 | 4.9 ± 0.1 |

The experimental results in Table 1 show that the response time of FPGA-controller module is mostly smaller than that of BPM-107R1 module. It means that the FPGA-controller is in good response to the ASUZ-14R control system requirement. The response time of reactor power in the full range is 0.05 s.

The obtained results allow concluding that the FPGA-controller compound with the neutron detector KNK-3 or the UDPN-27R1 unit can be performed as an independent neutron flux measurement channel for testing reactor parameters, research, and training purposes at the DNRR, and this NFME can replace the BPM-107R module when needed. However, the results are just the first step for the next study on the design of a controller module for reactor reactivity monitor and automatic power regulation of the ASUZ-14 complex.

# RESEARCH, EVALUATE UNCERTAINTY THROUGH RANDOM VARIATION OF PARAMETERS IN SOME PHYSICAL MODELS OF RELAP5 / MOD 3.3 SOFTWARE BASED ON FEBA EXPERIMENTAL DATA

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**Project information:**

- **Project name: Research, evaluate uncertainty through random variation of parameters in some physical models of RELAP5 / MOD 3.3 software based on FEBA experimental results**
- **Code: CS/20/10-01**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020 - Dec 2020)**
- **Contact email: tttram80@yahoo.com**
- **Published papers related to the project:**

1. Hoang Tan Hung et al., Study on the sensitivity of physical models used in RELAP5 code based on experimental data of FEBA, The sixth Conference of Nuclear Science and Technology for young nuclear energy staff, Hanoi, Vietnam, Otc. 2020.
2. Tran Thanh Tram et al., A sensitivity study of physical models using RELAP5 code based on FEBA experimental data, Nuclear Science and Technology (NST), (under reviewed). Vol. 10 No. 4 (2020). DOI: https://doi.org/10.53747/jnst.v10i4.12

Recently, uncertainty analysis is an emerging issue around the world. Major projects in this area have been organized, such as BEMUSE and PREMIUM, to evaluate the sources of uncertainty, advantages, and disadvantages of each existing uncertainty assessment method, propose and develop the most optimal uncertainty assessment methods. The thermal-hydraulics codes are often used for licensing nuclear power plants. They are built by solving conservation equations using assumptions, simplifications, ideal processes, and correlations. Many correlations or physical models are used in these codes. It is suggested that physical models have a strong influence on the calculated results. It means that the uncertainty of the physical models needs to be considered.

Nowadays, methods of analysis of uncertainty have also been developed, and they could be grouped into two groups, input-based and output-based methods. While the input-based method analyzes considered input-parameters separately, the output-based one considers the global effect of input parameters. Moreover, the input-based method has additional limitations,

such as the need to use a lot of expert judgment in parameter selection, distribution function selection, and ranking parameters. In turn, the output-based method requires a large amount of experimental data from separate effect test, integrated effect test, and real data from NPPs.

Our chosen method is based mainly on the input-based method. However, the expert opinions are used to choose the PDF of each input parameter in this method. Therefore, CIRCÉ was chosen developed by CEA to evaluate the uncertainty in the CATHARE code to avoid expert subjective judgment in choosing the PDF of input parameters.

This project includes three main parts. The first part is an overview of uncertainty methodology, calculating tool, and the experiments related to the reflood phase. The second is sensitivity evaluation of the physical model for test 216 of FEBA. The last one is uncertainty analysis of chosen physical models.

As mentioned, we combine the input-based method with the CIRCÉ software.

FEBA system is selected. This test focuses on thermal-hydraulic phenomena related to the reflooding phase during LOCA. The reflood phase is the most complex thermal-hydraulic scenario because many heat transfer mechanisms of vapor, two-phase mixture, and liquid phases exist during this phase. As a result of the phase change, the flow regimes also change differently.

RELAP5 code has been chosen. This software is widely used in safety analysis and licensing. It is also capable of simulating the reflooding phase. Moreover, uncertainty analyses have also been performed using this software.

In the first phase of the project, sensitivity studies of the physical models are carried out. From 16 initial physical models, four physical models have a significant effect on the calculation results. These physical models are related to the reflooding process, such as the heat transfer coefficient at different flow regimes, the wet and dry criteria for cladding.

The calculation results of CIRCÉ software shows that the distribution band calculated by this software is significantly reduced compared to the uncertainty band recommended by experts.

Based on the calculated results using CIRCÉ, the uncertainty calculations for several tests in Serie I conducted on FEBA (214, 216, 218, 220, 222) are analyzed. The obtained results showed that simulation results predict PCT values well. It means that the simulated uncertainty band covers all PCT data in all the tests. However, around the time that quenching happens, the calculated uncertainty bands do not contain all experimental data. It means that the simulated results quenched faster than measured data. The faster quenching time results were obtained by other researchers using RELAP5 code for reflood phase simulations.

Based on the sensitivity study and the uncertainty analysis in this project, it can be seen that the physical models have a significant influence on the calculation results. Among four considered physical models, the cladding's dry/wet criterion has the highest impact on the output. Therefore, further works need to be done to improve the code prediction capability related to the quenching phenomenon.

# 2.2. INSTRUMENTATION, NUCLEAR ELECTRONICS

# RESEARCH ON INTEGRATING OF ONLINE RADIOACTIVE MONITORING DATA SOURCES (ONLINE) AND DATA PROCESSING PROCEDURE

**Vuong Thu Bac[1], Truong Hoang Tuan[2], Duong Duc Thang[1], Bui Dac Dung[1], Nguyen Thi Thu Ha[1], Cao Duc Viet[1], Nguyen Van Khanh[1], Doan Thuy Hau[1] , Nguyen Hai Ninh[1].**

[1] *Institute for Nuclear Science and Technology, 179 Hoang Quoc Viet, Cau Giay, Hanoi.*

[2] *Center for Nuclear Technologies, 217 Nguyen Trai, District I, Ho Chi Minh City.*

**Project information:**

- **Project name**: *"**Research on integrating of online radioactive monitoring data sources (online) and data processing procedure**"*
- **Managerial level: Ministry**
- **Code: DTCB.03/19/VKHKTHN**
- **Implementation time: 24 months (Jan 2019 - Dec 2020).**
- **Contact email: vtbac@yahoo.com hoặc vtbac@vinatom.gov.vn**
- **Published papers related to the project**:

1. Vuong Thu Bac, Truong Hoang Tuan, Duong Duc Thang, Bui Dac Dung, Cao Duc Viet, Nguyen Van Khanh, Nguyen Thi Thu Ha, Doan Thuy Hau, Nguyen Hai Ninh. Calculating radiation dose rate from online real-time environmental -spectrum using NaI(Tl) detector. Journal of NST. Vol.11 No.1, 2021. DOI: https://doi.org/10.53747/jnst.v11i1.128
2. Cao Duc Viet, Vuong Thu Bac, Bui Dac Dung, Nguyen Van Khanh. Current status of online environmental radiation monitoring and warning of Vietnam. Reported in the 13th National Conference of Nuclear Science and Technology, Halong 7-9, Aug. 2019 *(in Vietnamese).*

Currently, the Center of National Network for Environmental Radiation Monitoring and Warning (CONNERMAW) located at the Institute of Nuclear Science and Technology (INST), is operating 03 types of online radiation monitoring devices designed and manufactured by measurement technologies, transmitting and storing monitoring data of many different countries (German, Japanese and Vietnamese technology). The German SARA devices can record total environmental gamma dose equivalent rate (H*(10)), gamma radiation spectrum and can calculate H*(10) for some interest radioisotopes; Japanese NAH devices consist of 2 models. NAH2 model only records total H*(10). NAH3 can record total H*(10) and gamma radiation spectrum, but cannot calculate H*(10) for some interest radioisotopes; RADMON devices of Vietnam can record total H*(10) and gamma radiation spectrum, also cannot calculate H*(10) for some interest radioisotopes. Especially, the data format of these

databases is very different, inconsistent and encrypted, and stored in the database of each device system. Each system measures and transmits data to a separate server, so it is not systematically manageable, cannot integrate simultaneously, and display the ambient radiation status at desired times.

To overcome the above difficulties and contribute to supporting the operation of the network of environmental radiation monitoring and warning, the project has been set up with 2 goals: 1) To unify the collecting online environmental radioactive monitoring data from different stations in the CONNERMAW into a common database with the same format; 2) To have a procedure for processing the unified database to support the network management and operation.

To achieve the two above-mentioned goals, the project has set out the following main research works: 1) To build a procedure of converting and integrating online radioactive monitoring data sources from different devices into a common database of the same unified format. Applying to convert online monitoring data from operating stations from 2016 to 2020; 2) To build a procedure for processing the unified database, displaying results on the Web interface. Applying to process the unified database from 2016-2020 for management.

The approach, research method, and technique used in this project are presented as follows. Firstly, the project has gathered and studied documents about the software and data formats used in the CONNERMAW; has researched and developed software to read, extract and convert data formats from different monitoring device systems, thereby building a common database with a unified format; has researched and developed software to process data and display processing results on Web interface in windows operating system. Secondly, it also studied data formats such as IRIX, ANSI/IEEE N42.42, SQL; and used several popular data management systems such as MySQL, Oracle, RDBMS, PostgreSQL; as well as applied some programming languages such as Java, Python, Windows PowerShell, HTML and C # and so on. Thirdly, the project has researched and applied the function G(E) method to calculate the total H*(10), the photopeak area method of calculating the area of characteristic photopeaks to calculate H*(10) for the interest radioisotopes.

After 2 years of implementation, the project has completed and over completed the registered contents and has achieved the following main scientific research results:

Firstly, the project has had an overview of the software to receive, manage, transmit data, and format data from the online environmental monitoring equipment systems in use, including SARA equipment and NMC software, NAH equipment and software included RADMON equipment and ERMS software.

Secondly, the project has built the procedure of data conversion and integration, including modules to extract source data from SARA, NAH, and RADMON devices. These modules have been integrated into the software called RADACOIN V.1, which allows converting and integrating online radiation monitoring data sources from the above devices into a unified format, including total average H*(10) and spectrum data of 2048 channels corresponding to a 10-minute, 1-hour, and 1-day measurements. These data all have a unified SQL format, convenient for subsequent data processing. The quality of this product exceeds

the assigned target of the project. The project requires converting and integrating data sources from 3 devices, the project has been implemented for 15 devices (including 12 additional devices installed during the implementation of the project).

In addition, the project has built a procedure to process the uniform environmental radioactive database, process online gamma spectral data to determine the total H*(10), H*(10) for some radioisotopes K-40, Bi-214, and Tl-208 in the form of specialized software called RADAPROC V.1 that can automatically calculate and display the results in a Web browser. The quality of this product also exceeds the assigned target of the project. The project requires a processing spectrum from 2 devices, the project has been implemented for 8 devices (including 6 spectrometer devices that were installed in the process of implementing the project).

The results calculated using RADAPROC V.1 software have been compared with the results of other methods. The difference in the results between the methods was less than 25% (see Table 1). Figure 1 is one of the typical interfaces of the RADAPROC V.1 software.

**Table 1.** Average H*(10) in 2020 according to different determination methods at some monitoring stations

| **Monitoring station** | **H*(10) calculated from soil radioactivity, nSv/h** | | **H*(10) calculated with SARA (a), nSv/h** | | **H*(10) calculated with RADAPROC (b), nSv/h** | | **Ratios (b)/(a)** |
|---|---|---|---|---|---|---|---|
| | H*(10) | Error | H*(10) | Error | H*(10) | Error | |
| Cao Bang | 90.50 | 1.97 | 90.29 | 6.19 | 109.90 | 7.80 | 1.22 |
| Da Nang | 123.50 | 7.21 | 132.36 | 8.08 | 162.90 | 10.20 | 1.23 |
| Vinh | 90.69 | 5.29 | 86.54 | 10.88 | 107.07 | 14.25 | 1.24 |

Table 2. shows that the calculation results H*(10) from spectrum data recorded by SARA device using RADAPROC V.1 software is higher than those calculated by NMC software. For the K-40, the result is quite consistent with a difference of only about 15.5%. For Bi-214 and Tl-208, the result is more different. This difference is due to the relatively small number of peaks at Bi-214 and Tl-208 that do not guarantee statistics when processing the spectrum. On the other hand, the spectral smoothing technique applied in the software may have caused the spectral data to be increased. This issue will be further studied in the coming time to get better software to serve the operation of the National Network.

RADACOIN V.1 and RADAPROC V.1 software have been working automatically and continuously 24 hours a day at the CONNERMAW, effectively supporting the current task of

environmental radiation monitoring and warning. However, these are the first versions that need to be updated every year, especially when the equipment is added to the monitoring network.

The online environmental radiation database created by the 2 above software including H*(10), gamma spectral data, H*(10) for some radioisotopes such as K-40, Bi-214, and Tl-208 measured in different durations (10 min, 1 h, and 1 d) have the same uniform format. This is the first online environmental radiation database in Vietnam and is regularly updated 24/24h at the CONNERMAW. This database is getting bigger and bigger, so backups need to be taken care of.

**Table 2.** Average H*(10) of the interest radionuclides in some monitoring stations

| **Monitoring station** | **Average H*(10) in 2020 of K-40, Bi-214, and Tl-208 calculated with different software, (nSv/h)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | RADAPROC V.1 (a) | | | SARA-NMC (b) | | | Ratios (a/b) | | |
| | K-40 | Bi-214 | Tl-208 | K-40 | Bi-214 | Tl-208 | K-40 | Bi-214 | Tl-208 |
| Cao Bang | 8.538 | 6.558 | 8.279 | 5.577 | 4.772 | 5.672 | 1.531 | 1.374 | 1.460 |
| Da Nang | 20.262 | 8.399 | 23.394 | 21.970 | 7.374 | 13.666 | 0.922 | 1.139 | 1.712 |
| Vinh | 4.935 | 10.347 | 11.990 | 4.877 | 6.292 | 9.064 | 1.012 | 1.644 | 1.323 |
| Ave. Values | 11.245 | 8.435 | 14.554 | 10.808 | 6.146 | 9.467 | 1.155 | 1.386 | 1.498 |

The server computer and ancillary equipment are equipped to serve the project of stable operation at the National Center for Network Operations of the CONNERMAW.

The project has produced one report at the National Conference of Nuclear Science and Technology in Quang Ninh in August 2019 and one paper published in the journal of the INST.

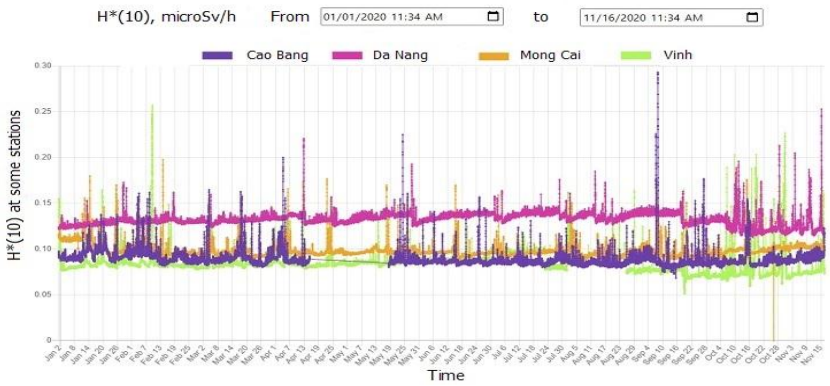


**Figure 1.** Timeseries of H*(10) at Cao Bang, Da Nang, Vinh, and Mong Cai stations in 2020

The project was completed well and exceeded the registered contents.

The research results of the project are of scientific significance and have high practical application value in unifying the data format of online radiation monitoring data, processing and storing monitoring data for management, and Scientific research in the field of monitoring and timely warning the status of the environmental radiation in Vietnam.

After the project is finished, the main products of the project will be transferred to the INST for use. Network operators will be guided to use the project's software for their research.

# OPTIMIZATION OF THE ENERGY RESPONSE FUNCTION OF THE NEUTRON SURVEY METER USING A $^{3}$He PROPORTIONAL COUNTER

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**Project information:**

- **Project name: Optimization of the energy response function of the neutron survey meter using a $^{3}$He proportional counter**
- **Code: CS/20/04-02**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020- Dec 2020)**
- **Contact email: maivandien.inst@gmail.com**
- **Published papers related to the project:**

1. Mai Van Dien, Nguyen Duc Tuan, Nguyen Ngoc Quynh, Vu Trung Tan, Vu Van Tien, **"**Study on design and construction of neutron survey meter", The 6th Vietnam Conference on Nuclear Science and Technology, 10/2020 (in Vietnamese)
2. Mai Van Dien, Nguyen Duc Tuan, Nguyen Ngoc Quynh, Vu Trung Tan, Le Ngoc Thiem, Vu Van Tien, **"**Development of a neutron detector for radiation protection monitoring", Nuclear Science and Technology, Vol. 10 No. 4 (2020). DOI: https://doi.org/10.53747/jnst.v10i4.14

In recent years, neutron sources are increasingly being applied in various fields such as research, industrial process, radiation biology and medicine. Accompanying with those useful applications, there are existing potential threats from neutrons. According to the recommendation of the International Commission on Radiological Protection (ICRP) for area monitoring, the ambient dose equivalent $H^{*}(10)$ is used as an approximation of the protection quantity in radiation measurements of external exposure. The mensuration of the ambient dose equivalent will furnish the necessary information for controlling the radiation at workplaces and the definition of controlled or forbidden areas. However, it is still difficult to measure neutron dose precisely due to its intrinsic characteristics as no-charge, continuous neutron fluence spectrum, etc. In order to strengthen and support radiation protection in Vietnam, the objective of this study was to develop a neutron detector with the appropriate response function and provides a feasible method for measuring the neutron ambient dose equivalent.

In this study, Monte Carlo simulations were performed to optimize the configuration of the neutron detector. As a result, a prototype of neutron detector assembly was developed for

measuring the neutron ambient dose equivalent rate, H*(10), with the energy range from thermal to 15 MeV. The signal processing circuit consists of a multichannel analyzer (MCA-1024 channels) and a single channel analyzer (SCA) that allows for gamma rejection on the basis of pulse height, while still maintaining good sensitivity to neutron radiation.

The instrument consists of a $^{3}$He proportional counter embedded in a multi-layer moderator made of high-density polyethylene (HDPE, ρ=0.95 g/cm3) and Cadmium (Cd, ρ=8.65 g/cm3). It is about 6 kg weigh with the outer dimensions of 20.5 cm in diameter and 24.5 cm in length. Figure 1 shows the developed neutron detector, in which the helium counter is surrounded by a 6 cm thick outer polyethylene moderator, a 2.7 cm thick inner polyethylene moderator, and a 3 mm thick cadmium shell. In order to extend the response to thermal neutrons, the cadmium shell is perforated so that the opening accounts for 10% of the surface area of the $^{3}$He counter. The characteristics of the developed neutron detector including neutron fluence response and ambient dose equivalent response are shown in Figure 2.

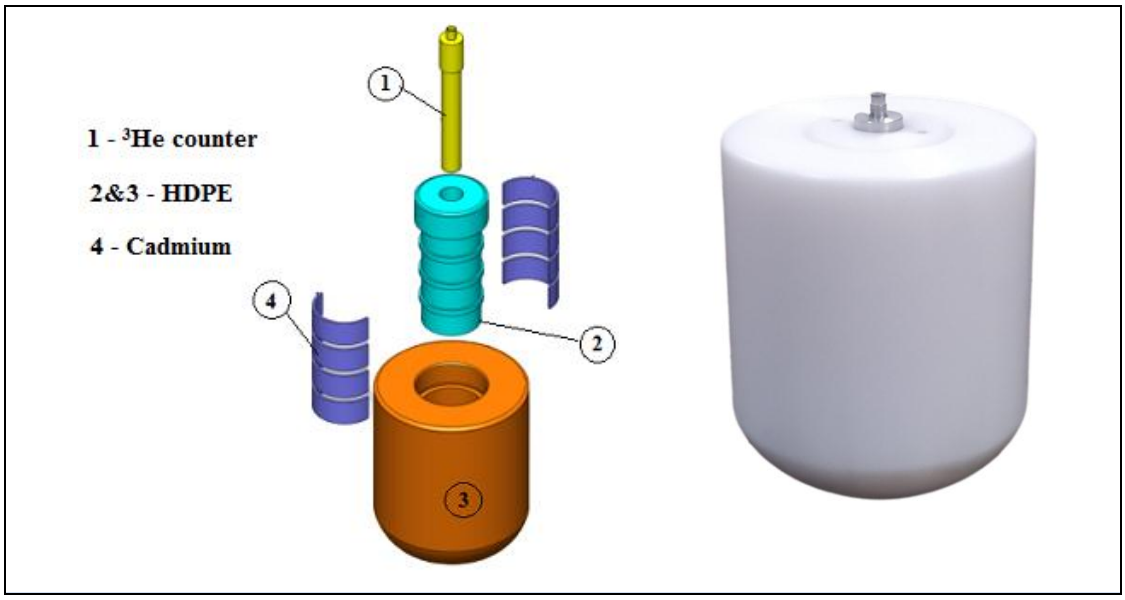


**Figure 1.** The developed neutron detector

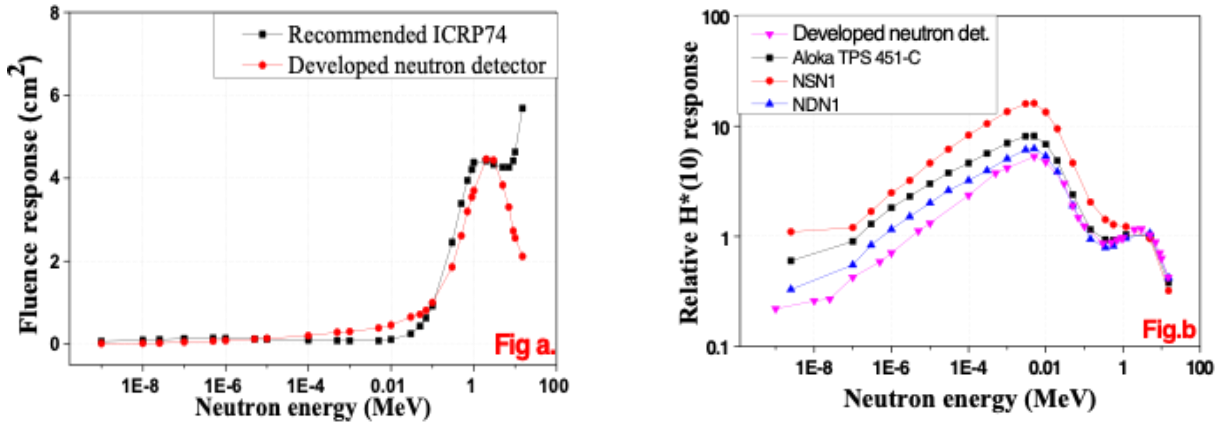


**Figure 2**. Neutron fluence response (a) and relative H*(10) response (normalized to $^{241}$Am-Be) (b) of the developed detector

The fluence response of the developed detector closely follows the shape of the neutron fluence-to-dose equivalent conversion curve given by ICRP 74 (see Fig.2a). The developed neutron detector over-estimates the neutron ambient dose equivalent rate by a factor between 1.2 and 5.3 in the energy region from 10 eV to 50 keV and under-estimates the neutron ambient dose equivalent rate from 30% to 50% at energies above 10 MeV. In the energy range from 50 keV to 10 MeV, the relative $H^*(10)$ response varies from 0.71 to 1.5. It can be seen that the relative $H^*(10)$ response of the developed neutron detector has a similar tendency with those of other commercial neutron survey meters (see Fig.2b). These values also comply with the recommendations of the International standard IEC 61005-2014. The results deduced from experimental measurements at the Secondary Standards Dosimetry Laboratory of the Institute for Nuclear Science and Technology (INST) show that the instrument has high sensitivity (2.84 cps/μSv/h) and good performance in the workplace.

In the framework of this study, the instrument was designed for measuring neutrons in the energy range from thermal to 15 MeV. In future work, to monitor neutrons at radiation fields outside the shielding of nuclear reactors and high energy accelerator systems, the instrument will be further developed to complete and extend the measurable energy range.

# DEVELOPMENT OF A FAST NEUTRON SPECTROMETER SYSTEM AND ACCOMPANYING UNFOLDING SOFTWARE

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**Project information:**

- **Project name: Development of a fast neutron spectrometer system and accompanying unfolding software**
- **Code: 08/HD/DTCB**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan 2019 - Dec 2020)**
- **Contact email: nnquynh.inst@gmail.com**
- **Published papers related to the project:**

1. Le Ngoc Thiem *et. al.,* "Cylindrical Neutron Spectrometer System: Design And Characterization", The European Physical Journal Plus, 2020
2. Nguyen Ngoc Quynh *et. al.,* "Neutron Spectrum Unfolding Using Various Computer Codes: A Comparison", The 6th Conference On Nuclear Science And Technology For Young Staff Of The Atomic Energy, 2020 (In Vietnamese).
3. Nguyen Ngoc Quynh *et. al.,*" Comparison Of Total Neutron Spectrum Unfolded By Different Unfolding Codes", Journal Of Military Science And Technology, 2020 (In Vietnamese).
4. Le Ngoc Thiem, "Establishment Of Neutron Reference Fields In Vietnam: A Review", Philippine Journal Of Science, 2020.

In the last few decades, many types of neutron spectrometers have been developed, of which the Bonner bridge spheres spectrometer is the most commonly used. However, this spectrometer has a major disadvantage that the measurement time is very long. Therefore, the goal of the study is to develop a new neutron spectrometer system that allows: (1) to more accurately determine the neutron dose compared to the hand-held neutron dosimeter and (2) simple operation. with acceptable measurement times (not as long as the BSS system) and usable in strong neutron fields, mixed with high energy photons (linear medical accelerators).

A new neutron spectrometer system (referred to as DNSV) consists of a rectangular box made of polyethylene of various sizes and the thermal neutron-sensitive sensor is the thermoluminescence dosimeter TLD8806. Polyethylene moderators are selected for their high ratio of hydrogen atoms, and easy to process. The moderators have the same bottom dimensions (4.5 x 4.5 cm) but different heights. The TLD8806 have 4 chips: 2 chips TLD600 have a main component of $^{6}$LiF and 2 chips TLD700 made of $^{7}$LiF. In this study, only TLD chips was used.

Response function of the DNSV system, $\boldsymbol{R_{\varphi}}$, was determined by the following equation:

$$\boldsymbol{R_{\varphi}} = \frac{\sum(n,\alpha)}{\varphi} \quad (1)$$

where, $\sum(n,\alpha)$ represents the number of reactions, $\varphi$ represents the incident neutron fluence

The response function of the neutron spectrometer system simulated by program MCNP 6.1 (Fig. 1). The shape of the response function shows that the spectrometer is capable of measuring neutron radiation from thermal energies up to 20 MeV .

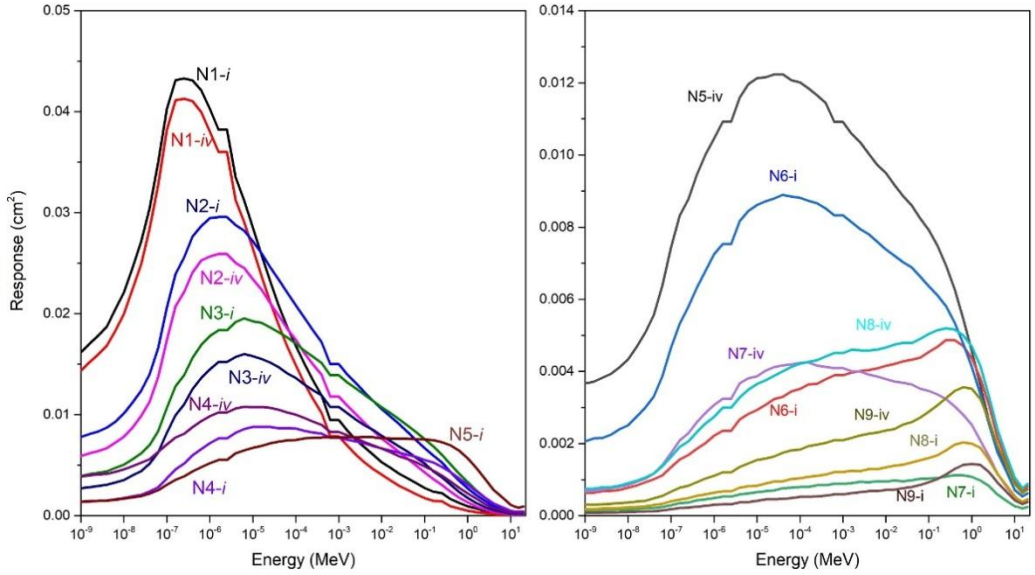


**Figure 1:** Response function of the DNSV system: N1-i is response of chip I at moderator N1, N1-iv is response of chip iv at moderator N1

The UFCV code uses the SVD neutron unfolding method, based on the method proposed by Andreas Hocker and Vakhtang Kartvelishvili. Accordingly, the neutron spectrum will be the solution of the following equation:

$$\|d - R.\varphi\|_2^2 + \lambda.\|L.\varphi\|_2^2 = min \quad (1)$$

where d is experimental readings, R is response matrix, φ is neutron spectrum, λ>0 is constant, L is regularization matrix, which has the form:

$$L = \begin{pmatrix} -1 & 1 & & & 0 \\ 1 & -2 & 1 & & 0 \\ & \ddots & \ddots & \ddots & \\ 0 & & 1 & -2 & 1 \\ 0 & & & 1 & -1 \end{pmatrix} \quad (2)$$

With the form of the regularization matrix L as shown in Eq. (2), the solution of Eq. (1) will be ‘‘smooth”. The smoothness of the solution is controlled through the constant λ. In the case, λ = 0, the Eq. (1) becomes the equation of the least-squares method. When the value of λ is small, the solution of Eq. (1) will fit the experimental data but will fluctuate greatly. As λ increases, the solution of the equation will be smoother and at the same timeless consistent with the experimental data. When λ is very large, the solution will be constant and do not fit with the experimental data. Therefore, the appropriate value of λ needs to be determined and this value depends on the problem. For the DNSV spectrometer, the appropriate value of λ is 2 or 3.

The DNSV system and the UFCV software were tested and compared with the BSS system and other neutron unfolding codes (FRUIT, MAXED) on neutron standard sources at the Institute for Nuclear Science and Technology. The results show that the DNSV system is capable of unfolding neutron spectra and determining neutron dose with the difference from the standard value of less than 20%. The UFCV spectrometry software was compared with two other codes (FRUIT, MAXED) for the readings of the BSS system and the nested cylindrical spectrometer system. The form of neutron spectrum obtained from three software is similar (*Fig.2 and Fig.3*). The integral values of the neutron spectrum (total fluence, average energy and ambiant dose equivalent) were consisting within 15% (*table 1, table 2*).

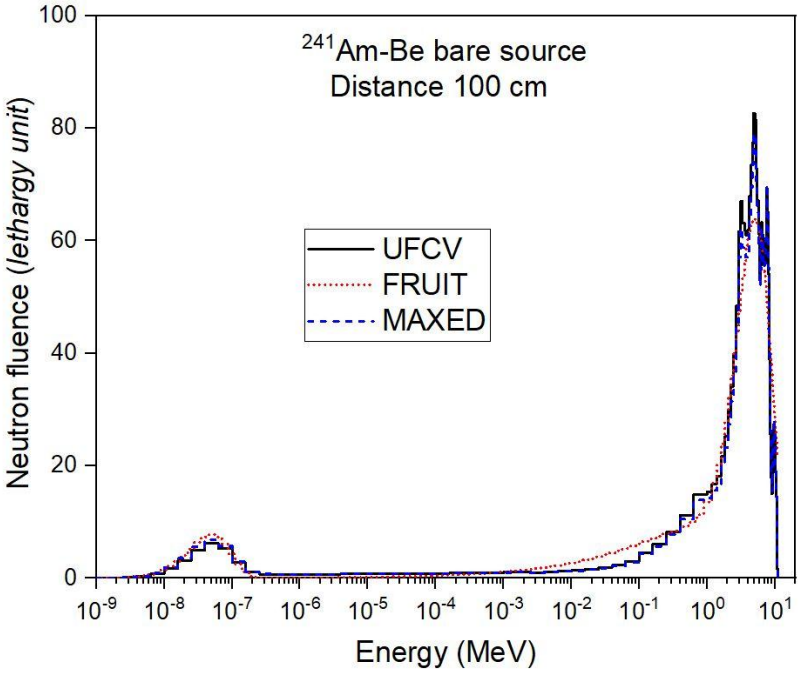


**Figure 2.** Compare unfolded total neutron spectrum of $^{241}$Am-Be source.

**Table 1.** Compare the integral quantities of the neutron spectrum of $^{241}$Am-Be source

| | UFCV | FRUIT | MAXED |
|---|---|---|---|
| Φ (cm$^{-2}$.s$^{-1}$) | 148 | 147 | 143 |
| $\bar{E}(MeV)$ | 3,1 | 3,1 | 3,2 |
| H*(10) (μSv/h) | 172 | 164 | 164 |

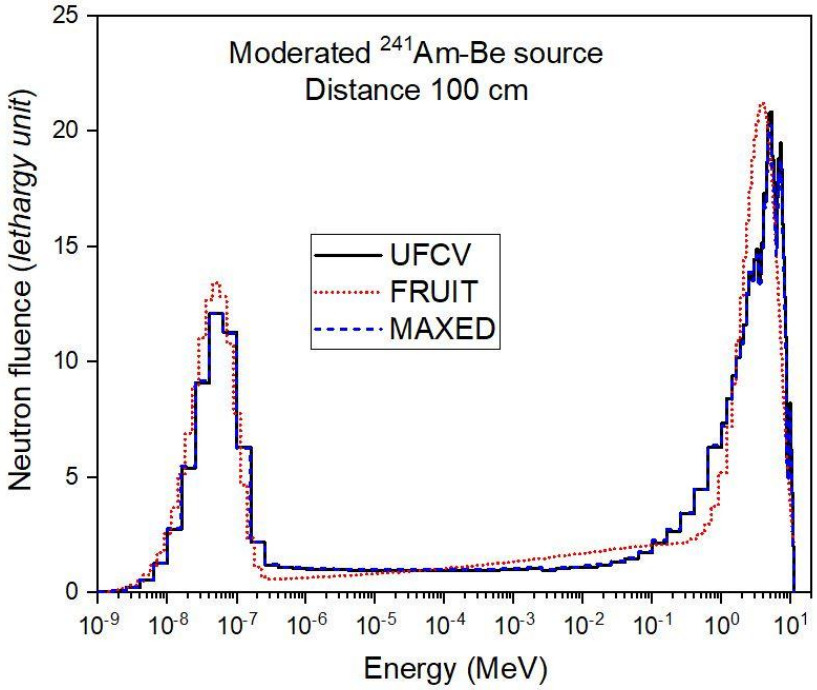


**Figure 3.** Compare unfolded total neutron spectrum of moderated $^{241}$Am-Be source

**Table 2.** Compare the integral quantities of the neutron spectrum of moderated $^{241}$Am-Be *source*

| | UFCV | FRUIT | MAXED |
|---|---|---|---|
| Φ (cm$^{-2}$.s$^{-1}$) | 104 | 104 | 97 |
| $\bar{E}(MeV)$ | 1,9 | 1,8 | 1,9 |
| H*(10) (μSv/h) | 82 | 78 | 74 |

The DNSV spectrometer system and the UFCV spectrometer software can completely determine the neutron spectrum exactly like the Bonner spheres spectrometer. The DNSV spectrometer system has the advantage of fast measurement time and the ability to exclude the influence of gamma radiation in the mixed radiation field. The spectrometer system can be used for rapid determination of neutron spectrum at radiation facilities for the purpose of radiation safety assessment.

# 2.3. INDUSTRIAL APPLICATIONS

# STUDY ON NON-DESTRUCTIVE EXAMINATION APPLIED FOR DETECTING CORROSION UNDER INSULATION ON TYPICAL PETROLEUM PIPING IN VIETNAM

**Nguyen The Man and CUI project team**

*Center for Non-Destructive Evaluation, 140 Nguyen Tuan, Thanh Xuan, Hanoi*

**Project information:**

- **Project name: "Study on non-destructive examination applied for detecting corrosion under insulation on typical petroleum piping in Vietnam"**
- **Code: DTCB.17/19/TTNDE**
- **Managerial level: Ministry**
- **Implementation time: 30 months (Jan 2019 - Jun 2021)**
- **Contact email: ntman.nde@gmail.com**
- **Published papers related to the project:**

1. Nguyen The Man, "NDT application for detection of corrosion under insulation on petroleum piping in Viet Nam", Journal of Nuclear Science and Technology Information, Vol 67, 2021 (in Vietnamese).
2. Vu Duc Vinh, Nguyen The Man. "NDT application for detection of corrosion under insulation on petroleum piping in Viet Nam". Proceedings of the 6th Vietnam Conference on Nuclear Science and Technology for Young Researchers, Hanoi, Vietnam, 2020 (in Vietnamese).

Insulation materials are used widely not only in industry but also in civil engineering for thermal protection, energy conservation, or process stabilization. In the oil and gas industry, insulation materials can be used for piping systems, tanks, and vessels in either low- or high-temperature applications. Corrosion under insulation (CUI) is any type of corrosion that occurs due to moisture present on the external surface of insulated equipment. It can cause equipment degradation, fluid leak, which lead to explosion or environmental pollution and the cost will very expensive. Therefore, CUI needs to be detected early to prevent damage.

In recent years, a lot of non-destructive methods are developing to detect and control effectively CUI. From 2019 to 2020, the Center for Non-Destructive Evaluation (NDE) has studied successfully stablishing, demonstrating and applying 4 non-destructive testings (NDT) procedures for CUI examination on typical petroleum piping using in Vietnam: Thermal/infrared imaging examination (i.e. thermography) and Neutron backscatter examination methods using for detecting quickly high potential CUI location without jacket removing by monitoring of moisture or hydrocarbon content in insulation material. Pulsed eddy current and Digital radiographic methods are used for measuring pipe wall loss due to corrosion.

From survey results at 3 oil and gas factories: Nghi Son Refinery and Petrochemical LLC, PV gas GPP Dinh Co, and Petrovietnam Camau Fertilizer Joint Stock Company, an

experimental facility has been constructed in order to verify the sensitivity of the method and optimize examination parameter. The test system involves a boiler and 18 pipes with an outer diameter of around 200mm and a thickness range of 6 to 31mm. On the test pipes, different water contents were created in the isolated insulation sections and artificial defects such as step wedges and localized holes were machined to simulate various corrosion forms. The boiler system provides steam with pressure up to 5kG/cm2 and temperature up to 160$^{o}$C to simulate the real operating condition of the pipes. It was connected to the pipe by removable valves and fittings. This system is shown schematically in Figure. 1

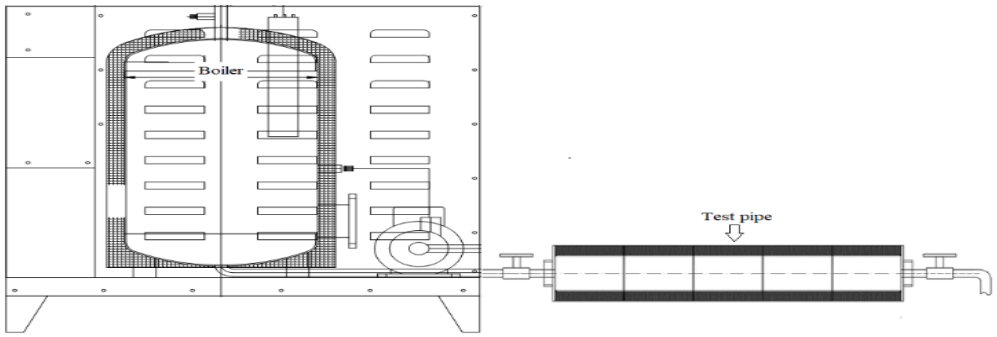


**Figure 1.** Test system

**Figure 2.** Conducting examination method

In the experiment, the pressure and temperature of the test pipes are changed step by step. Different examination conditions were also arranged to analyze the impact of examination parameters on the result. Only optimized parameters relating to equipment; operating condition; examination sequences; ... were selected to establish examination procedures. Based on the experimental results, 4 examination procedures were developed successfully, these are:

- Thermal/infrared imaging examination procedure No. **NDE-CUI-IR-01**
- Neutron backscatter examination procedure No. **NDE-CUI-NB-01**
- Pulsed eddy current examination procedure No. **NDE-CUI-PEC-01**

- Digital industrial radiographic examination procedure No. **NDE-CUI-DR-01**

**Figure 3.** CUI location detected by DR (before and after surface treatment)

CUI inspection program which is combined from 4 examination methods above applied successfully in the Tien Hai Gas Distribution Center (GDC) with 2 CUI detected locations. In the near future, it is expected to apply widely at Dung Quat Refinery and other petroleum plants.

The research and application result indicates that CUI can be detected and controlled by using NDT methods. Not only oil and gas factories but other industry (such as: electric power, construction,..) also can apply these methods with low-cost. In 4 CUI examination methods, 2 methods use ionizing radiation include: NB and DIR, it indicates that the application of ionizing radiation have played significant role more and more in industrial activities and human life.

# ESTABLISH THE TRAINING PROGRAM OF ALTERNATING CURRENT FIELD MEASUREMENT LEVEL II ACCORDING TO SNT-TC-1A

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**Project information:**

- **Project name: Establish the training program of alternating current field measurement level II for welding inspection according to SNT-TC-1A of The American Society for Nondestructive Testing.**
- **Code: CS/20/09-02**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020 - Dec 2020)**
- **Contact email: thinhlvt@gmail.com**
- **Published papers related to the project:**

1. Le Duc Thinh, Vo The Lu, Nguyen Van Duy, Vu Duc Vinh, Ngo Thi Kieu Oanh. Establish the training program of Alternating current field measurement level II according to SNT-TC-1A (in Vietnamese).
2. Le Duc Thinh, Vo The Lu, Nguyen Van Duy, Vu Duc Vinh, Ngo Thi Kieu Oanh. Establish the training program of Alternating current field measurement level II according to SNT-TC-1A. Nuclear Science and Technology magazine, 2020-2021.

Alternating Current Field Measurement (ACFM) is a technique of the Electromagnetic method used to detect surface defects of metal materials. Currently, this technique is widely applied in the field of maintenance of Oil and Gas projects as an alternative to the Magnetic Particle Testing method. The establishment of the ACFM training program according to Recommended Practice No. SNT-TC-1A of The American Society for Nondestructive Testing (ASNT) will promote the autonomy of the domestic testing of human resources, especially advanced techniques. Based on documents and standards combined with the actual survey, training programs and reference standard block developed to meet the requirements of international standards and in accordance with the conditions applied in Vietnam.

Research method: The actual survey of ACFM technical application needs is focused on the industrial sector, especially in the oil and gas which often has high requirements on the quality of the project as well as has enough economic potential for the application of advanced testing technique.

From the survey results and practical conditions in Vietnam, the NDE Center has established a training program under the internal certification system by following the training program requirements of the SNT-TC-1A and ANSI/ ASNT CP-105 document, researching the technical requirements contained in the standards ASTM and ASME. The project team has achieved the following results:

**Training program** has been established over 80 hours' duration, ensuring to satisfy the requirements of the recommended practice No. SNT-TC-1A given for personnel to study directly to Level II

| No. | Contents | Training Hours |
|---|---|---|
| 1 | Introduction to common welding methods and related discontinuities | 4 |
| 2 | Introduction to Nondestructive Testing (NDT) | 4 |
| 3 | Principle of Electromagnetic Testing (ET) | 4 |
| 4 | Principle of Eddy Current Testing (ECT) | 4 |
| 5 | Principle of Alternating Current Field Measurement (ACFM) | 4 |
| 6 | Alternating Current Field Measurement equipment systems | 8 |
| 7 | Procedure | 8 |
| 8 | Practice of Testing | 32 |
| 9 | Introduction to application standards | 8 |
| 10 | Review and discussion | 4 |
| **Total:** | | **80** |

**Training materials** including Training book, Presentation Lectures cover the contents of the training program.

**Review question bank** has 130 multiple choice questions with 04 answer options and includes the following contents: Welding process and related discontinuities; Principles, Methods, and techniques, Equipment system used, Function check before & after Testing and Applications.

**The examinations** for ACFM Level II meet the requirements of the recommended practice No. SNT-TC-1A, 2016 edition, was including:

a) Vision examinations: the content to test the ability to near vision acuity and color contrast differentiation.

b) General examination: includes 40 multiple-choice questions with 04 answer options, similar questions but not the same review questions bank provided to students. The content focuses based on test principles, equipment operating principles, advantages and limitations of testing techniques, welding processes and related discontinuities. The duration of the exam is 60 minutes.

c) Specific examination: includes 20 multiple-choice questions with 04 answer options. The question addresses the equipment (used), testing procedures, applicable standards. The duration of the exam is 60 minutes. Candidates are allowed to use the references (procedures, applicable standards).

d) Practical examination: requires the candidate to demonstrate the ability to operate the equipment system proficiently, standard / confirm the standard before and after the test, perform on 02 different samples, issue show and define the position parameters of the discontinuity size, evaluate the discontinuity based on given criteria. The practical test must have at least 10 different checkpoints to evaluate the candidate's ability. The duration of the exam is 120 minutes.

**Reference standards** according to ASTM E2261/2261M and ASME V, article 15

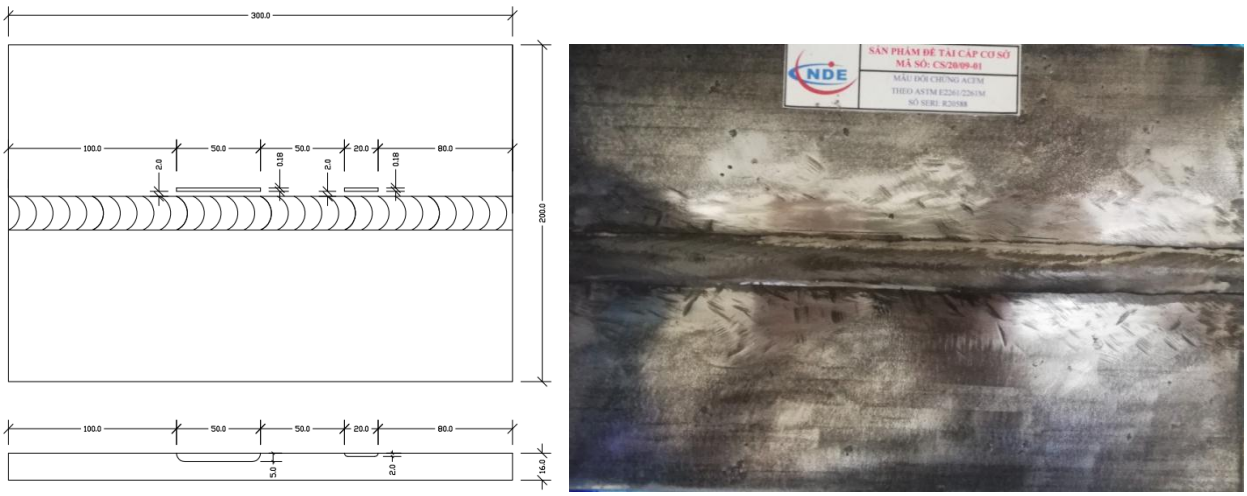


**Figure 1.** The ACFM reference standards

The subject has built the ACFM technical training program to meet the requirements of international standards with the introduction of a system supporting documents for the training program including training materials, lectures, question bank, examination in Vietnamese which could be suitable to the needs of practical application in Vietnam. The completion of the ACFM level II training program could create the foundation of the training program development for Electromagnetic Testing level III with knowledge cover three techniques: Eddy Current Testing (ECT), Alternating Current Field Measurement (ACFM), and Remote Field Testing (RFT).

# 2.4. APPLICATIONS IN ECOLOGY, ENVIRONMENT AND GEOLOGY

# ASSESSMENT OF CARBON SEQUESTRATION IN AGRICULTURAL LAND

**Le Dinh Cuong [1], Bui Dac Dung[1], Pham Dinh Rinh[2], Duong Duc Thang[1], Duong Van Thang[1], Doan Thuy Hau[1], Nguyen Thi Thu Ha[1], Nguyen Van Khanh[1], Nguyen Thi Oanh[1], Nguyen Huyen Trang[1]**

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**Project information:**

- **Project name: Assessment of carbon sequestrationin agricultural land.**
- **Code: 11/17/VKHKTHN**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan 2017 - Dec 2018)**
- **Contact email: ledinhcuong.inst@gmail.com.**
- **Published papers related to the project:**

1. Le Dinh Cuong, Bui Dac Dung, Pham Dinh Rinh, Duong Duc Thang, Duong Van Thang, Doan Thuy Hau, Nguyen Thi Thu Ha, Nguyen Van Khanh, Nguyen Huyen Trang. Using nuclear techniques to assesses the redistribution of soil properties due to erosion on cultivated hill slopes. VINANST-13, (2019), (in Vietnamese).
2. Le Dinh Cuong, Bui Dac Dung, Pham Dinh Rinh, Duong Duc Thang, Duong Van Thang, Doan Thuy Hau, Nguyen Thi Thu Ha, Nguyen Van Khanh, Nguyen Huyen Trang. Evaluation on soil erosion and sedimentation in agricultural cultivation hillsides by using isotopic technique Cs-137. Vietnam Soil Science Journal (accepted in July, 2020) (in Vietnamese).

Evaluation of carbon sequestration potential in the soil and showing soil properties that help store carbon in the soil are important for managers to plan and change farming practices to significantly reduce carbon emissions into the atmosphere. There are many factors influencing the carbon sequestration potential in agricultural soils, but within the scope of this study we focus to evaluate factors affecting the SOC sequestration potential in the soil, such as topography, landuse history, grain size composition and soil properties….

The catchment belongs to Dong Cao village in Tien Xuan commune, Thach That district, Hanoi city. A total of 150 sampling locations across 08 transects were taken along the catchment slopes to ensure passage through areas with different landuse history: The first landuse area is mainly regenerating forest, with shrub vegetation cover at the bottom. The No. 2 landuse area with a history of changing annual crops, planting mainly maize and cassava,

has been abandoned since 2014. Landuse area No. 3 has steep terrain, fallow for many years, partly regenerating forest, vegetation without shrubs.

The soil samples, after being processed in the laboratory, were taken to measure the content of Cs-137. Samples were also analyzed for the physical and chemical components of the soil (Table 1) at SFRI.

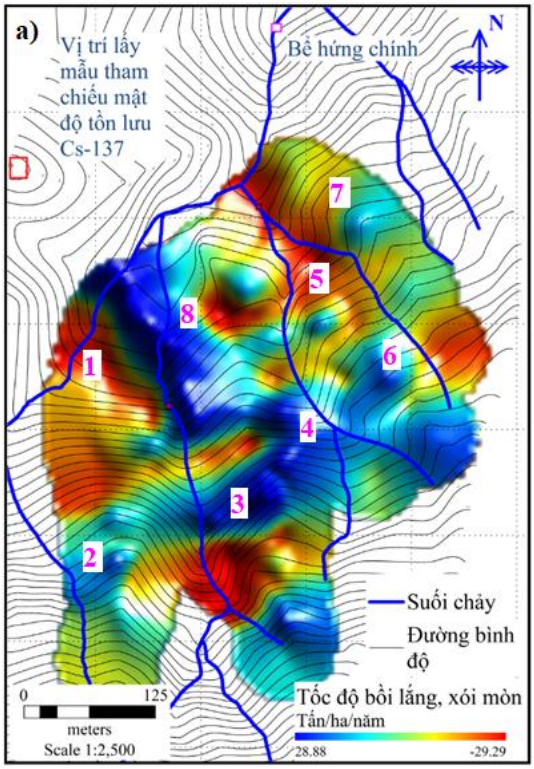


**Figure 1.** Distribution of RATE of erosion and sedimentation

**Table 1.** Correlation between SOC and soil properties and composition in different landuse areas

| Correlation between SOC and soil properties and composition | Landuse 1 | Landuse 2 | Landuse 3 |
|---|---|---|---|
| **Cs-137** | - | 0,68 | 0,54 |
| **pH Kcl** | 0,43 | 0,39 | - |
| **Total nitrogen-Nts** | 0,52 | 0,52 | 0,54 |
| **Cation exchange-CEC** | - | -0,20 | - |
| **Total $P_2O_5$- $P_2O_{5ts}$** | -0,28 | 0,24 | - |
| **Adsorption $P_2O_5$** | 0,24 | -0,49 | - |
| **Total $K_2O$- $K_2O_{ts}$** | - | - | 0,44 |
| **Adsorption $K_2O$-$K_2O_{dt}$** | - | - | -0,67 |
| **Ca2+** | - | -0,28 | - |
| **Mg2+** | - | - | - |
| **Fe2+** | - | 0,29 | - |
| **Sand (0.02-2)** | -0,59 | -0,59 | -0,63 |
| **Limon (0,02-0,002 mm)** | - | - | - |
| **Clay (<0,002 mm)** | 0,53 | 0,63 | 0,60 |
| **Slope (Δh/Δx)** | - | - | - |

*Evaluation of soil redistribution due to erosion and sedimentation:* Results of calculation of erosion and sedimentation rate with a thickness of the planting soil layer 15 cm according to the the Proportional Model for the entire eroded catchment of 4.35 (tons/ha/year). From the map of erosion rate distribution in the catchment (Figure 1), it is found that Cs-137 is accumulated at the sloping, lower slope positions such as position 8, 6 and 2; At fallow areas, with scrub of shrubs (as 3, 4). Whereas in positions 5 and 7 are the positions near the intersection of two streams, with strong currents, so the erosion rate is higher.

*Distribution of SOC in different landuse areas:* Landuse area No. 1; 2 and 3 have the average SOC content of 4.32%; 3.37%; and 3.79%, respectively. Using the hypothesis test of the T-Test overall average, the results showed that the SOC content in the three landuse areas was independent of each other. It can be seen that for each landuse area in the catchment there is a characteristic SOC concentration.

*Evaluation of the correlation between SOC and soil properties and composition in different landuse areas:* SOC was positively correlated with Cs-137 in landuse areas 2 and 3

(with correlation coefficients of 0.68 and 0.54, respectively, Table 1). The effects of erosion and steep topography are also reflected by the relatively low average SOC content. Lots of researchs have found a strong relationship between the SOC and Cs-137 concentrations that were conducted in the tillage agricultural areas. SOC is not clearly correlated with Cs-137 in landuse area number 1. The effect of the vegetation cover that is the shrub makes the landuse area have an SOC content of 4.32%. Plant biomass appears to be the major contributor to the SOC content in the catchment compared to their redistribution by topographical factors.

SOC is closely correlated with clay in all three landuse areas with the corresponding coefficients in regions 1, 2 and 3: 0.53; 0.63 and 0.60, respectively (Table 1). SOC is often correlated with clay because clay particles have a large surface area for SOC binding and provide an effective SOC protection against microbial degradation. SOC is inversely correlated with sand in all three landuse areas with the corresponding coefficients in zones 1, 2 and 3 respectively -0.59; -0.59; -0.63 (Table 1). SOC did not correlate clearly with Ca2 +, Mg2 +, Fe2 + and CEC in all three landuse areas. In the Dong Cao catchment, soil is predominantly acidic (acidic soil, with a pH of 3.0 - 6.5). The SOC did not correlate with directly field-measured slope values (Table 1). Around the world, some studies also found no association with slope or elevation.

*Evaluation of the ability to store SOC in different* landuse *areas:* Using SPSS software to evaluate multiple correlation regression for each different landuse area:

| | | |
|---|---|---|
| Landuse area 1: | $\boldsymbol{SOC = (2{,}92 \pm 1{,}62) + (0{,}353 \pm 0{,}19)* pH\_KCl + (0{,}113 \pm 0{,}045)*CEC - (0{,}54 \pm 0{,}01)*Sand - (0{,}082 \pm 0{,}009)* Slope}$ | **(1)** |
| Landuse area 2: | $\boldsymbol{SOC = -(1{,}33 \pm 1{,}71) +(0{,}123 \pm 0{,}037)*CEC - (0{,}438 \pm 0{,}023)* Sand +(0{,}94 \pm 0{,}015)*limon -(0{,}332 \pm 0{,}006)* Slope}$ | **(2)** |
| Landuse area 3: | $\boldsymbol{SOC = - (2{,}325 \pm 6{,}078) - (0{,}423 \pm 0{,}082)* Sand + (0{,}285 \pm 0{,}099)*Clay}$ | **(3)** |

The results of the multi-variable regression model show that the adjusted R-squared coefficients of the model for the landuse areas 1; 2; and 3 are 0.691; 0.798; and 0.735, respectively. That mean: 69.1%; 79.8% and 73.5% variation of the dependent variable SOC of each landuse area respectively is explained by 06 independent factors.

The equations (1), (2), (3) are linear regression models of SOC on soil composition factors, respectively, of landuse areas No. 1, 2 and 3. In these formulas, Factors have negative normalized coefficients (beta), meaning that they have a negative effect on the SOC dependent variable. Conversely, if they are positive, they have a positive effect. The larger the coefficient of absolute value, the greater its influence on the dependent variable SOC.

For landuse area No. 1 is fallow area with shrub vegetation below. SOC is negatively affected by sand, BD, slope and is positively affected by the remaining factors (pH_KCl, CEC,

Limon) which is most strongly impacted by sand with beta coefficient of great value for 0.540 SOC in this landuse area is not affected much by small particles such as clay, limon. This is also the case with Cs-137 when they are not strongly correlated in this landuse area. The reason is explained by the vegetation cover is the main source of carbon supplementation for the soil. The soil is also unaffected by tillage due to landuse and the impact of erosion. The No. 2 landuse area has a SOC that is inversely correlated with sand, BD, slope and positively correlated with the remaining factors CEC and Limon, the strongest impact is Limon with the coefficient of absolute value as high as 0.94. In contrast to landuse 1, SOC in this landuse area is heavily influenced by smaller aggregates such as limons. This is also the area that has the most influence of slope on the accumulation of SOC in the soil when the beta coefficient of slope has an absolute value of 0.332. The formula also shows the strong impact of CEC on SOC retention, with previous studies around the world showing that landuse practices promote SOC loss through continuous cultivation and plowing increase aeration, leading to C mineralization and the metabolism of $CO_2$ into the atmosphere. Together with the high correlation of SOC and Cs-137 it is evident that the redistribution of SOC and soil properties is influenced by erosion in this landuse area. Landuse area No. 3 has steep terrain, fallow for many years, partly regenerating forest, vegetation without shrubs, SOC is adversely affected by sand and affected by clay. The SOC in this landuse area is heavily influenced by the grain composition.

In conclusion, the highest concentration of SOC is found in fallow areas for many years, is regenerating forest, with shrub vegetation below. Whereas SOC is found at least in the No. 2 landuse with a history of annual crop change, growing mainly maize and cassava, which have been abandoned since 2014. The results of evaluating the effects of SOC-dependent factors in all three landuse areas showed that highly dependent SOC on grain, sand composition had a negative impact on the retention of SOC, clay and limon. Has a major impact on SOC retention. Other factors such as slope, density also have negative effects on C storage capacity in the soil.

Based on the results of correlation and linear regression modeling of SOC on soil composition factors of each landuse area, it is possible to confirm that landuse history has a great influence on carbon storage capacity. In slopes, the vegetative layer is an important factor for storing and supplying an important SOC to the topsoil, reducing the effects of soil loss due to erosion. Areas with a history of plantation and regeneration forests are more likely to retain SOC than areas with a history of annual crop landuse.

# DETERMINATION OF WARNING LEVELS AT LANG SON ENVIRONMENTAL RADIATION MONITORING STATION

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**Project information:**

- **Project name: Determination of Warning Levels at Lang Son Environmental Radiation Monitoring Station**
- **Code: CS/20/04-03**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020 - Dec 2020)**
- **Contact email: nguyenvankhanh.hus88@gmail.com**
- **Published papers related to the project:**

1. Nguyen Van Khanh et al., Study on the correlation between continuously monitored gamma dose rate and meteorological conditions at Lang Son environmental radioactive monitoring station. Young Researcher Conference on Nuclear Science and Technology – 6th, Hanoi, 2020 (in Vietnamese).

The Ambient dose equivalent rate (ADER) is mostly contributed from $^{238}U$ và $^{232}Th$ và $^{40}K$ in soils. The terrestrial background of each region is different due to natural radioactive nuclei and radon. In addition to the background level due to the contribution of natural radioactive nuclei present in the soil, the contribution of Radon (Rn) and its progeny in surface air causes fluctuations in the ADER. The contributions of Rn and its progeny are mainly influenced by meteorological conditions. Rain leads to the accumulation of Rn's progeny on the soil surface by depositing aerosols containing Rn progeny present in the atmosphere. Rn progeny deposited on the soil surface are capable of emitting Gamma radiation (mainly $^{214}Pb$ and $^{214}Bi$), leading to an increase in the ADER. The corresponding peaks in the ADER monitoring data time series are often referred to as the Rn peak or the rain peak. The “Rn peaks” can be high enough to exceed alarm levels. This warning level is intended to alert the managers of the ADER increase when the ADER value measured by the device exceeds the alarm level value. ADER caused by radiation incidents or nuclear accidents at long distances usually only gives a small increase in ADER which can be confused by fluctuations in ADER due to the influence of meteorological conditions. So to distinguish the increase in ADER caused by radiation and nuclear incidents or meteorological conditions. We proceed to determine the warning level for ADER based on estimating the value of ground background due to the contribution of natural factors in the soil and assessing the influence of meteorological parameters on ADER. Lang Son monitoring station was selected because it was the first installed station. The device of the

ambient dose equivalent rate SARA (ENVINET - Germany) is located on the premises of Lang Son meteorological station. This device is working relatively stably and has enough database. The total sensitivity of the NaI(Tl) probe is 270 (cpm/nSv/h) and that of the photopeak is 70.6 (cpm/nSv/h).

SPSS software is used to define the meteorological correlation. Meteorological data is collected for 3 years (2017-2019). As the results, 07 meteorological parameters 7 meteorological parameters including precipitation, air temperature, dew point, air pressure, relative humidity, wind direction and wind speed. influence the ADER from 8.2 – 15.2%. The results have a standard error of the estimate from 11.2 to 14.8% with a high-reliability level of 99% (Sig = 0.000). Precipitation, relative humidity, and air temperature are positively correlated with ADER, and barometric pressure negatively correlated with ADER.

Rn Peak Removal Algorithm – The average method that removes the contribution of Rn to the ADER to estimate the ground background is used. The data of ADER is collected for 3 years (2017-2019). The data series must be ordered by time and there is no change or movement of the equipment during this time. The ADER contribution due to cosmic radiation based on the height above sea level at the instrument site is 44.3 nSv/h and the self-absorption of the NaI(Tl) probe has been subtracted. Rn peak removal algorithms written in Python software with the following content:

Within a window of a given length (20 days chosen), starting at the beginning of the series, arithmetic mean (AM) and standard deviation (SD) of the values are computed. The values less than or greater than AM ± α(remove) * SD are excluded (α(remove) = 1.65 chosen). The procedure is repeated until no more values are being excluded from the window. Note that only upwards extremes are removed. Then the window proceeds one-time step ahead (1 day chosen), until the end of the series. Usually, three or fewer iterations are required. The algorithm assigns a baseline value for each time step (1 day), resulting in an estimate of the baseline's time series. The AM of these values is calculated; This is defined as the mean of the baseline or the ground background value of the ADER. The results are shown in Figure 1. The mean value or the background value of the ADER at Lang Son station is 39.85 nSv/h with a standard deviation of 7.58 nSv/h. The warning level after using the algorithm is determined by the formula (1):

[Warning level] = ([Mean value of ADER remaining after the algorithm] + [Standard deviation of the Mean value * 6]) (1)

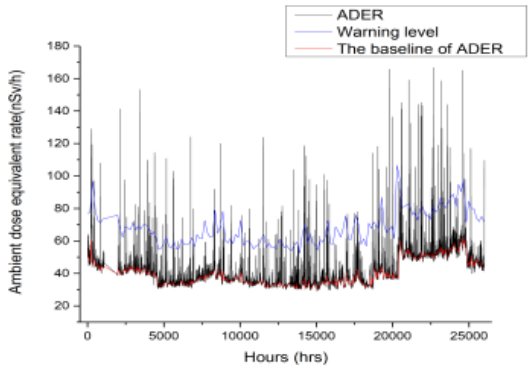


**Figure.1.** Diagram showing the estimated baseline of ADER and warning level

Applying formula (1), the estimated value of alarm level at Lang Son station is 85.33 nSv/h. In addition, we collected soil samples around the location of the SARA online Gamma dose rate measuring device for laboratory analysis. The total number of samples taken is 03 samples. The activity concentration of $^{226}Ra$, $^{232}Th$, and $^{40}K$ in soil samples was analyzed on a low background gamma spectrum using an HPGe detector. The value of the ADER contributed from natural radioactive nuclides in soil ($^{226}Ra$, $^{232}Th$, and $^{40}K$) is equal to 39.84 ± 2.87 nSv/h, approximately equal to 39.85 nSv/h which is calculated by the Rn peak removal algorithm - Average method. So the average method is reliable.

# 2.5. APPLICATIONS IN BIOLOGY, AGRICULTURE AND MEDICINE

# STUDY ON THE EFFECTS OF *Cordyceps militaris*'S EXTRACT ON THE DNA STRUCTURE OF IRRADIATED BACILLUS SUBTILIS

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*Hanoi Irradiation Center, Minh Khai - Tu Liem - Hanoi*

**Project information:**

- **Project name: "Study on the effects of *Cordyceps militaris* extract on the DNA structure of irradiated Bacillus subtilis".**
- **CODE: CS/20/08-01**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020 - Dec 2020)**
- **Contact email: ank55b1@gmail.com**
- **Published papers related to the project:**

1. Tran Xuan An, Nguyen Thi Thom, Hoang Dang Sang, Nguyen Van Binh, Tran Bang Diep, "Effect of *Cordyceps militaris*'s extract on the cell and DNA of irradiated *Bacillus subtilis*", Vietnam Conference on Nuclear Science and Technology VI ( for young people), Ha Noi, 08-09/10/2020.

The effects of gamma rays on cells and DNA have been studied in many different subjects such as fibroblasts, human blood cells, mouse cells, plasmids, and strawberry cells. Gamma rays are known as mutagens for cells and DNA. Under the influence of gamma rays, DNA has some major changes such as single strand breaks, double strand breaks of DNA molecules, creating branches, creating bridges between molecules and creating dimers. These mutations are responsible for the formation of cancers. Cordyceps is an intracellular parasite fungus in the Ascomycota group. *Cordyceps militaris* (*C. militaris*) have successfully been cultivated under artificial conditions to meet the needs of individuals for disease treatment and health promotion. *C. militaris* has currently attracted considerable research attention as a potential source of immune enhancement and anti-radiation, thanks to its high antioxidant activity. Our study focuses on the effects of *C. militaris* extract on cells and DNA of irradiated B. *subtilis* B5.

*C. militaris* was isolated and cultivated at the Hanoi Irradiation Center, *B. subtilis* B5 strain was provided by the Institute of Biotechnology - Hanoi University of Technology. Chemicals and equipment are provided by Radiation Technology Research Department – Hanoi Irradiation Center.

The quality of *C. militaris* extract was assessed through antioxydant activity by radical oxygen species scavenging method (DPPH). The scavenging effect increased with the increasing concentrations from 0.5– 3.0 mg/mL. At concentrations of 3.0–9.0 mg/mL, it was found to be approximately 90%, significantly higher than that of vitamin C at the same

concentration. Similar observation was reported by Zhan et al (2006), in the same concentration range.

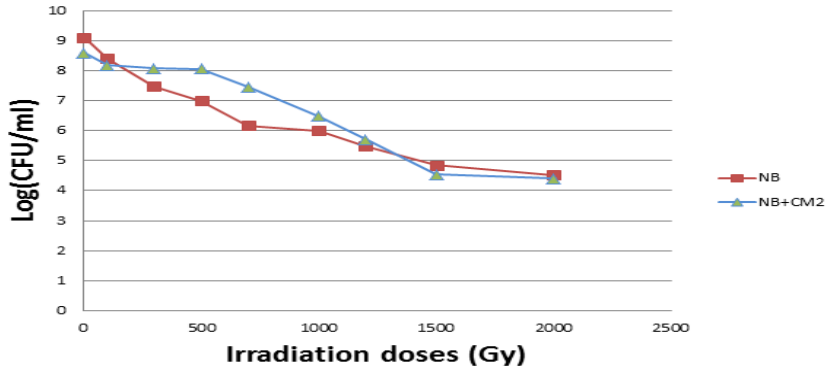


**Figure 1.** Survival rate of B. subtilis B5

The effects of *C. militaris* extract on reducing cell and DNA damages at irradiated *B. subtilis* was estimated based on the survival rate of bacteria in the medium (NB) supplemented *C. militaris* extract (CM2). From 0Gy to 1000Gy, the survival cell count of the bacteria in NB medium decreased from $10^9$ to $10^6$ CFU/ml. Meanwhile, the survival cell count of the bacteria in the NB medium supplemented with CM2 extract decreased from $10^9$ to $10^7$ CFU/ml. (Figure 1).

Besides, the modification in *B. subtilis* DNA after irradiation was investigated by gene amplification and 16S rRNA gene sequencing. The bioinformatics analysis of sequencing results showed that at dose of 300Gy, the rate of genetic modification of 16S dropped from 1% to 0%. At dose of 700Gy, it decreased from 2% to 0% and at dose of 1500Gy, it decreased from 3% to 1% (Table 1).

**Table 1.** Variation rate of analyzed samples

| Doses | CM2 extract | Homologous compared with control samples | The modification rate compared with the control sample |
|---|---|---|---|
| 300Gy | - | 99% | 1% |
| 300Gy | + | 100% | 0% |
| 700Gy | - | 98% | 2% |
| 700Gy | + | 100% | 0% |
| 1500Gy | - | 97% | 3% |
| 1500Gy | + | 99% | 1% |

* Control samples are non-irradiated samples

The results confirmed the protective effects of the *C. militaris* extract on cells and DNA of *B. subtilis* B5. In the future, this research may be extended to the radioactive protective effects on other organisms.

# RESEARCH ON THE DEVELOPMENT OF ISOTOPE TECHNIQUE (C-13 AND O-18) TO SUPPORT FOR DETECTING THE ORIGIN OF AGRICULTURAL PRODUCTS (APPLE)

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**Project information:**

- **Project name: Research on the development of isotope technique (C-13 and O-18) to support for detecting the origin of agricultural products (apple)**
- **Code: DTCB.07/18/VKHKTHN**
- **Managerial level: Ministry**
- **Implementation time: 33 months (Jan 2018 - September 2020)**
- **Contact email: meetanh@yahoo.com**
- **Published papers related to the project:**

1. Ha Lan Anh, Dang Duc Nhan, Nguyen Thi Tuoi, Mai Đinh Kien, Vo Thi Anh. Investigation into the method for stable isotope analysis of water in apple using lazer spectroscopic to assist in verifying geographical origin of the product. Vietna Journal of Sicence and Technology 62(6) 3.2020. *(In Vietnamese)*
2. Ha Lan Anh, Nguyen Thi Tuoi, Mai Đinh Kien, Vo Thi Anh, Vu Hoai, Đoan Thuy Hau. Reseach on the method for stable isotope analysis of water in apple using lazer spectroscopic LWIA - 24D - Losgatos to assist in verifying geographical origin of the product. 13th National Conference on Nuclear Science and Technology, Quang Ninh, August 2019. *(In Vietnamese).*

Traceability is common requirement for exported and imported commodities, particularly for food and agricultural products. Nowadays, there is an increase in different trends in food consumption. On the one hand, globalization boosts the identity in tendency and standardization of consuming models. On the other hand, markets with various demands appear and are featured by further sensitivity towards quality. They mainly concern about features like feeling, health, natural origin and culture of territories where the products are produced.

In Vietnam, although the traceability is a rather new activity, it has been swiftly deployed. The use of traceability stamps on products and goods is becoming more and more popular, which enables consumers and involved units to promptly trace accurate information via software such as scanner or checker GS1 and strengthens customers' belief towards products labeled origin-tracing stamps.

Stable isotope ratios of H, C, O are reliable scientific basis to assess product origin and promising scientific tools in tracing food origin. The IAEA has been conducting research and training programs to apply isotope compositions $\delta^{2}H$, $\delta^{18}O$, $\delta^{13}C$ into identifying geographic origin of the products. This identification is based on the relationship between two isotope compositions $\delta^{2}H$, $\delta^{18}O$ in the water with global meteoric water line. The regional features of $\delta^{2}H$, $\delta^{18}O$ and $\delta^{13}C$ isotope compositions depend on climate, environment and geographic characteristics in farm land.

All things considered, researching and developing analysing technique on isotope compositions $\delta^{18}O$ and $\delta^{2}H$ to apply into building database for the purpose of tracing food in general and imported fruit in particular in Vietnam are newly scientific base and in need of development.

The research used isotope technique and focused on assessing geographic origin of imported apple. Isotope compositions $\delta^{2}H$, $\delta^{18}O$ in fresh apple juice and $\delta^{13}C$ one in flesh and peel of apple planted in Washington – USA were analysed to assess geographic origin. The water of fresh apple sample was extracted by Cryogenic vacuum according to guide of IAEA Techdoc 1783 IAEA.

The samples of flesh and peel were freeze-dried at 55$^{o}$C under 100µbar of pressure with Thermo Savant, after that they will be crushed in liquid nitrogen and package in tin capsule for the purpose of analyzing isotope compositions $\delta^{13}C$.

Sotope compositions $\delta^{2}H$, $\delta^{18}O$ were analyzed by using lazer LWIA-24D spectrometer. The measurement of $\delta^{13}C$ performed in Isotope ratio mass spectrometer EA-IRMS. An isotope abundance is generally reported as a deviation of the isotope ratio of a sample relative to that of a standard:

$$\delta\,{}^{A}E = \left(\frac{R_{{}^{A}E,sample}}{R_{{}^{A}E,std}} - 1\right) * 1000 \quad (‰)$$

Where:

$\delta^{A}E$ : Heavy isotope composition with mass A (2, 13,18, amu) in isotope mixture of element E ($^{2}H+^{1}H$, $^{13}C+^{12}C$, $^{18}O+^{16}O$);

$R_{sample}$: Ratio isotope of sample

$R_{std}$: Ratio isotope of standard

Stable isotope composition results of apple samples originating from Washington - USA were used to evaluate origin assessment procedure of imported apples. For USA Gala apples, the correlation of the two isotope compositions $\delta^{2}H$ and $\delta 1^{8}O$ had the determination coefficient $R^{2} = 0.782$ with P = 1.05E-07 which was smaller than the significance level $\alpha = 0.05$; therefore, two variables was closely correlated. Similarly, P values for correlation test of two variables $\delta^{2}H$ and $\delta^{18}O$ in the apple sample Red, Fuji and Autum Glory were $R^{2} = 0.951$ with $P_{Red} = 0.005$; $R^{2} = 0.979$ with $P_{Fuji} = 0.0002$ and $R^{2} = 0.978$ with $P_{Autum\ Glory} = 0.01$. This means that the correlation of these two variables is tight and reliable (Figure 1).

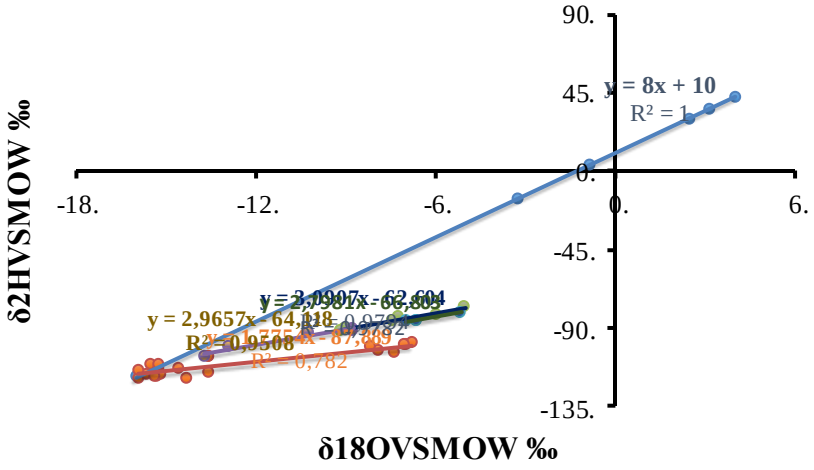


**Figure 1.** Correlation of isotope composition in Melbourne apple water

After the correlation equations for each type of apple were formed and tested, a simultaneous mathematical solution was used to find the intersection point of the evaporation line of the apple sample with the global meteorological water line. The results are shown in Table 1.

**Table 1.** The intersection value between the correlation lines of the isotope compositions $\delta^2H$ and $\delta^{18}O$ of Washington - USA's and Melbourne - Australia's apple samples with the global meteorological water line

| Isotope composition in source water | Gala (USA) | Red (USA) | Fuji (USA) | Autum Glory (USA) |
|---|---|---|---|---|
| $\delta^2H_{VSMOW}$ (‰) | -115.81 | -107.78 | -108.31 | -108.16 |
| $\delta^{18}O_{VSMOW}$ (‰) | -15.73 | -14.72 | -14.79 | -14.76 |

When comparing isotope composition in source water with $\delta^2H$ and $\delta^{18}O$ values of rainwater in Washington in Figure 2, it shows that $\delta^2H$ had the value from -103 ‰ to -135 ‰ and $\delta^{18}O$ value from -13.8 ‰ to -18.2 ‰.

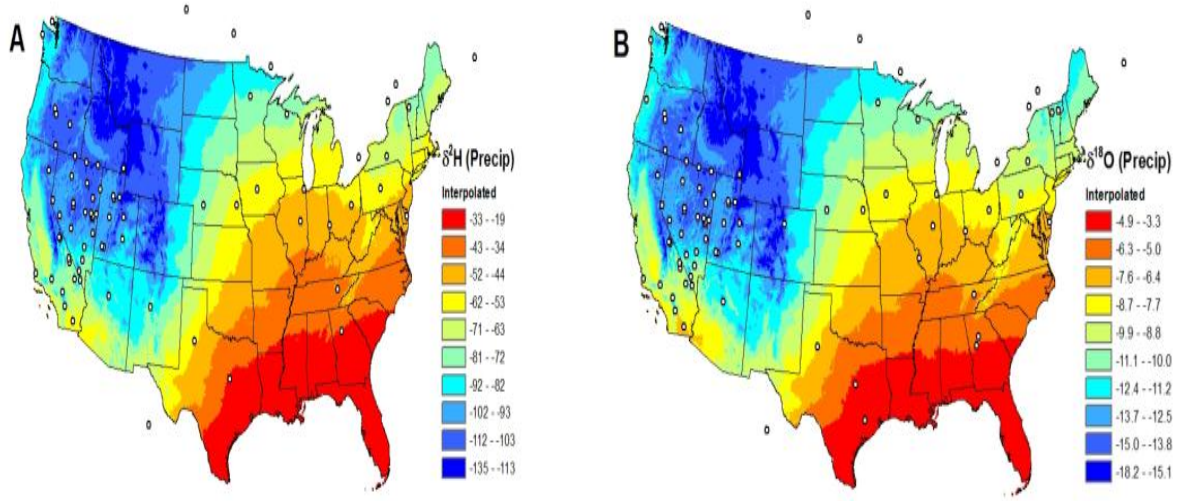


**Figure 2.** Mean annual values of $\delta^{2}H_{VSMOW}$ and $\delta^{18}O_{VSMOW}$ in precipitation USA

The results of the isotope composition of $\delta^{13}C$ in the flesh and peel of apple samples are combined with $\delta^{18}O$ value presented in Figure 3 shows that it is possible to discriminate apple from different countries quite clearly.

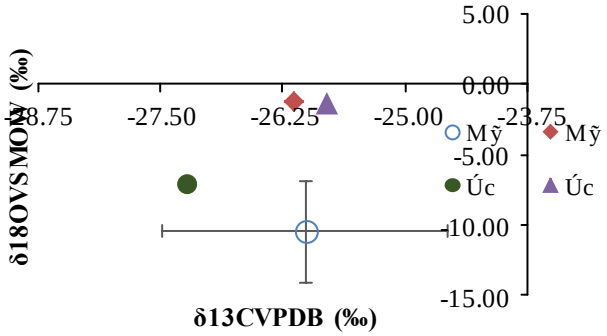


**Figure 3.** Distinguishing regions apple growing

The obvious difference of the value $\delta^{13}C$ is not large for the same plant, thus, to distinguish regions, it is recommended to combine the value $\delta^{13}C$ with isotopic component $\delta^{18}O$.

The objectives of the research to establish the method for analyzing the stable isotope composition $\delta^{2}H$, $\delta^{18}O$ in fresh apple water, and $\delta^{13}C$ in apple flesh and peel to assist in verifying the geographical origin of imported apple products has been achieved. The analytical procedure for $\delta^{2}H$ and $\delta^{18}O$ using the LWIA-24D laser absorption spectrometer system with an accuracy of ≤ 0.3 ‰ and ≤ 0.1 ‰ for the analysis $\delta^{2}H$ and $\delta^{18}O$ respectively was set up. The analytical process of $\delta^{13}C$ in apple flesh and the peel was also studied and completed with high accuracy of ≤ 0.3 ‰. These procedures were applied to analyze fresh apple samples to serve the problem of building the origin assessment process of apple products.

# APPLICATION OF THE METHOD OF STABLE CARBON ISOTOPE COMPOSITION ANALYSIS FOR SUGAR ($\delta^{13}C$) TO IDENTIFY THE AUTHENTIC QUALITY OF FRUIT JUICES (APPLE AND ORANGE JUICE)

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**Project information:**

- **Project name: Application of the method of stable carbon isotope composition analysis for sugar ($\delta^{13}C$) to identify the authentic quality of fruit juices (apple and orange juices)**
- **Code: CS/04/2020/VKHKTHN**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan. 2020 - Dec. 2020)**
- **Contact email: meetanh@yahoo.com**
- **Published papers related to the project:**

1. Ha Lan Anh, Pham Duc Khue, Mai Đinh Kien, Nguyen Thi Tuoi, Vo Thi Anh. Determination of the mixing extent of sugar from C4 plants in juice using the isotopic signature of carbon ($\delta^{13}C$) in sugar. Vietnam Journal of Sicence and Technology. (Accepted).(In Vietnamese)
2. Ha Lan Anh, Nguyen Thi Tuoi, Mai Đinh Kien, Vo Thi Anh, Vu Hoai. Application of variation in $\delta^{13}C$ to detect sugar adulteration of juice beverage. 6$^{th}$ National Conference on Nuclear Science and Technology for young staff of atomic energy, Hanoi, October 2020. (In Vietnamese).

The present food consumption shows various trends. On the one hand, globalization promotes uniformity in taste and standardization of consumption patterns. On the other hand, consumers are mainly concerned with the sensory characteristics, quality, and attached label of the natural origin and the production territory of the product. Consumers always want to know where their food comes from and how high the quality of the products is included, they are willing to pay for quality, geographic labels. As a result, techniques related to food quality control are ceaselessly developed and widely applied. Among others, the stable isotope analysis technique has an advantage in the identification of blends to assess the authentic quality of food.

The method of measuring the stable isotope ratio of carbon is often used to determine the origin of sugars in food products and fruit juices due to the apparent isotope fractionation under biochemical and physical processes occurring during the photosynthesis of plants. Most

plants on the Earth use the Calvin process to fix $CO_2$ from the atmosphere (plant of C3 type). The $CO_2$ fixation phase thanks to a receptor called RiDP (ribulose 1,5 - diphosphate) with the catalysis of the enzyme ribulose 1,5 - Diphosphate carboxylase in which compound 6C is formed. The C6 compound is unstable, and it quickly breaks down into two 3C molecules, APG (phosphoglyceric acid). Therefore, the first product of this $CO_2$ fixation process is the 3C compound, so it is called the C3 plant. The enzyme ribulose 1,5 - diphosphate carboxylase (rubisco) involved in this process preferentially reacts with $CO_2$ containing lighter carbon isotope ($^{12}CO_2$) and cleaves the heavy isotope of carbon ($^{13}C$). On the other hand, some special plants from warm climates such as sugar cane, corn, millet plants use the Hatch - Slack cycle to fix $CO_2$ in an intermediate C4 compound, and they are called plant of C4 type. The enzyme phosphoenolpyruvate carboxylase catalyzing the Hatch-Slack process is less dissociated than that of rubisco in C3, so the composition of the heavy isotope of carbon ($\delta^{13}C$) in C4 plants are less likely to be enriched. As a result, in C4 plants and their metabolites/products $^{13}C$ composition are more enriched compared to those in C3 plant metabolites/products. Plants C4 have $\delta^{13}C_{VPDB}$ values ($^{13}C$ composition relative to the International Standard: Vienna Pee Dee Belemnites: the biogenic carbonate minerals collected from South Carolina, USA) ranging from -17 to -9 ‰, the average is -13 ‰, while plants C3 shows $\delta^{13}C_{VPDB}$ values ranging from -32 to -20 ‰, with an average value of -27‰.

In case of sugar of C4 origin (e.g. canes) is added to sugar of C3 products (e.g. honey), the sugar blend would have a modified value of $\delta^{13}C$, it became more enriched compared to that in sugar of original honey that bees took from flowers of C3 plants. Based on this principle the isotopic method of $\delta^{13}C$ in sugar mixed in syrups as well as fruit juices has been established and applied worldwide.

Samples of orange juice and apple juice were collected from supermarkets in Ha Noi and transported to the laboratory. It was processed, and analyzed following the European standard ENV12140: 1996: Determination of the stable isotope ratio ($^{13}C/^{12}C$) of sugar from fruit juices using an isotope ratio mass spectrometer.

Isotope composition is calculated by the following formula:

$$\delta = \frac{R_S - R_{Std}}{R_{Std}}.1000 \quad (‰)$$

In which: $R_s$is the ratio of $^{13}C/^{12}C$ of samples to be measured; $R_{Std}$ is the ratio $^{13}C/^{12}C$ of the Standard (VPDB).

The Quality Control Programme for the analysis was applied in this study with the use of standard (QC) samples. The QC standards used were IAEA CO-8 ($\delta^{13}C$: -5.75 ± 0.06 ‰;), IAEA CO-9: ($\delta^{13}C$: -47.14 ± 0.15 ‰) , NBS-19 ($\delta^{13}C$: + 1.95 ± 0.03 ‰), Sucrose: ($\delta^{13}C$: -10.45 ± 0.13 ‰), IAEA 600: ($\delta^{13}C$: -27.77 ± 0, 04 ‰). The $\delta^{13}C$ of the standards is relative to the $\delta^{13}C$ of the primary V-PDB (Vienna Peedee Belemnite).

The research team used standard samples to construct calibration curves and check for the accuracy of the analysis. The results show that the correlation coefficient of the standard curve using all 5 points above reaches $R^2 = 1$ with the slope a = 0.998 ± 0.001 and intercept b

= -0.02 ± 0.01 with ($P = 8.64 * 10^{-10} < 0.05$). The relative analytical accuracy is smaller than 0.3 ‰.

Research results show that the $\delta^{13}C$ isotope composition of sugar from fresh apple juice and pure apple juice has a value in the range of -27.00 ‰ to - 24.00 ‰. Meanwhile, the isotope component $\delta^{13}C$ of sugar cane products has a $\delta^{13}C$ value in the range of -13.00 to -11.00 ‰. Based on this $\delta^{13}C$ isotope signature, it was revealed that there were some blends of C4 sugar apple and orange juices products available in the markets in Ha Noi city.

# 3D IMAGE-BASED DOSE SIMULATION USING GEANT4 TOOLKIT FOR APPLICATION IN PLANNING FOR LIVER CANCER TREATMENT BY MICROSPHERE $^{90}$Y: NEW DICOM INTERFACE DEVELOPMENT AND SELECTION OF PHYSICS MODEL

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**Project information:**

- **Project name: Development of a software for 3D dose histogram simulation applied in research and treatment on liver cancer by $^{90}$Y radio-embolization therapy**
- **Code: DTCB.12/19/TTNCTK**
- **Managerial level: Ministry**
- **Implementation time: 30 months (Jan 2019 - Jun 2021)**
- **Contact email: pvcuong0406@gmail.com**
- **Published papers related to the project:**

1. L. T. Anh P. V. Cuong, N. H. Ha, H. T. Thao. Intercomparison of Geant4 low energy electromagnetic models in 90Y dosimetry. Applied Radiation and Isotopes (accepted)
2. Integrating ITK toolkit into Geant4-based project to handle DICOM data for medical physics application. Physica Medica (submitted)
3. Phan Viet Cuong, Ho Thi Thao, Le Tuan Anh, Nguyen Hong Ha, Ha Quang Thanh, Tran Bai. An optimal segmentation method for processing medical image to detect the brain tumor. Communication in Physics (accepted)
4. Ho Thi Thao, Le Tuan Anh, Phan Viet Cuong, Nguyen Hong Ha. A convolutional neural network for 90Y SPECT/CT scatter estimation. Nuclear Science and Technology (2rd review round)

5. Phan Viet Cuong, Le Tuan Anh, Nguyen Hong Ha, Ho Thi Thao. Simulation of liver cancer treatment using 90Y microspheres based on anatomical image segmentation technique and Geant4 tookit. International Conference on Medical Physics and School. Quy Nhon, July 29th to August 2nd, 2019.
6. Ho Thi Thao, Phan Viet Cuong, Le Tuan Anh, Nguyen Hong Ha. Reseach and development of CT, MRI, SPECT and PET images segmentation software for automatic detection and extraction of brain tumor using ITK, VTK, Qt. International Conference on Medical Physics and School. Quy Nhon, July 29th to August 2nd, 2019.
7. Ho Thi Thao, Phan Viet Cuong, Le Tuan Anh, Nguyen Hong Ha. Optimal segmentation methods for detection brain tumors from medical images.Vietnam Conference on Nuclear Science and Technology-VINANST 14. Ha Long 07-09 Augsut 2019.
8. Nguyen Hong Ha, Phan Viet Cuong, Le Tuan Anh, Ho Thi Thao. Simulation of the image-based 3D dose distribution by Geant4: Application to liver cancer treatment with 90Y. Vietnam Conference on Nuclear Science and Technology-VINANST 14. Ha Long 07-09 Augsut 2019.

$^{90}$Y radio-embolization is a well-established therapy for the treatment of hepatocellular carcinoma, and also of metastatic liver deposit from other malignancies. To maximize the effectiveness of the treatment, ultimate goal is to accurately calculate patient-specific dose based on anatomical (CT data) and functional (SPECT or CT) DICOM image. Here CT data is for the target geometry construction while anatomical one is for a quantitative map of cumulated activity of $^{90}$Y. There are several Monte-Carlo codes which can be used in dose calculation as: MCNP, Fluka, PENELOPE and Geant4. This code can take into account tissue density distribution and radionuclide emission for the internal radiotherapy or the complicated beam profile for the external radiotherapy, leading to extremely accurate dose distribution simulation. Within our project, in order to develop a Treatment Planning System (TPS) in liver cancer treatment using $^{90}$Y radio-embolization therapy, Geant4 toolkit, CERN was selected as a base code. Advantages of Geant4 in comparison to other codes mentioned above are: there are many existing physics models from hadronic to electromagnetic which were well-validated for users to select. In addition, Geant4 was developed by Objective-Oriented Programming (OOP) technique C++ and it is the open-source toolkit then users would easily inherit based classes and extend application.

To read and extract data for the construction of simulation geometry as well as for mapping $^{90}$Y, we have developed a new DICOM interface based on ITK toolkit (Insight Toolkit). The ITK is a powerful open-source, cross-platform library with many useful algorithms for performing, processing, segmentation, and registration. ITK is known for providing high performance algorithm for several medical images processing commercial software as Osirix, NIRViz. New interface was integrated into Geant4 and allowing users to read multimodal DICOM image easily and automatically.

For absorbed dose simulation in radiotherapy, users could use low energy electromagnetic (EM) interaction models of Geant4. In this study, we implemented EM physics list G4EnDNAPhyiscis_option2, G4EmLivemorePhysics, G4EmPenelopePhysics and G4EmLowEPPhysics (G4DNA_opt2, G4Livermore, G4Penelope and G4Lowenergy in short) in our code to simulate energy deposit of mono-energetic electrons and  emitted from $^{90}$Y along the radial of a simple sphere (Dose Point Kernel-DPK) filled by liquid water or liver tissue equivalent material. Besides, the influence of cut values to DPKs and computation time also was taken into account. In Monte-Carlo simulation a lower cut value more accuracy is obtained. Lower cut value, however, implies to more computation resource needed. Therefore, one of our aim is to choose the most suitable EM models which is compromised between the accuracy and computation time.

Fig. 1 shows the DPKs of the mono-energetic electrons corresponding to four physics list as discussed above, the results with G4Livermore, G4Penelope, G4Lowenergy and G4DNA_opt2 are market as blue, green, black and pink curves respectively. Among energies of 50 keV, 100 keV, 933 keV and 1.5 MeV, which were chosen for simulation based on the energy spectrum of  emitted from $^{90}$Y with maximum energy of 2.28 MeV, the value of 993 keV is the mean value. Due to the applicable upper energy limit of below 1 MeV for G4DNA_opt2 physics list, so at 1.5 MeV, only the results for the three remaining physics list were presented. The applied “production cut” is 0.1 m for all physics list, except G4DNA_opt2 because it is only a discrete model so a production cut is not applied. Relative difference between the simulated results by three models and G4Penelope are display in Fig.2. As can be seen from Fig.2a and Fig.2b, the differences between G4Penelope with another physics list are less than 14 %. At 933 keV, the maximum relative differences are 8.4 and 6.8 % respectively for G4Livermore and G4Lowenergy. Meanwhile, DPKs by G4DNA_opt2 show a big difference with ones of other models.

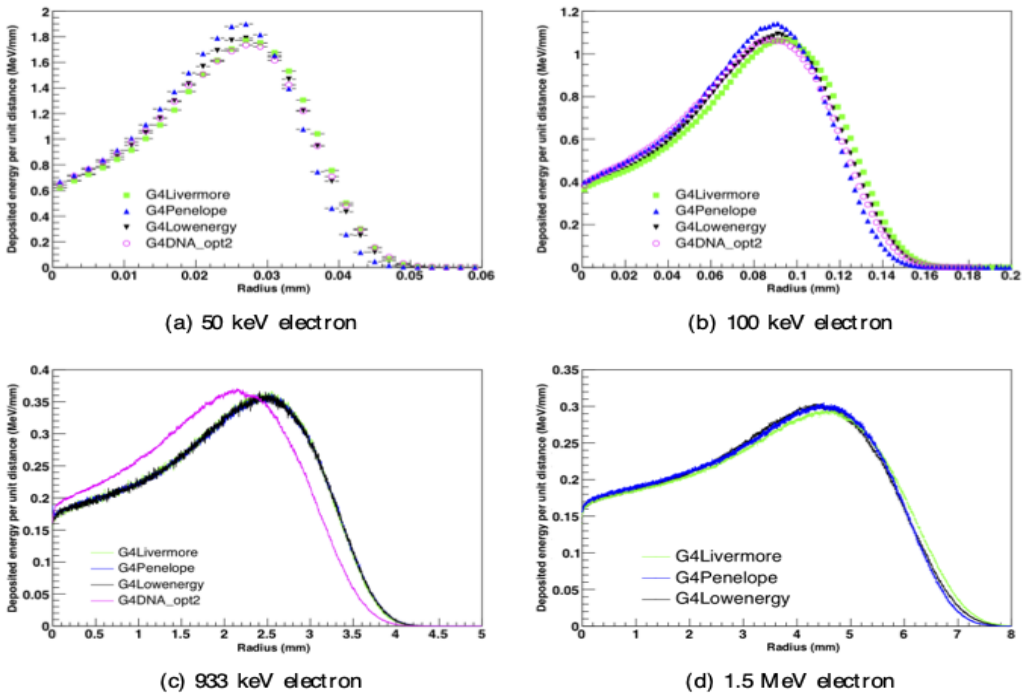
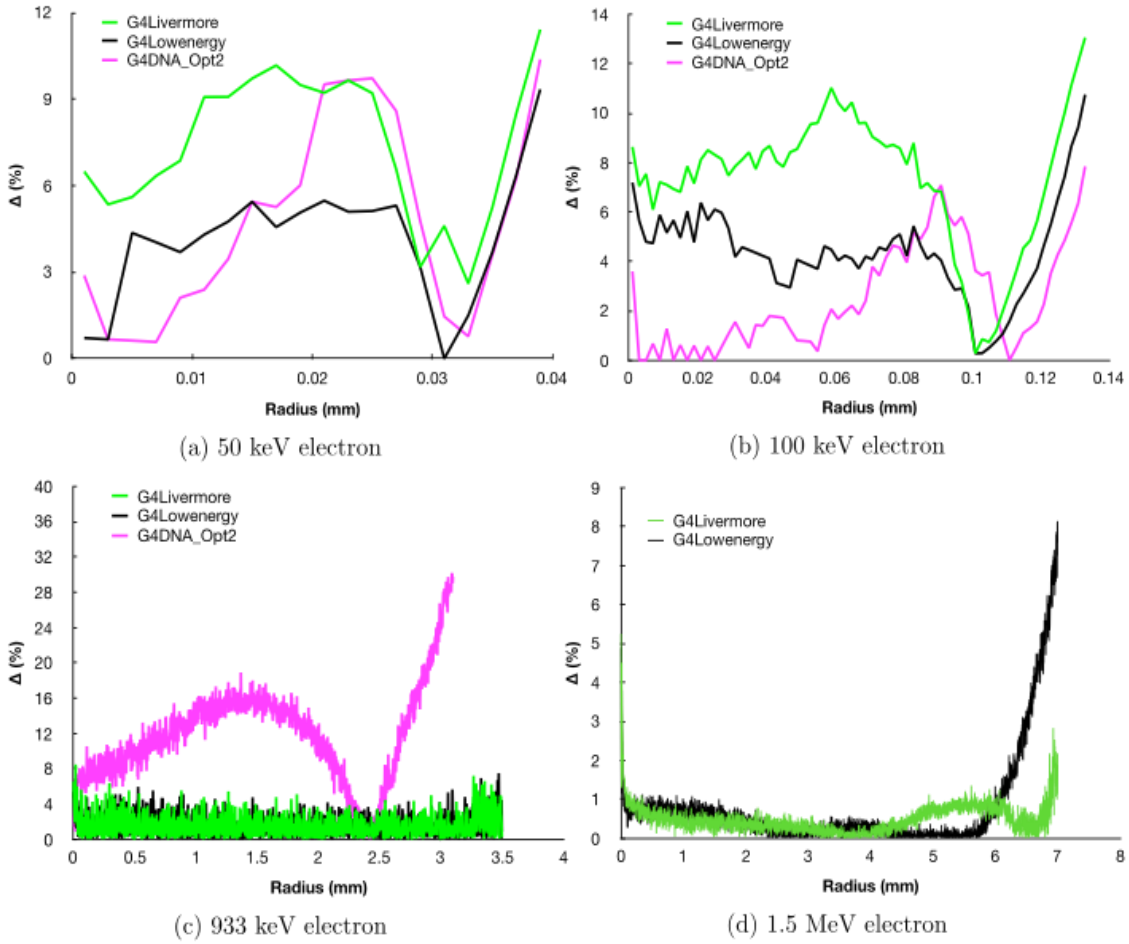



**Figure 1.** DPK of mono-energetic electron in the liquid water sphere

Previous studies concluded that G4DNA provides accurate results of the radial profile of energy deposit for incident electron having energies ranging from 10 keV to 100 keV. Therefore, in order to increase the accuracy of the simulation for 90Y microsphere therapy, Geant4 users can use G4DNA_opt2 in combination with another physics list for energy range up to 2.28 MeV. However, in reality the computation resource required may prevent us from applying this approach. For the demonstration, the simulation time corresponding to physics lists has been taken into account and show in Fig.3. As can be seen, G4DNA_opt2 costs a lot of the computation resource while G4Penelope is optimal.




(a) 50 keV electron (b) 100 keV electron

(c) 933 keV electron (d) 1.5 MeV electron

**Figure 2.** Relative differences of DPK results simulated by different low EM models in Geant4.

Furthermore, we investigated the influence of cut value to the simulated DPKs, cut values 1 nm, 0.1 μm, 1 μm, 1 mm was applied one by one. In principle, with cut value of 1 nm, most accurately simulated DPK results will be gained. It however, implies to longer computation time. While the simulation results shown that the difference of DPKs with cut values 1 nm and 0.1 μm is ignorable.

The obtained results indicated that G4Penelope with cut value of 0.1 μm is the optimal model for using in framework of Planning the Treatment of liver cancer with $^{90}Y$ microsphere.

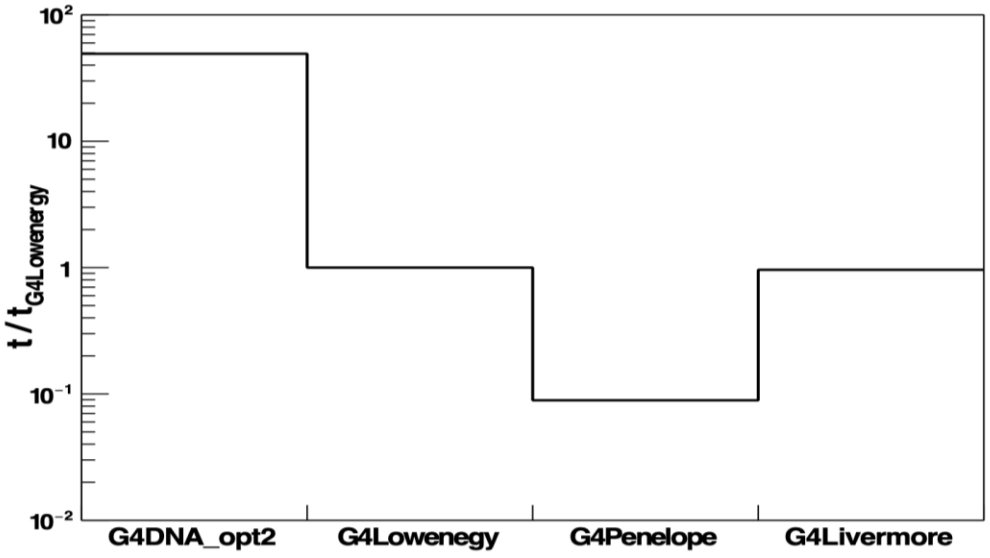



**Figure 3.** Computation time of each EM models in relative comparison to G4Lowenergy model

# STUDY ON PREPARATION OF HYDROGEL FROM GELATIN/CARBOXYMETHYL-CHITIN AND GELATIN/CARBOXYMETHYL-CHITOSAN BY IRRADIATION METHOD FOR APPLIFICATION AS STEM CELL SCAFFOLDS (ADIPOSE-DERIVED STEM CELLS)

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**Project information:**

- **Project name: Study on preparation of hydrogel from gelatin/carboxymethyl-chitin and gelatin/carboxymethyl-chitosan by irradiation method for application as stem cell scaffolds (adipose-derived stem cell)**
- **Code: DTCB.05/19/TTNCTK**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan 2019 - Dec 2020)**
- **Contact email: phu659797@yahoo.com**
- **Published papers related to the project:**

1. Dang Van Phu, Nguyen Ngoc Duy, Le Anh Quoc, Tran Thanh Phuoc, Tran Le Bao Ha, Nguyen Quoc Hien. Synthesis of radiation-crosslinked gelatin/carboxymethyl chitosan hydrogel scaffold for tissue culture. VINANST-13, Aug 07th – 09th, Ha Long City, Quang Ninh Province, Viet Nam, 2019 (in Vietnamese).
2. Dang Van Phu, Bui Duy Du, Le Nghiem Anh Tuan, Tran Le Bao Ha, Nguyen Quoc Hien. Radiation-crosslinked gelatin/carboxymethyl chitosan hydrogel scaffold for tissue culture. Vietnam Journal of Chemistry, 57(4e1,2), 223-226, 2019 (in Vietnamese with English abstract).
3. Dang Van Phu, Nguyen Quoc Hien, Le Anh Quoc, Nguyen Ngoc Duy, Phan Phuoc Thang, Nguyen Thi Ly, Nguyen Thi Kim Lan, Tran Le Bao Ha. Radiation-crosslinked scaffolds from gelatin/CM-chitin and gelatin/CM-chitosan for adipose-derived stem cell culture. Nuclear Science and Technology. Vol. 10 No. 3 (2020) DOI: https://doi.org/10.53747/jnst.v10i3.4

Tissue engineering is a quickly enlarging interdisciplinary field that attempts to provide solutions for the regeneration of defected or damaged tissues. Designing biologically active scaffolds with proper characteristics is one of the most key-factors for successful tissue engineering. The hydrogel-scaffolds from biocompatible natural polymers have been

extensively investigated and developed for application in tissue engineering. In practice, the hydrogel-scaffolds in tissue engineering ought to meet several design criteria to mimic the natural extracellular matrix (ECM). These are dependent on the cultured source cells and the targeting tissues. Alternatively, in the soft tissue-regeneration technique from the adult mesenchymal stem cells, a biomaterial scaffold should be owned to the functional specifications as follows: the hydrophilic 3D-microporous structure, porosity >70% and pore size ~100–300 m, swelling degree ~6–12 g/g, compressive strength ~1–80 kPa, admissible biodegradability, non-cytotoxicity, and providing a good platform for cell adhesion, function, differentiation, and transplantation. To create a suitable hydrogel scaffold, the selection of polymer compounds and hydrogel production methods are always the main topic that attracted many studies. Radiation technology has been providing a useful tool to modify polymers including radiation crosslinking of hydrogels. The crosslinking reaction in polymer solution occurred through the recombination of macromolecule free radicals, which were produced by the indirect and direct effects of radiation interactions. The radiation-crosslinked gelatin is a promising cell culture scaffold due to its chemical resemblances to the ECM. Despite the advantages, poorly mechanical and physicochemical properties, and enzymatic degradation beyond controllability have restricted applications of gelatin-based hydrogels. Because of the many inherent useful bio-properties of carboxymethyl-chitosan (CM-chitosan) and carboxymethyl-chitin (CM-chitin), they have been considered as the leading materials to make hydrogels for biomedical applications. So far, the investigation of the effect of CM-chitosan and CM-chitin in a mixture with gelatin (G) on the features of scaffolds using for the culture of human adipose-derived stem cells (hADSCs) are still lacking. Thus, this work aims to characterize the scaffolds derived from G/CM-chitin and G/CM-chitosan hydrogels, prepared by radiation-crosslinking combined freeze-drying and radiation sterilization for applying hADSCs culture to generate soft tissue.

Hydrogels from mixtures of G/CM-chitin and G/CM-chitosan with the different weight ratios of 9.5/0.5, 9/1, 8.5/1,5, and 8/2 were prepared by $\gamma$-ray radiation-crosslinking. The porous scaffolds were obtained by hydrogel freeze-drying and sterilized by -ray irradiation with 25 kGy. The physicochemical properties of hydrogel scaffolds, such as the gel fraction, swelling, porosity and pore size, mechanical strength, were determined by commonly appropriate techniques. The bio-degradability of them was estimated through the weight loss after immerging in PBS solution containing collagenase. Their cytotoxicity, adherence, proliferation for hADSCs were evaluated with the standard methods used in tissue engineering.

It was determined that the total polymer concentration of 15% (w/v) in water and a dose of 30–35 kGy were necessary to prepare the hydrogels with a gel fraction of 68–82%. The 8.5/1.5 component weight ratio for G/CM-chitin and G/CM-chitosan was the most suitable for making hydrogel-scaffolds (Fig.1). The physicochemical properties of the prepared hydrogel-scaffolds from G/CM-chitin and G/CM-chitosan were almost identical. In particular, the degree of swelling in phosphate buffer solution (PBS), compressive modulus, porosity, and pore size of the scaffolds were 7.0-9.1 g/g, 45.6-66.4 kPa, 70.6-73.3%, and 100-300 $\mu$m, respectively.

These characteristics are to satisfy the requirements for hADSCs culture scaffold to the regeneration of soft tissue.

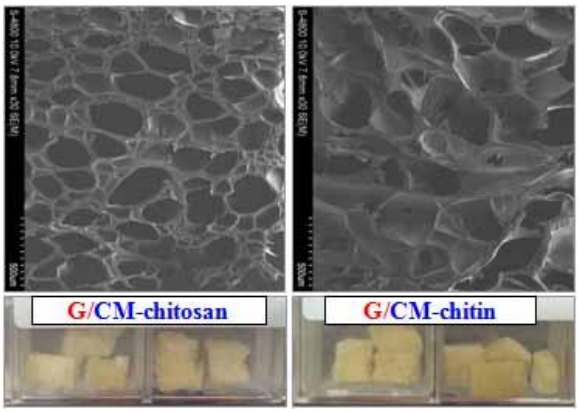


**Figure 1.** SEM images and photographs of the hydrogel-scaffolds

The prepared scaffolds were almost entirely degraded by collagenase enzyme activity. After 21 h incubation, the biodegradability of both the scaffolds was around 81–83% evenly. Besides, the scaffolds still retained their original shape after two weeks of immersion in the hADSC cell culture medium (DMEM/F12 + 10% FBS + 1% antibiotic). This positive result is suitably considered for culturing hADSCs for soft tissue formation. The cytotoxicity of G/CM-chitosan and CM-chitin scaffolds was assessed according to ISO 10993-5:2009 by incubating hADSCs with the extracts of them. The hADSCs morphology and density for treatments with the hydrogel-scaffolds were almost unchanged from that of the negative control group (fresh culture medium). From these results, it may be suggested that the G/CM-chitosan and G/CM-chitin scaffolds exhibited non-cytotoxicity for hADSCs. Concerning cell ingrowths, the relative growth rate (RGR,%) values of the hADSCs after an incubation period of 24 h were 96.2%-97.1%, which appropriated 7.3-fold higher than that of the positive control group (latex extract). These values could be assorted to scoring 1 (non-cytotoxicity) and qualified. The superb non-cytotoxicity of hydrogel-scaffolds was assigned to the biocompatibility of the gelatin, CM-chitosan, and CM-chitin.

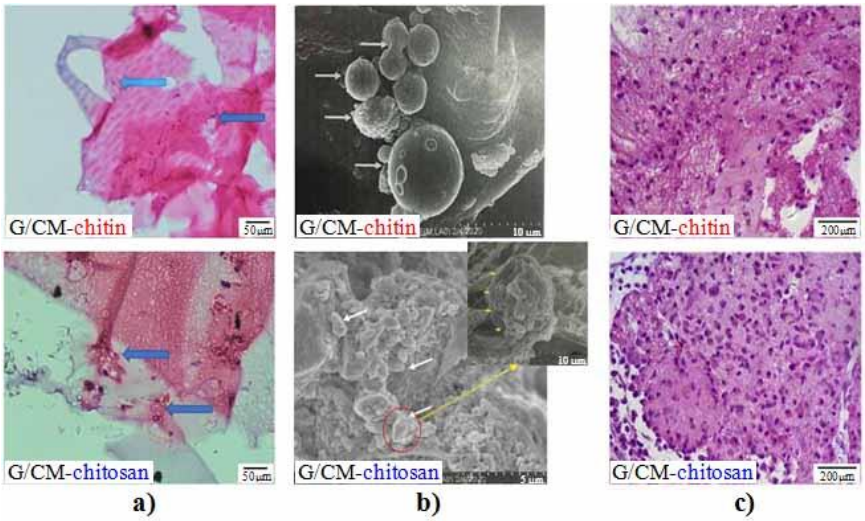


**Figure 2.** The hADSC-cultured scaffolds for 7 days: a) stained H&E - confocal micrographs; b) SEM images; and c) stained MTT assay - confocal micrographs

The surface properties, chemical compositions, and porous characteristics of hydrogel scaffolds are known to strongly influence the adsorption of proteins, which can subsequently regulate cell behavior such as attachment, spreading, migration, and proliferation. The results of Figure.2a and 2b showed that hADSCs were discernably attached and aggregated in porous channels of both scaffolds. The scaffolds contained gelatin accommodating affinity amino acid sequences and CM-chitosan/chitin carrying charged functional groups, which promoted cell adhesion to scaffold materials. After seven days of incubation, cell density accounted for 60-70% of the field area on optical microscope images (Fig.2c). The proliferating hADSCs on the scaffolds increased over culturing time and reached a threshold density after 7-9 days of culture (Table 1). These results are virtually similar to the study of Yang et al., (2010) and Debnath et al., (2015). Moreover, paired Student's t-test showed that the $OD_{570}$ values were not significantly different over the time of culture between the two scaffolds. This result suggests that CM-chitin or CM-chitosan could be used to blend with gelatin to create cell culture scaffolds.

**Table 1.** The measured $OD_{570}$ values of hADSC-cultured scaffolds over time

| **Incubation time (day)** | **$OD_{570}$ value** | | **T-test pF(pT)** |
|---|---|---|---|
| | G/CM-chitin | G/CM-chitosan | |
| 1 | $0.121^{d} \pm 0.016$ | $0.186^{b} \pm 0.018$ | 0.863(0.065) |
| 3 | $0.136^{d} \pm 0.055$ | $0.219^{b} \pm 0.017$ | 0.166(0.072) |
| 5 | $0.207^{cd} \pm 0.082$ | $0.300^{b} \pm 0.096$ | 0.843(0.463) |
| 7 | $0.316^{bc} \pm 0.188$ | $0.486^{ab} \pm 0.029$ | 0.047*(0.269) |
| 9 | $0.359^{ab} \pm 0.149$ | $0.627^{a} \pm 0.059$ | 0.271(0.088) |
| 11 | $0.488^{a} \pm 0.059$ | $0.696^{a} \pm 0.044$ | 0.719(0.002*) |
| *$LSD_{0.05}$* | *0.141* | *0.315* | *p <0.05* |

pF: F-value probability of two variances and pT: t-value probability of two means
*pF or pT <0.01: significant (**); 0.01 ≤ pF(pT) < 0,05: significant (*);*
*and pF(pT) ≥ 0.05: non-significant.*

In conclusion, the scaffolds of G/CM-chitin and G/CM-chitosan were successfully fabricated using radiation-crosslinking combined freeze-drying. The performance of ameliorating the inherent properties of the gelatin scaffold by CM-chitin and CM-chitosan is in the same behaviors as demonstrated and compared. Both prepared scaffolds from G/CM-chitin and G/CM-chitosan possessed the swelling degree, porosity and pore size, mechanical strength, biodegradability, non-cytotoxicity, and support of cell adhesion and proliferation in suitability for human adipose-derived stem cell culture for soft tissue regeneration. Based on the experimental results, two fabrication processes for gelatin/CM-chitin and gelatin/CM-chitosan scaffolds with 10-18 units/batch were also established.

# DESIGN, CONSTRUCTION OF SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT) CONFIGURATION FOR SERVING RESEARCHING FLOW MODELS

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**Project information:**

- **Project name: Design construction of single photon emission computed tomography (spect) configuration for serving testing flow models**
- **Code: CS/20/06-01**
- **Managerial level: Institute**
- **Implementation time: 18 months**
- **Contact email: chuannv@canti.vn**
- **Published papers related to the project:**

1. Nguyen Van Chuan, Nguyen Thanh Chau, Nguyen Ngoc Nhat Anh. Construction of single photon emission computed tomography (spect) configuration for serving testing flow models. Nuclear Science and Technology conference for young scientists. (In Vietnamese) 10/2021.
2. Nguyen Van Chuan, Nguyen Thanh Chau, Nguyen Ngọc Nhat Anh,. Design construction of single photon emission computed tomography (spect) configuration for serving testing flow models. Scientific journal of Thu Dau Mot University 05/2021.

Radioactive tracer techniques collect data about residence time distributions, computational flow dynamics techniques, and other tracing techniques that require lengthy computations with a large volume of data. Especially, the complex chemical reaction systems require complex calculations and a large volume of data, many redundant calculation results, making it difficult to interpret the results. Single Photon Emission Computed Tomography (SPECT) is a technique that combines tomography reconstruction and radioactive tracer techniques. SPECT uses multiple radiation detectors at a cross-section of the system, tomographic images of the tracer distribution at that cross-section can be reconstructed from the measurement dataset with a suitable rendering algorithm that is a useful method that allows verifying the results of experiments in tracer and study flow patterns visually. With the initial goal of accessing fast SPECT technique and supporting tracer experiments to study flow patterns through tracer movement, the research team at the Centre for Applications of Nuclear Technique in Industry have performed a study **"Design, construction of single-photon emission computed tomography (SPECT) configuration for serving testing flow models".**

Based on reference to the development of SPECT technology developed in the medical field and the application of SPECT technology researched at domestic and abroad, the Research Team simulated (used MCNP - Monte Carlo N - Particle) 36 ½ inch Na(TI) detectors to design, and construct a regular hexagonal SPECT structure consisting of 12 ½ inch Na(TI) detectors to survey objects with a maximum diameter of 200mm called HexSPECT which includes:

- The hexagonal SPECT mechanical configuration includes 6 sets of mechanics and controls corresponding to the 6 sides of the hexagon. Each mechanical set is arranged with 2 collimators with 10cm apart conect with 2 ½ inch NaI(TI) detectors, which are connected to an electronic control system via a stepper motor and an optical sensor that controls the transducer linear.

- Image reconstruction software written in C# language supports SPECT image reconstruction base on algorithms: Filtered Back Projection (FBP), Algebraic Reconstruction (ART), Statistics (expectation maximization – EM) and other image processing algorithms.

- Nuclear data acquisition and control box include: The mechanism for nuclear data acquisition and control includes a computer that connects a 12 detectors single-channel nuclear meter (Ludlum M4612) via RS232 signal transmission port to receive the nuclear data and it is also connected to the control box via the USB port to control the linear motion of the transducer through the motor. The computer has both received nuclear data and controlled the motion according to the desired number of rays through a control program on the computer.

- SPECT scanning configuration control program: The program is written in C# language allows setting SPECT measurement configuration, and connecting, controlling SPECT configuration motion and Ludlum 4612 device to obtain measurement results from 12 NaI ½ inch probes on the computer.

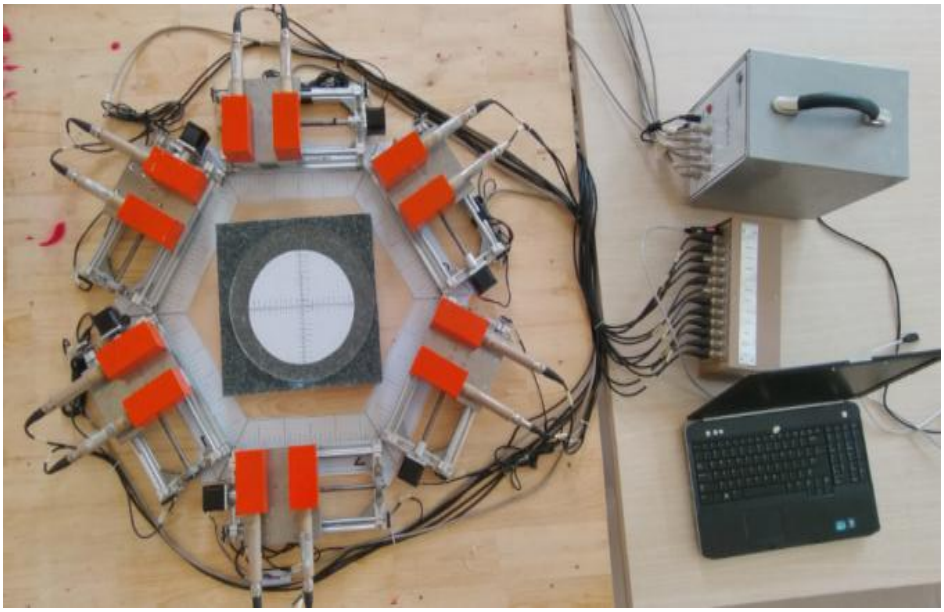


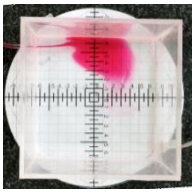
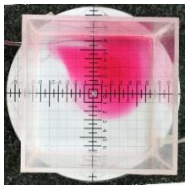
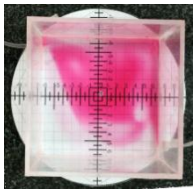
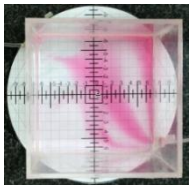
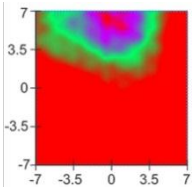
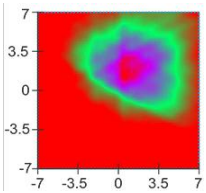
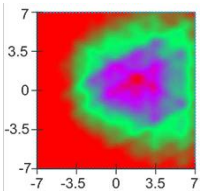
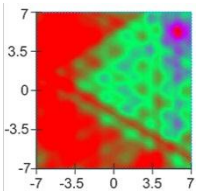
**Figure 1.** HexSPECT configuration

The HexSPECT configuration used for testing on physical models includes:

The static sample is used to evaluate the image spatial resolution of the configuration. HexSPECT static sample with outer diameter 3cm, thickness 2mm, height 5cm (inner diameter 2.6cm), 1mCi radioisotope I-131 completely dissolved in 15ml water was added to the sample. The results show that the best SPECT image is taken when setting up the measurement with 20rays, good spatial resolution with a relative error of about 12%, time taking a SPECT image is about 20 seconds.

The HexSPECT dynamic sample used for the experiment has a size of 140mm x 140mm x 100mm and is arranged at the entrance, exit, and pump position for radioactive isotope I-131 mixed with dye with 3mCi activity. The water level in the sample is 14mm high. The inlet and outlet valves are the same and have the same flow rate of 200ml/min. Perform SPECT profile scan with 24 rays and measurement time 30 seconds for each slice. During migration, the tracer movement was recorded by video to compare with the resulting image reconstruction. Tables 1 show that the reconstructed image clearly shows the movement and distribution of the tracer in the liquid medium at different times. The movement of the tracer follows the inlet side from the initial time to 00 hours 04 minutes 30 seconds, and then move circulation follow outlet side at 00 hours 12 minutes 30 seconds

**Table 1.** Image reconstruction results when the tracer begins to be injected into the sample at a time (00 hours:00 minutes :00 seconds) at different times

| | | | | |
|---|---|---|---|---|
| Snapshot (cut from video) |  |  |  |  |
| Reconstructed image |  |  |  |  |
| Timeline | 00:00:30 | 00:04:30 | 00:12:30 | 00:55:40 |
| Position of tracers center | (0;5) | (2;2.5) | (2;1) | (3.5;0) |

The obtained results show that the Research Team initially successfully approached the fast SPECT technique for serving experiments in tracer research. The next research direction will focus on developing SPECT technique with better spatial resolution serving dynamic samples with higher flowrate.

# 2.6. RADIATION SAFETY AND RADIOACTIVE WASTE MANAGEMENT

# RESEARCH AND EVALUATE THE CURRENT STATUS AND TEST TECHNOLOGY FOR SOLID AND LIQUID WASTE TREATMENT AT A R-D RARE AND RADIOACTIVE ORE PROCESSING FACILITY

**Nguyen Huy Cuong et al.**

*Institute for Technology of Radioactive and Rare Elements,*
*48 Lang Ha, Dong Da, Hanoi, Vietnam*

**Project information:**

- **Project name: Research and evaluate the current status and test technology for solid and liquid waste treatment at a R-D rare and radioactive ore processing facility.**
- **Code: DTCB.12/17/VCNXH**
- **Managerial level: Ministry**
- **Implementation time: 30 months (Jan 2017- Jun 2019)**
- **Contact email: huycuong1961@gmail.com**
- **Published papers related to the project:**

1. Nguyen Thi Kim Dung, Ngo Quang Huy, Nguyen Thi Lien and Nguyen Huy Cuong "Assessing the level of heavy metal residues in soil and water of industrial points in Dong Thap commune, Dan Phuong, Hanoi". Journal of Chemistry, Physics and Biology Analysis, T-24 Issue 2, p. 181-190 (2019) (in Vietnamese)
2. Luu Cao Nguyen, Nguyen Huy Cuong, Nguyen Quoc Hoan, Ha Dinh Khai, Tran The Dinh and Than Quang Minh "Research and evaluate the absorption capacity of bentonite towards U, Th, Fe, Mn". The 5th Conference on Nuclear Science and Technology of Young Staffs working in the field of Atomic Energy, Vietnam Atomic Energy Institute (2018). (in Vietnamese).

The second facility of Institute for Technology of Radioactive and Rare Earth Elements in Phung, Dong Thap Commune, Dan Phuong District (Base of Phung, BoP) has been operating for research and testing production since 1981. Production activities at the Base of Phung released solid, liquid and gaseous waste. Beside, in the second facility of ITRRE also have 2 temporary radioactive waste storages with total area of 1.000 $m^2$. The wastewater treatment plant built in Phung hasn't been effectively employed. Wastewater collected into a pond of the BoP contained several heavy metals at the level exceeded the National Technical Standard for wastewater (QCVN 40:2011/BTNMT) and could not be released directly in to the city wastewater treatment system. The facility also doesn't have a separate system for treatment, isolation and storage hazardous solid waste. Therefore research and evaluate the current status and test technology for solid and liquid waste treatment in the BoP is essential.

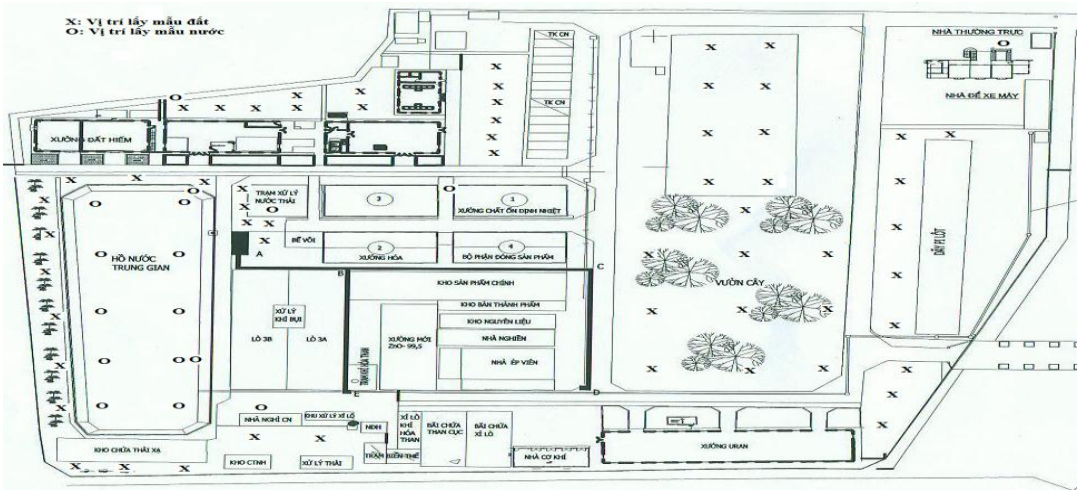



**Figure 1.** A scheme showing locations of sampling points for environment monitoring at the BoP

The soil and water along with sludge samples taken in dry and rainy season of the 2018 were analyzed for the heavy metals, radioactive nuclides (38 soil, 20 water and 2 sludge samples from the pond inside the BoP).

The result shows that: most of heavy metal contents in the pond of BoP wastewater are below the limit of QCVN 40:2011/BTNMT, excepted for Cd, which is 5 times higher than the limit value. After treatment in the wastewater treatment station, the treated water satisfied the limit value indicated in column B – QCVN 40:2011/ BTNMT. The air quality in BoP was almost clean and no signal of pollution was discovered. The high concentration of Zn of the soil exceeded the allowable level from 6 – 15 times or Cd exceeded 1 – 6 times according to the QCVN 03:2015 (for both in the dry and rain seasons). Uranium content was almost the same compared with those in normal surface soil in other countries (2,8 mg/kg) but thorium content was 2 – 10 times higher (7,4 mg with surface soil sample from other countries). This proved a fact that although facility's soil hasn't been contaminated from uranium ore processing pilot scale research, but it possibly affected by rare earth processing activities.

**Study on the treatment process of wastewater in pond of BoP using ion exchange resin**

The ion-exchange method using cationic resin Resinex™ KW-S was studied for removing Cd. Heavy metals content in this water such as Zn, Fe, Mn, Cr... was considerably decreased. From these studies, a conclusion regarding the treatment of 200L water in the pond of BoP by 0.6 kg ion-exchange resin with the flow rate of 200 mL/minute was drawn.

**Study on proposing a method for treatment of the wastewater in pond of BoP**

*Option 1*: Firstly, wastewater was neutralized by NaOH, Na2S then added in order to decrease Cd2+ content followed by the coagulation with PAC to precipitate the metal hydroxides and the flocculation with anion polymer to fasten the precipitate process of these hydroxides. After precipitation, secondary neutralization (to increase pH value to 7 - 8) and filtration by absorbent to completely removing of floating debris were carried out.

*Option 2*: Treating of 9,000 $m^3$ wastewater in the pond: Slowly pumping NaOH solution into the pond until the pH value of water in the pond reach to 9. Water in the pond was tumbled thoroughly by the tumbler installed on the floating platform. $Na_2S$ agent, PAC and polymer solution was then added evenly on the pond and the tumbling continues. After analysis to confirm the water in the tank follow the QCVN 40:2011/BTNMT water would be pumped to the garden in the territory of the facility. Sludge mixture would be pumped through sand filtration tower.

**Study on using Vietnamese bentonite to isolate hazardous waste**

Experimental results showed that the passing speed of ion $UO_2^{2+}$ through soil – bentonite mixture was $2.85.10^{-10}$ m/s. Therefore, if isolation time for hazardous weight is approximately 50 years, the thickness of isolation layer will be:

$$T = 2.85.10^{-10} \times 50 \times 265 \times 24 \times 3600 = 0.45 \text{ (m)}$$

According to the Construction Technical Standard of TCXDVN 320:2004 for designing hazardous waste dumping site, the isolation layer must have the thickness around 50 – 60 cm (compressed clay), therefore, the isolation layer thickness of 50 – 60 cm made from Binh Thuan bentonite (75%) from 50 to 60 cm is enough to safeguard hazards leaked from the solid waste.

**Proposal of environment monitoring and waste management program in Phung**

- Regular and Irregular environment monitoring and inspecting.
- Monitoring environmental quality outside and inside Phung facility follow environment monitoring program once per 6 months.
- Environment monitoring of radiation, wastewater, emission, solid waste management and hazardous waste.
- Waste management program in Phung includes the wastewater treatment, solid waste management, safety assurance and environment hazard response, infomation report and archive.
- Regulate organizations who do research and production activities in Phung facility, enforce them to collect, treat (if possible) gas, liquid and solid waste generated from their activities and/or temporarily manage it before sending to treatment area to ensure environment protection.
- The program of setting up the management frame for BoP environment protection activities can be adjusted according to capability of ITRRE and allocated fund.

# STUDY ON SYNTHESIS OF MULTI-FUNCTION MATERIALS POLYVINYL ALCOHOL -G- ACRYLIC ACID -CO- CACBOXYMETHYL CELLULOSE BY IRRADIATION TECHNIQUE - EVALUATE ADSORPTION CAPACITY FOR $Co^{2+}$; $Zn^{2+}$ AND $Cs^{+}$ IONS AND APPLICATION TO SURFACE DECONTAMINATION

**Nguyen Trong Hoanh Phong**

*Radiation Technology and Biotechnology center, Nuclear Research Institute*

**Project information:**

- **Project name: Study on synthesis of multi-function materials polyvinyl alcohol -g- Acrylic acid -co- Cacboxymethyl Cellulose by irradiation technique - evaluate adsorption capacity for $Co^{2+}$; $Zn^{2+}$ and $Cs^{+}$ ions and application to surface decontamination**
- **Code: CS/20/01-02**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020 - Dec 2020)**
- **Contact email: sharahio@yahoo.com**
- **Published papers related to the project:**

1. Pham Bao Ngoc, Nguyen Giang, Le Van Toan, Le Xuan Cuong, Nguyen Minh Hiep, Vu Ngoc Bich Đao, Tran Thi Tam, Le Van Thuc, Le Thi Thuy Linh, Le Thi Bich Thy, Han Huynh Dien, Nguyen Trong Hoanh Phong[1] "Study on the absorption ability of metal ions $Co^{2+}$, $Zn^{2+}$, $Ni^{2+}$, $Pb^{2+}$ of copolymers prepared by γCo-60 irradiation grafting technique" Journal of Science and Technology of Vietnam (in Vietnamese).

Nowadays, the development of nuclear technology brings a lot of benefits to people's daily lives in many fields such as energy, environmental health ... In addition to these great benefits, there are many issues related to the dangerous radioactive contamination levels from production activities (nuclear power, radioisotopes ...). These fission products are deposited on machinery, equipment, and objects over time and cause contamination.

Very small radioactive substances attach to all surfaces of the system and accessing them is dangerous because the dose of radiation emitted from them is very high. Not only that, equipments are used for a long time when disassembling because of expiration date has extremely high dose rate. For these devices, storing or discharging them into the environment without reducing the amount of radiation on the surface will have a huge and long-term impact on the surrounding environment.

Surface decontamination technique using polymer coating may peel is an effective decontamination technique, simple and has been applied in many nuclear facilities around the world. A polymer gel solution is a mixture of one or more polymers dissolved in a suitable solvent with several additives and decontamination agents. When using, it is necessary

tospray or coat polymer gel onto the contaminated surface. After a short time, this coating will dry to form a thin and firm film that can be easily removed with absorbed radioisotopes.

This report presents the results of research on applying radiation technique to synthesize copolymers gel capable of decontamination radioactive isotopes on the surface. Products created with high purity, easy to use, cheap price, easy peeling to apply as radioactive isotope decontamination in undesirable locations to ensure the health of workers, the community, and the present and future environment. Use Modde 5.0 software to find the optimal parameters for the grafting process of PVA-g-AA-co-CMC copolymers on Co-60 gamma source satisfying 2 conditions are fast drying time and highest tensile strength. FT-IR; DSC; SEM is used to evaluate the structural properties of materials. The adsorption of metal ions of copolymers has also been studied by atomic absorption spectroscopy AAS and inductively coupled plasma source spectroscopy ICP-MS. The absorption efficiency of $Zn^{2+}$; $Co^{2+}$; $Cs^{+}$ ions was also investigated.

Multi-functional material Polyvinyl alcohol -g- Acrylic acid -co- Carboxymethyl cellulose were prepared by radiation technique with composition: PVA (14.5%); acrylic acid (5.9%); CMC (1.5%) and radiation dose is 3.7 kGy, tensile strength reaches maximum value (1700 g / $cm^2$) and dry time reaches minimum value (13 hours).

FT-IR analysis showed that AA monomers were grafted onto PVA molecules and copolymed with CMC. The differential thermal analysis also showed that AA was grafted onto PVA molecules through cross-linking; these bonds are broken at about $268^0$C. The surface of the coupling material is very rough and the complex surface structure of the PVA-g-AA-co-CMC copolymers consists of many overlapping layers.

The adsorption capacity of the copolymer for $Co^{2+}$; $Zn^{2+}$ and $Cs^{+}$ have been studied, the maximum absorption of the copolymer for $Co^{2+}$; $Zn^{2+}$ and $Cs^{+}$ ions were 268; 286 and 215 mg/g, respectively. Evaluation of the test of decontamination on the surface of ceramic tile, stainless steels, and cements show that the decontamination performance is dependent on the surface. For all isotopes studied, decontamination efficiency on the research surface is from 95-99% after one decontaminated. The activity on the surface after decontamination is below 3.7 Bq/$cm^2$, satisfy the regulations of IAEA for the maximum permissible contaminated surface. Decongel 1101 is almost higher than that of polymer gel on studied surfaces for all isotopes but the difference isn't noticeable.

The research team is currently continuing to work to improve the properties of the product, such as shortening the dry time, increasing the rate of adsorption, and testing the decontamination of radioisotopes on many different surfaces, to create a product effective surface decontamination directed to the commercialization of products in the future.

# STUDY ON DESIGN OF RADIATION-SHIELDING CONCRETE MIX USING BARITE AGGREGATES FOR COBALT-60 RADIATION SOURCE

**Duong Ngoc Duc[1], Pham Xuan Dinh[1], Mai Thai Nam[1], Nguyen Trung Kien[1], Tran Thanh Quang[1], Do Tien Thinh[2]**

*[1]Center for Non-Destructive Evaluation, 140 Nguyen Tuan, Thanh Xuan, Ha Noi*

*[2]VietNam Institute for Building Science and Technology, 81 Tran Cung, Cau Giay, Ha Noi*

**Project information:**

- **Project name: Study on design of radiation-shielding concrete mix using barite aggregates for Cobalt-60 radiation source**
- **Code: CS/20/09-03**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2017- Dec 2017)**
- **Contact email: duongngocduc@gmail.com**
- **Published papers related to the project:**

1. Study on design of radiation-shielding concrete mix using barite aggregates for Cobalt-60 radiation source (in Vietnamese).

The advent of the nuclear energy industry indicates the need for concrete technology to shield against radiation. One of the directions is to replace traditional aggregates with other natural aggregates or artificial aggregates to increase the refractive properties of concrete against gamma and neutron radiation sources. The research team has conducted research and selected suitable concrete materials that resist barite aggregate, satisfy the same mechanical properties as conventional concrete but have a higher refractive index, meet the requirements bridge for structural items to ensure bearing capacity as well as ensure radiation shielding, applied in construction works with specific features but limited construction area.

Project implementation contents: Design the common concrete components, change the aggregate of sand and stone with barite ore aggregate. Determine the parameters of compressive strength, slump, volume weight, and refractive value through the experiments, thereby determining the aggregate composition for the refractive concrete with the optimum refractive value.

Materials used in this study: Nghi Son Cement PCB40, Lo River sand, Ha Nam crushed stone, water, chemical additive Sika 300-2M, Barite ore in Bac Giang ore mine is used.

Design of concrete mix: according to theoretical calculation method combined with conducting experimental tests based on the theory of "absolute volume", the process has been done following "Technical instructions - the selection of concrete components"- Ministry of

Construction. In the experiment, the cement weight, slump, and water /cement ratio (N/X) were kept unchanged. 4 concrete mixes have been implemented. In CP1, the fine aggregate was replaced with barite, in CP2 coarse aggregate was replaced with barite, in CP3 fine aggregate and coarse aggregate was replaced with barite, in CP4- reference mix, the conventional concrete mix was kept.

Sampling, making, and curing of test specimens according to TCVN 3015: 1993, determine sample slump under TCVN 3106: 1993, determine compressive strength according to TCVN 3118: 1993, determination of density according to TCVN 3115: 1993.

Shielding test: Radiation shielding tests were performed using Cobalt-60 as the source for gamma rays, use a NaI(Tl) detector to record the count. Use lead for radiation protection and gamma beam collimation. The experimental samples include 4 sample groups corresponding to 4 designed concrete mixes, cube sample size 100mm, each group 3 samples. Irradiated samples with different irradiation times and thicknesses.

The relationship between the intensity of photon I, Io and the thickness x of the absorbent is exponential:

$$I = I_0.e^{-\mu x} \qquad 1)$$

It is more convenient to refer to the layer or thickness of shield required to reduce the original radiation intensity by a factor of 2 or by a factor of 10. These are called the “half value layer” and “tenth value layer” thickness respectively (HVL, TVL). From the test, it is possible to calculate the thickness required to reduce the dose by HVL and TVL from the attenuation coefficients μ or the equation estimated from the curve of normalized radiation dose as a function of distance.

The results of the experiments are shown in Table 1.

**Table 1.** Technical specifications

| Sample | Technical specifications | | | | |
|---|---|---|---|---|---|
| | **Compressive strength (MPa)** | **Slump (cm)** | **Density (kg/m3)** | **HVL (mm)** | **TVL (mm)** |
| **CP1** | 48.9 | 11.5 | 2660 | 49.3 | 163.7 |
| **CP2** | 37.4 | 11.5 | 3328 | 42.2 | 140.9 |
| **CP3** | 49.9 | 11 | 2844 | 48.2 | 160.1 |
| **CP4** | 51.8 | 10 | 2406 | 55.8 | 185.3 |

From the above results, we can see: The slump of the sample has a higher content of barite aggregate than the conventional concrete sample, so reduce the amount of water so that the slump is low, the concrete is not stratified. The density and radiation shielding coefficient (HVL, TVL) of barite concrete is higher, due to the higher mass of barite sand aggregate and barite rock. When barite ore aggregate is used, the compressive strength is reduced, because the elastic modulus of the barite sand is lower, the barite rock hardness is lower than that of conventional concrete.

The study has determined that the optimal concrete aggregate composition is CP2 aggregate with mechanical and mechanical parameters that meet the requirements of concrete grade M300, when replaced with barite aggregate, CP2 aggregate sample gives results on radiation shielding coefficient, HVL and TVL values are 23,9% higher than conventional concrete. For constructions, it is possible to replace conventional concrete with barite aggregate refractive concrete to ensure the bearing capacity and ensure radiation safety when the construction area is limited.

# METHOD FOR CORRECTION OF PHOTON CONTRIBUTION IN NEUTRON CALIBRATION FIELDS OF $^{241}$Am-Be SOURCE

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**Project information**

- **Project name: Method for correction of photon contribution in neutron calibration fields of $^{241}$Am-Besource**
- **Code: 07/HD/DTCB**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan.2019 - Dec.2020)**
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- **Published papers related to the project:**

1. Le Ngoc Thiem, Hoang Sy Minh Tuan, Nguyen Ngoc Quynh, Tran Hoai Nam. Evaluation of the Calibration Factors of Neutron Dose Rate Meters in a Neutron Field. Nuclear Science and Techniques 30 (2019).
2. Ngoc-Thiem Le, Nguyen Ngoc Quynh, Dang Thi My Linh, Bui Thi Hong, Tran Hoai Nam. Developing a Simulated Workplace Neutron Field by Moderating Am–Be the source. DTU Journal of Science and Technology (2019).
3. National Conference on Nuclear Science and Technology (Quang Ninh - Vietnam).

There are existing photons in neutron calibration fields, this fraction may affect the neutron dose component during the calibrations of neutron doserate meters which are sensitive to photons in the fields; therefore, correction of photon contribution in a neutron calibration field is a crucial need in order to ensure the proper calibrations of neutron doserate meters. This work presents the method for correction of the photon dose contribution in neutron calibration fields of $^{241}$Am-Be source.

In this works, two neutron calibration fields of $^{241}$Am-Be source (i.e. a field of a bare $^{241}$Am-Be source and a simulated workplace neutron field moderated using a spherical PMMA with a diameter of 30 cm, denoted as "Mod30-($^{241}$Am-Be)") were investigated. The standard

values of neutron dose equivalent rates (i.e., $H_{n\_std}$) and those values for photons (i.e., $H_{g\_std}$) are mentioned in Table 1.

Various neutron doserate meters were also used in this work for measuring the relevant neutron dose equivalent rates (i.e., neutron ambient dose equivalent - $H^*(10)_n$ or neutron personal dose equivalent - $H_p(10)_n$). Photon dose equivalent/rates were measured using gamma spectrometers (with scintillator detector – NaI(Tl) or semiconductor detector - HpGe) and/or an ion chamber.

In addition to those, Monte Carlo simulations using MCNP6 code were also conducted to investigate the related quantities in order to confirm the suitability of the experimental methods.

In order to investigate the sensitivities of neutron doserate meters, those meters were irradiated in a gamma field of $^{137}$Cs and/or $^{60}$Co with a known standard value of $H_{g\_std}$ to obtain the meters' readings ($H_{g\_read\_}$). There are several approaches to determine the standard values of $H_{g\_std}$ in neutron fields (i.e., using gamma spectrometers, ion chambers, etc.). In this work, the values $H_{g\_std}$ were measured using gamma spectrometers (with scintillator detector – NaI(Tl) or semiconductor detector - HpGe). The sensitivities to photons of the neutron meters (or the calibration factors of neutron meters in a photon field - $CF_\gamma$) are then deduced as Eq. (1)

$$CF_\gamma = \frac{H_{g\_std}}{H_{g\_read\_\gamma}} \qquad (1)$$

The readings of neutron meters due to photons existing in neutron fields ($H_{g\_read\_n}$) can be given in Eq. (2).

$$H_{g\_read\_n} = \frac{H_{g\_std}}{CF_\gamma} \qquad (2)$$

When the neutron meters are irradiated in a neutron standard field with known standard values of neutron doses/rates ($H_{n\_std}$) and known standard values of photon doses/rates ($H_{g\_std}$), the readings of neutron doserate meters recorded due to both neutrons and photons ($H_{n-g}$) can be achieved. Therefore, the readings of neutron meters solely due to neutrons in the fields ($H_{n\_read}$) can be deduced as Eq. (3). The values of $H_{n\_read}$ must be corrected for influenced factors in compliance with the ISO 8529 series (scatter, linearity, the geometry of the meter, air attenuation,…) or the ISO 12789 series.

$$H_{n\_read} = H_{n-g} - H_{g\_read\_n} \qquad (3)$$

The calibration factor of neutron meters ($CF_n$) are determined as Eq. (4).

$$CF_n = \frac{H_{n\_std}}{H_{n\_read}} \qquad (4)$$

From Table 1, one can figure out that the ratio between $H_{g\_std}$ and $H_{n\_std}$ varies from 3% to 7% for different neutron fields

**Table 1.** Standard ambient dose equivalent rates (for neutrons: $H_{n\_std}$ and for photons: $H_{g\_std}$) in neutron fields

| Distance | Ambient dose equivalent rates ($\mu Sv.h^{-1}$) | | | |
|---|---|---|---|---|
| | Bare $^{241}$Am-Be | | Mod30-($^{241}$Am-Be) | |
| (cm) | $H_{n\_std}$ | $H_{g\_std}$ | $H_{n\_std}$ | $H_{g\_std}$ |
| 80 | 234.3 | 7.70 | 79.4 | 4.85 |
| 100 | 149.9 | 6.03 | 52.1 | 3.18 |
| 125 | 96.0 | 3.99 | 34.2 | 2.26 |
| 150 | 66.6 | 3.08 | 26.4 | 1.59 |
| 175 | 49.0 | 2.18 | 21.1 | 1.20 |
| 200 | 37.5 | 1.74 | 17.0 | 0.97 |
| 225 | 29.6 | 1.30 | 14.1 | 0.76 |
| 250 | 24.0 | 1.10 | 12.5 | 0.66 |

The calibrations of three neutron meters were conducted in the neutron standard field of a bare source taking (and not taking) into account the corrections of photon contribution in the neutron fields. The values of $H_{n\_read}$ (in Eq. 3) measured at various distances by neutron meters were then corrected for influenced effects (following the ISO 8529 series) in order to obtain the reading of neutron meters due to the direct component of the neutron standard field. These values were observed at 150 cm from the source's center as 68.8, 65.6, and 67.3 for the Aloka TPS451C, KSAR1U.06, and Model 12-4, respectively. As the results, the calibration factors of neutron meters ($CF_n$) were deduced as shown in Fig. (1). The standard uncertainties (with the coverage factor of 1, k=1) of calibration factors ($u_{CF}$) for two cases (i.e., taking and not taking into account the contribution of photons in neutron fields) were also calculated and tabulated in Table 2.

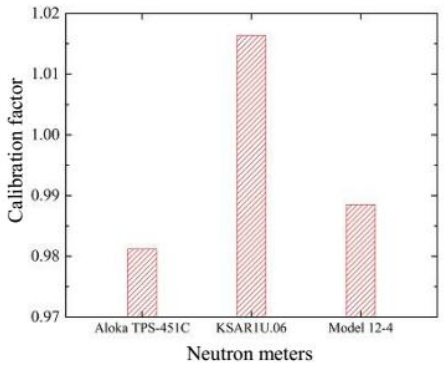


**Figure 1.** Calibration factors of neutron meters in the neutron standard field of a bare source

**Table 2.** Uncertainties of calibration factors ($u_{CF}$) for correction and not correction of photon contribution in neutron fields

| Uncertainty budgets | | Uncertainty, $u_{CF}$ (%) | |
|---|---|---|---|
| | | ***Not correction for photon contribution*** | ***Correction for photon contribution*** |
| $H_{n\_std}$ | neutron unfolding process | 5 | 5 |
| | conversion factor converting neutron fluence to dose equivalent | 4 | 4 |
| | statistical uncertainty of measurement | 5 | 5 |
| | photon contribution | 5 | 0 |
| $H_{n\_read}$ | statistical uncertainty of measurement | 5 | 5 |
| | photon contribution | 2 | 0 |
| | distance, time, and others | 1 | 1 |
| Standard uncertainty, $u_{CF}$ (k=1) | | **11.9** | **9.6** |

In this work, the contribution of photons in neutron standard fields has been investigated and corrected during the calibrations of neutron dose/rate meters. Due to different neutron standard fields, the ratio between photon and neutron dose equivalent rates may vary from 3% to 7%. When correcting for the photon contribution in neutron fields, the uncertainties of calibration factors of neutron meters are smaller by about 2% compared to the cases of no-correction.

# 2.7. RADIATION TECHNOLOGY

# SYNTHESIS OF SELENIUM NANOPARTICLES BY IRRADIATION METHOD FOR UTILIZATION AS ADDITIONAL INGREDIENTS FOR WHITE SHRIMP FEED

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**Project information:**

- **Project name: Synthesis of selenium nanoparticles by irradiation method for utilization as additional ingredients for white shrimp feed**
- **Code: DTCB.04/19/TTNCTK**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan 2019 - Dec 2020)**
- **Contact email: ngocduy158@gmail.com**
- **Published papers related to the project:**

1. Nguyen Ngoc Duy, Dang Van Phu, Le Anh Quoc, Nguyen Thi Kim Lan, Cao Van Chung, Nguyen Quoc Hien, Tran Thi Thu Ngan, ‘‘Study on the preparation of selenium nanoparticles by gamma co-60 method and investigate the stability” The Vietnam conference on Nuclear science and Technology 13th (07-09/08/2019, Ha Long-Quang Ninh) (in Vietnamese)
2. Ngoc Duy Nguyen, Van Phu Dang, Anh Quoc Le, T. Kim Lan Nguyen,Quoc Hien Nguyen, T. Thu Ngan Tran, ‘‘Study on the preparation of selenium nanoparticles by gamma co-60 method and investigate the stability”, Nuclear Science and Technology. Vol 10 (2), (2020), 26-31. DOI: https://doi.org/10.53747/jnst.v10i2.34
3. Ngoc Duy Nguyen, Van Phu Dang, Anh Quoc Le, T. Kim Lan Nguyen, Quoc Hien Nguyen, T. Thu Ngan Tran, Le Bao Ha Tran, Dinh Tuan Phan, ‘‘Preparation and effect of selenium nanoparticles/oligochitosan on the white blood cell recovery of mice exposed to gamma-ray radiation”, Journal of Chemistry (under review).

In recent years, the farming of white leg shrimp is fast-growing and offering relatively high benefits for farmers in the Mekong Delta of Vietnam. However, disease outbreaks resulted from intensive and unhygienic farming are not only constraining the expansion of shrimp farms but also seriously threatening the development of our aquaculture. Overuse of antibiotics and chemotherapeutics in controlling these diseases had been leading to other undesired problems

such as the evolution of drug-resistant pathogens, suppression of the aquatic animal's immune system, ultimately affecting customers, and causing hazards to our environment. It has been found that selenium having a potent antioxidant that can protect against redox-mediated immune suppression, and its selenium nanoparticles (SeNPs) have been also reported to have superb biological activities and low toxicity compared to initial selenium compounds. Furthermore, SeNPs play an important role in the regulation of immune responses and then control immune-related diseases. Thus, SeNPs have been proposed to use as an essential micronutrient in the feed to increase the immune response and weight of white shrimp. Similar to chitosan, oligochitosan (OCS) also has various biological effects including immunomodulatory, antioxidant, anti-tumor, and its bioactivities even higher than those of chitosan. Therefore, supplementation of both SeNPs and OCS into the shrimp feed may induce a synergistic or combined effect, which improves the immunomodulation function of the white leg shrimps. Besides, the electron-rich functional groups in OCS molecule such as –NH2, –OH can easily stabilize SeNPs by coordinate bonds and electrostatic interactions like other polysaccharides. In this study, SeNPs were synthesized by the irradiation method in the solution containing OCS as a stabilizer, then SeNPs/OCS was incorporated into the foods feeding to the white leg shrimp (*Litopenaeus vannamei*). The effects of SeNPs/OCS supplementation on growth, innate immunity, and disease resistance of the experimental shrimps were also investigated.

An aqueous solution of 3% oligochitosan (molecular weight, Mw~5000 g/mol, and degree of deacetylation, DDA ~ 85%) has been prepared by Research and Development Center for Radiation Technology (VINAGAMMA). Selenium nanoparticles were prepared by gamma irradiation using OCS as a stabilizer according to Hien et al. . Briefly, a predetermined amount of $SeO_2$ was dissolved in the oligochitosan solution with various ratio, then the $SeO_3^{2-}$ /oligochitosan solutions were irradiated under γ-ray Co-60 (SVST Co-60/B irradiator) at dose rate 1.3 kGy h−1 to synthesize SeNPs. The effects of selenium, OCS (stabilizer) concentration, radiation dose, pH on the SeNPs were investigated. The resulting SeNPs/OCS were characteri zed by using UV-Vis, Fourier-transform infrared (FTIR), X-ray diffraction (XRD), dynamic light scattering (DLS), and transmission electron microscope (TEM). White leg shrimp (*Litopenaeus vannamei*) with the initial body weight of 1.87 ± 0.006 g were fed with the food containing SeNPs of 0, 0.5, 1.0, and 2.0 mg/kg for 60 days, then infected with Vibrio parahaemolyticus bacteria to investigate their growth and immune stimulation.

Photographs of OCS, ion selenium, and SeNPs/OCS solutions, their UV-Vis spectra, TEM image of SeNPs, the photograph of SeNPs/OCS, and its EDX spectrum are shown in Figure 1. It is obvious that the irradiated $H_2SeO_3$/OCS solution turned from yellow-orange to orange-red, demonstrated the formation of selenium nanoparticles (SeNPs).

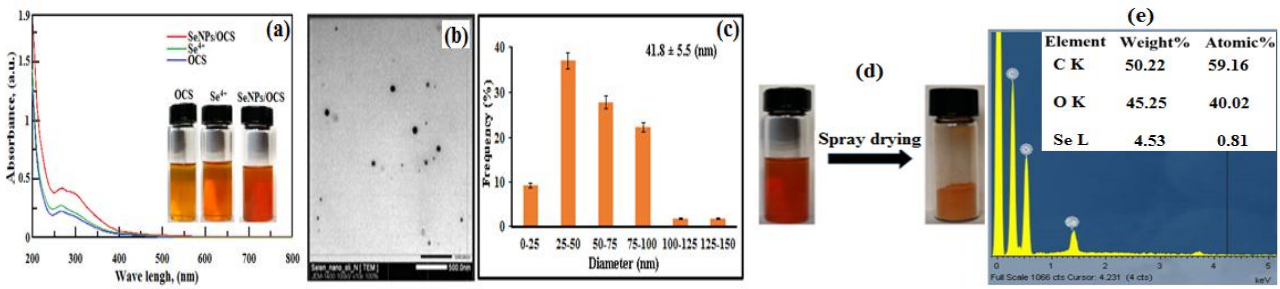


**Figure 1.** Photograghs of OCS, ion selenium and SeNPs/OCS solutions and their UV-Vis spectra (a); TEM image of SeNP (b), size distribution of SeNPs/OCS solution (c), SeNPs/OCS in powder form prepared by spray drying (d) and EDX spectrum of SeNPs/OCS powder (e)

The SeNPs were formed by water radiolysis products (e-, H•) to reduce $Se^{4+}$ to $Se^0$. However, no typical adsorption peaks of SeNPs could be observed in the UV-Vis spectrum as in Figure 1(a). It was reported that the SeNPs with size less than 100 nm did not have an absorption peak ($\lambda_{max}$) in the UV-Vis region (200-800 nm), the absorption peak only appeared for the particles with a diameter higher than 100 nm. In particular, the absorption peak appeared at the wavelength of 550 and 680 nm for SeNPs size of 146 and 240 nm, respectively. TEM images and the size distribution of SeNPs in Figure 1(b) and 1(c) showed that SeNPs were spherical morphology with an average diameter calculated to be of ~41.8 nm. SeNPs/OCS powder prepared by spray drying in Figure 1(d) had orange color, and the EDX spectrum in Figure 1(e) showed that the obtained SeNPs/OCS powder product was of high purity with composition only of three elements, namely selenium (4.53%), carbon (50.22%) and oxygen (45.25%).

**Table 1.** The effect of concentration of ion selenium and Oligochitosan, dose rate, pH, on particle size of SeNPs/OCS

| $Se^{4+}$ (mM) | [Oligochitosan] (%) | pH | Dose rate (kGy/h) | $d_{tb}$ (nm) |
|---|---|---|---|---|
| 0.625 | 1 | 7.5-8 | 1.3 | 64.6 ± 4.5 |
| 1.25 | | | | 116.2 ± 5.1 |
| 2.5 | | | | 129.3 ± 6.5 |
| 1.25 | 0.5 | 7.5-8 | 1.3 | 168.7 ± 8.8 |
| | 1.0 | | | 116.2 ± 5.1 |
| | 2.0 | | | 95.0 ± 3.7 |
| 1.25 | 1.0 | 4 | 1.3 | 350.6 ± 11.8 |

| $Se^{4+}$ (mM) | [Oligochitosan] (%) | pH | Dose rate (kGy/h) | $d_{tb}$ (nm) |
|---|---|---|---|---|
| | | 6 | | 122.9 ± 5.2 |
| | | 8 | | 117.3 ± 4.9 |
| | | 10 | | 132.6 ± 5.4 |
| 1.25 | 1.0 | 7.5-8 | 2.4 | 100.9 ± 4.5 |
| | | | 4.7 | 81.6 ± 3.6 |
| | | | 9.4 | 75.7 ± 2.4 |

As presented in Table 1, the size of SeNPs determined by dynamic light scattering increased from ~ 64.6 nm (0.625 mM $Se^{4+}$) to ~ 112.6 and 129.3 nm (1.25 and 2.5 mM $Se^{4+}$). The main reason for this phenomenon is due to the development of clusters and the agglomeration among SeNPs when the ratio of stabilizer and $Se^{4+}$ concentration is not appropriately high enough. The effect of oligochitosan concentration has been studied for 1.25 mM $Se^{4+}$ concentration. The average diameters of SeNPs were 168.7, 116.2, and 95.0 nm for oligochitosan concentration of 0.5, 1.0, and 2.0%, respectively. Oligochitosan has a good ability to stabilize SeNPs due to the chain of oligochitosan consists of –OH, $-NH_2$ groups which have an affinity with $Se^{4+}$. Results in Table 1 also indicated that the particle size of SeNPs is also affected by dose rate particularly when the dose rate increased from 2.4 to 9.4 kGy/h, the SeNPs size decreased from 100.9 to 75.7 nm. The reason for this phenomenon is due to the competition between the adsorption Se4+ onto resulted gold clusters and the reduction reaction of $Se^{4+} \rightarrow Se^{3+} \rightarrow Se^{2+} \rightarrow Se^{1+} \rightarrow Se^{0}$ to form new clusters. At a high dose rate, the reduction reaction is predominant, therefore there are many new clusters to form smaller SeNPs. Inversely, at a low dose rate, the absorption of $Se^{4+}$ onto clusters is predominant, therefore SeNPs will be larger. the pH of the solution also affected the particle size of SeNPs, the suitable pH to prepare SeNPs is the range of 6 to 8 with the particles size from 122.9 to 117.3 nm.

**Table 2.** Results of growth performance and and survival rate for white leg shrimp fed with SeNPs at different concentration of 0.5 mg/kg (NT5); 1,0 mg/kg (NT6); 2.0 mg/kg NT 7 and 100 mg/kg oligochitosan (NT8)

| Parameters | Treatments | | | | |
|---|---|---|---|---|---|
| | Control | NT5 | NT6 | NT7 | NT8 |
| IBW (g) | 1.87 ± 0.02 | 1.87 ± 0.01 | 1.88 ± 0.01 | 1.87 ± 0.02 | 1.88 ± 0.01 |

| | | | | | |
|---|---|---|---|---|---|
| FBW (g) | $15.99^{a} \pm 0.09$ | $16.25^{ab} \pm 0.31$ | $16.64^{ab} \pm 0.60$ | $17.53^{b} \pm 0.12$ | $17.47^{b} \pm 0.83$ |
| WG (g) | $14.11^{a} \pm 0.08$ | $14.38^{ab} \pm 0.32$ | $14.75^{ab} \pm 0.60$ | $15.66^{b} \pm 0.09$ | $15.59^{b} \pm 0.84$ |
| FCR | $1.17 \pm 0.01$ | $1.16 \pm 0.02$ | $1.16 \pm 0.02$ | $1.15 \pm 0.02$ | $1.16 \pm 0.01$ |
| SGR (%/day) | $3.57^{a} \pm 0.01$ | $3.60^{ab} \pm 0.04$ | $3.63^{ab} \pm 0.06$ | $3.73^{b} \pm 0.01$ | $3.71^{b} \pm 0.08$ |
| FI (%/day) | $3.30 \pm 0.14$ | $3.12 \pm 0.06$ | $3.07 \pm 0.08$ | $3.09 \pm 0.07$ | $3.14 \pm 0.04$ |
| SR (%) | $64.00^{a} \pm 4.00$ | $73.33^{ab} \pm 2.31$ | $74.67^{b} \pm 4.62$ | $82.67^{b} \pm 2.31$ | $82.67^{b} \pm 4.62$ |

*(Values are mean ± SD and in the same row with different superscript letter are significantly different (P< 0.05)).*

Results in Table 2 showed that there was no significant difference in the weight of the initial shrimp among treatments (average initial body weight (IBW) of shrimp ranged from 1.85 - 1.89 g). After 60 days of the trial, the final body weight (FBW) of the shrimps caught from treatments were 15.99 – 17.53 g/shrimp and the weight gain (WG) was 14.11 – 15.66 g/shrimp. There were also significant differences in the specific growth rate (SGR) among experiments. The highest values of WG and SGR of shrimp were obtained with the shrimps fed by the food containing 1.0 and 2.0 mg/kg SeNPs/OCS. However, there were insignificant differences in the food index (FI) and feed conversion ratio (FCR) of shrimp between treatments and control. Table 2 also revealed that the survival rate (SR) of the shrimps fed by the food supplemented with SeNPs was much increased. There was a statistically significant difference (64.00 - 82.67 %), and these values are the same as 82.67% in both NT7 and NT8 (with 100ppm oligo chitosan) treatments. Many researchers reported that feed supplemented with SeNPs improves shrimp growth. Davis et al. reported that the maximum growth of juvenile P. vannamei was achieved when fed with purified diets supplemented with 0.2–0.4 mg Se/kg diet (0.2–0.4 ppm) [8]. Wang et al proposed a dietary Se threshold of 0.44 μg/g (0.44 ppm) for *Penaeus chinensis* (*P. chinensis*). Yuchuan and Fayi showed that *P. chinensis* fed with a diet containing 20 ppm (20 mg/kg) Se had higher weight gain than those fed with 0.8 ppm Se.

In conclusion, SeNPs stabilized in oligochitosan solutions were successfully synthesized by gamma irradiation. The concentrations of ion $Se^{4+}$ and oligochitosan, dose rate, and pH affected significantly the properties of resulting SeNPs. SeNPs/OCS powder with rather high purity was obtained from SeNPs/OCS solution by spray drying. Supplementation of SeNPs/OCS to the shrimp feed at a suitable ratio could considerably improve the growth and survival rate of white leg shrimp. Thus, the SeNPs/OCS can be applied in aquaculture as an immunostimulant.

# IRRADIATION TREATMENT OF GRAPHENE OXIDE FOR UTILIZATION AS POROUS MATERIAL IN WATER DESALINATION

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**Project information:**

- **Project name: irradiation treatment of graphene oxide for utilization as porous material in water desalination**
- **Code: CS/20/07-01**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020 - Dec 2020)**
- **Contact email: hongphamkado@gmail.com**
- **Published papers related to the project:**

1. Pham Thi Thu Hong*, Nguyen Thanh Duoc, Nguyen Thi Ly, Chu Nhut Khanh, Cao Van Chung, Doan Binh, Effect of electron beam irradiation on characteristic properties of expanded graphite, Nuclear Science and Technology (in submitted on Nov, 2020)
2. Chu Nhut Khanh, Nguyen Thi Ly, Cao Van Chung, Nguyen Thanh Duoc, Doan Binh, Pham Thi Thu Hong, Effect of electron beam irradiation on characteristic properties of expanded graphite, Proceedings of the 6th Vietnam Conference on Young staff Nuclear Science and Technology, Ha Noi, Vietnam, 2020, 6p. (in Vietnamese)
3. Pham Thi Thu Hong, Nguyen Thanh Duoc, Nguyen Thi Ly, Chu Nhut Khanh, Cao Van Chung, Doan Binh, "Reduction of graphene oxide in ethanol solution by gamma irradiation for preparing reduced graphene oxide material with water desalination", Nuclear Science and Technology, No.9 (2019), 34-40. DOI: https://doi.org/10.53747/jnst.v9i1.58

Together with the irregular and unpredictable changes in weather recently, climate change not only causes saline intrusion, but also exacerbates water pollution seriously threatening our agricultural production. Therefore, the supply of fresh water to the farmers who are living in coastal and vulnerable areas is increasingly urgent. Among effective methods of water desalination, using specific membranes or filters to remove salts from saline water is one of the most potential way for reducing water salinity. To be structured with a mono- or multi-layers, which are stacked by a certain distance, the graphene/graphene oxide (GO) has been modified to utilize as porous material in many researches for fabricating osmotic membranes. Passing through these layers, salt ions are trapped in or adsorbed by polar functional groups of the GO structure. In the present study, GO has been suspended in ethanol and irradiated

with dose range of 0-60 kGy under electron beam from UELR-10-15S2, 10 MeV EB accelerator at VINAGAMMA for preparation the reduced graphene oxide (rGO). The resulting rGO was characterized for further application in water desalination.

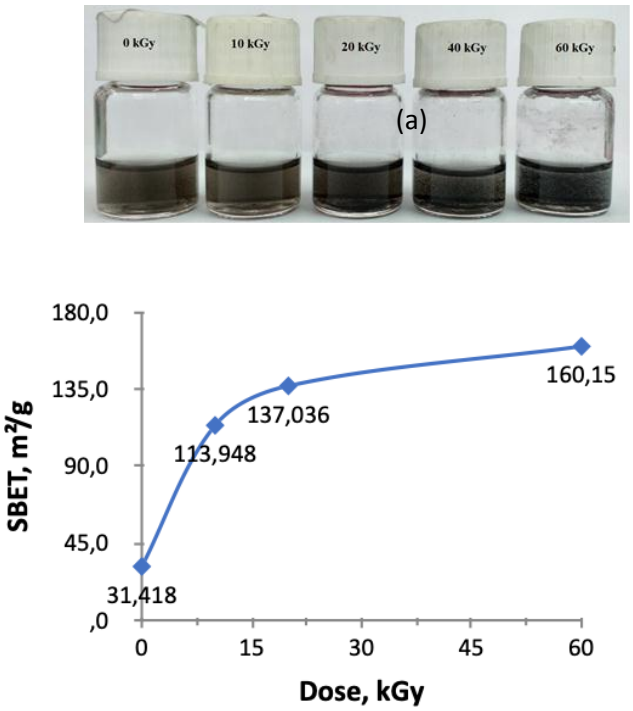


**Figure 1.** Photographs of irradiated GO solutions (a) and specific surface area ($S_{BET}$) of rGOs at various radiation doses (b)

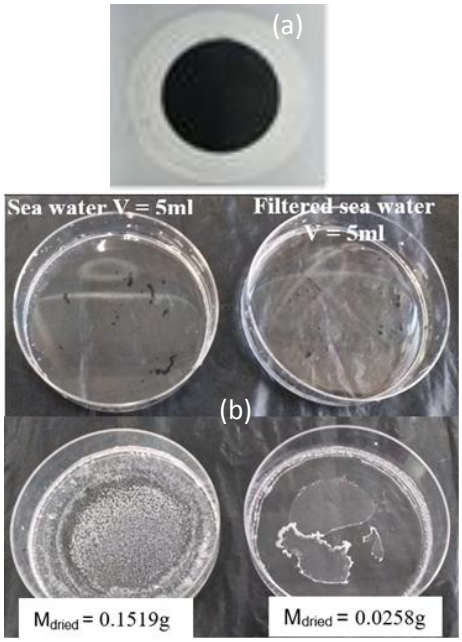


**Figure 2**. CA/rGO membrane containing 0.5% rGO (a) and its efficiency in water desalination (b)

It is obviously that the irradiated GO solutions become darker with increasing of radiation dose (Fig. 1a). This figure also indicated that specific surface area ($S_{BET}$) of the rGOs increased with the increase of dose. The $S_{BET}$ of rGO at 60 kGy (rGO60) reached 160.15 m²/g (Fig.1b), namely that the rGO60 with a large specific surface area can be prepared by EB irradiation for fabricating porous CA/rGO membrane. The results showed the CA/rGO60 membrane. The water desalination process was established for seawater, and the preliminary result revealed that the salinity of seawater reduced 83% by passing though this membrane at the filtration capacity of 12.1 L/m².h (Fig.2b).

Further studies need to clarify the effectiveness of higher radiation dose on specific surface area, pore size of the porous rGO obtained by EB irradiation. Influences of the graphite layers spacing in the rGO materials on their efficiencies in water desalination should be also investigated for establishing an efficient process that can be applied in large scale.

# STUDY ON THE ABILITY TO USE ELECTRON BEAM TO CREATE ZEOLITE ZSM5 WITH PROPERTIES OF HAZARDOUS WASTE TREATMENT AND INDUSTRIAL CATALYTIC APPLICATIONS

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*[4] Research and Development Center for Radiation Technology - Hochiminh City, Vietnam*

**Project information:**

- **Project name: Study On The Ability To Use Electron Beam To Create Zeolite Zsm5 With Properties Of Hazadous Waste Treatment And Industrial Catalytic Applications**
- **Code: DTCB.14/19/TTHN**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan 2019 - Dec 2020)**
- **Contact email: tuyenluuanh@gmail.com**
- **Published papers related to the project:**

1. L. Anh Tuyen, T. Dong Xuan, H. A. Tuan Kiet, L. Chi Cuong, P. Trong Phuc, T. Duy Tap, Van-Phuc Dinh, L. Ly Nguyen, N. T. Ngoc Hue, P. Thi Hue, L. Thai Son, D. Van Hoang, N. Hoang Long, and N. Quang Hung, *A hybrid model for estimation of pore size from ortho-positronium lifetimes in porous materials*, Radiation Physics and Chemistry 172, 108867 (2020)
2. P. Trong Phuc, C. Van Chung, H. A. Tuan Kiet, L. Thai Son, Van-Phuc Dinh, T. Dong Xuan, T. Duy Tap, L. Chi Cuong, N. T. Ngoc Hue, P. Thi Hue, L. Ly Nguyen, Le-Phuc Nguyen, D. Van Hoang, N. Hoang Long, H. Huu Thang, N. Van Tiep, N. Quang Hung, and L. Anh Tuyen, *Design of a unique holder for structural modication of ZSM-5 zeolite using a 10 MeV electron beam generated from an industrial UERL- 10-15S2 linear accelerator*, Radiation Physics and Chemistry 174, 108948 (2020)
3. P. Horodek, L. H. Khiem, K. Siemek, L. A. Tuyen, A. G. Kobets, "*Positron Annihilation Spectroscopy in Material studies"*, Communications in Physics 29, 501 (2019)
4. L. Anh Tuyen, T. Dong Xuan, H. A. Tuan Kiet, L. Chi Cuong, P. Trong Phuc, T. Duy Tap, Van-Phuc Dinh, L. Ly Nguyen, N. T. Ngoc Hue, P. Thi Hue, L. Thai Son, D. Van Hoang, N. Hoang Long, and N. Quang Hung, *Origin of the low lifetimes for the localized o-Ps in the large pores of porous materials: a new finding by The combination model of quantum*

*and semi- classical physics*, Vietnam Conference on Science and Technology - VINANST 13, Ha Long City, 8/2019

5. P. Trong Phuc, L. Anh Tuyen, T. Dong Xuan, H. A. Tuan Kiet, L. Chi Cuong, T. Duy Tap, Van-Phuc Dinh, L. Ly Nguyen, N. T. Ngoc Hue, P. Thi Hue, L. Thai Son, D. Van Hoang, N. Hoang Long, and N. Quang Hung, *MCNP simulation for setting up experiments of electron beam irradiation on zeolite ZSM-5 and mordenite*, Vietnam Conference on Science and Technology - VINANST 13 (Session B, Poster), Ha Long City, 8/2019.

Among the zeolite families, ZSM-5 is a common material for applications in heavy metal treatment and storage of radioactive waste. Zeolite ZSM-5 can be synthesized quite easily from natural kaolin, in which Vietnam is one of the countries having very large reserves (after China). In addition, ZSM-5 zeolite is a material with very high economic value in the petrochemical industry. Most recently, the study of the structural modification of zeolite by irradiation has been proposed and attracted much attention from the international scientific community. At the Center for Nuclear Technologies (CNT), the research process of zeolite materials such as 4A and ZSM-5 has been carried out since 2005 and recently promoted through cooperation with the Hungarian Academy of Sciences, Croatian Academy of Sciences and the Vietnam Academy of Sciences. The most recent studies also indicated that the heat treatment of zeolite ZSM-5 after synthesis can form defects and meso-pores, which is difficult to access by conventional methods. Furthermore, although zeolite has been studied quite widely for the purpose of radioactive waste treatment and storage, there is no study investigating the transformation of structural cages under the influence of radiation as well as their stability after long-term storage. Meanwhile, studies have shown that nuclear methods such as positron annihilation, Doppler broadening, X-ray diffraction,... can apply very successfully on zeolite research at a structural scale from angstrom to tens of nm.

In the project of "*Study on the ability to use an electron beam to create zeolite zsm5 with properties of hazardous waste treatment and industrial catalytic applications*", zeolite ZSM-5 has been synthesized in the laboratory. Its structure is then modified by irradiating with an electron beam at different energies and fluences. To perform the irradiation process on the electron beam linear accelerator (UERL-10-15S2), the simultaneous energy degrading and the sample containing holder (EDSCholder) was calculated and designed by MCNP simulation before irradiation. The structural changes of zeolite ZSM-5 after irradiation was studied on nuclear spectroscopies such as positron lifetime annihilation spectroscopy (PALS), positron-electron annihilation energy Doppler broadening (DB), X-ray diffraction (XRD) and electron microscopies (TEM, SEM). To evaluate microscopic structures in ZSM-5 materials, a hybrid model (HYB) between the quantum model (Tao-Eldrup model) and the semi-classical model was developed for calculations of pore size from the experimental lifetime of o-Ps. The investigations of the heavy metal adsorption capacity of ZSM-5 material after modifying was carried out on solutions containing $Co^{2+}$ and $Pb^{2+}$ ions. The SCT-MAT (Short Contact Time - Microactivity Test) method was applied to determine the conversion and product selectivity of catalytic cracking (FCC) in the temperature and catalytic-mass ratio for raw material (C/O), in which the contact time between raw material and catalysts is 12-second in laboratory scale.

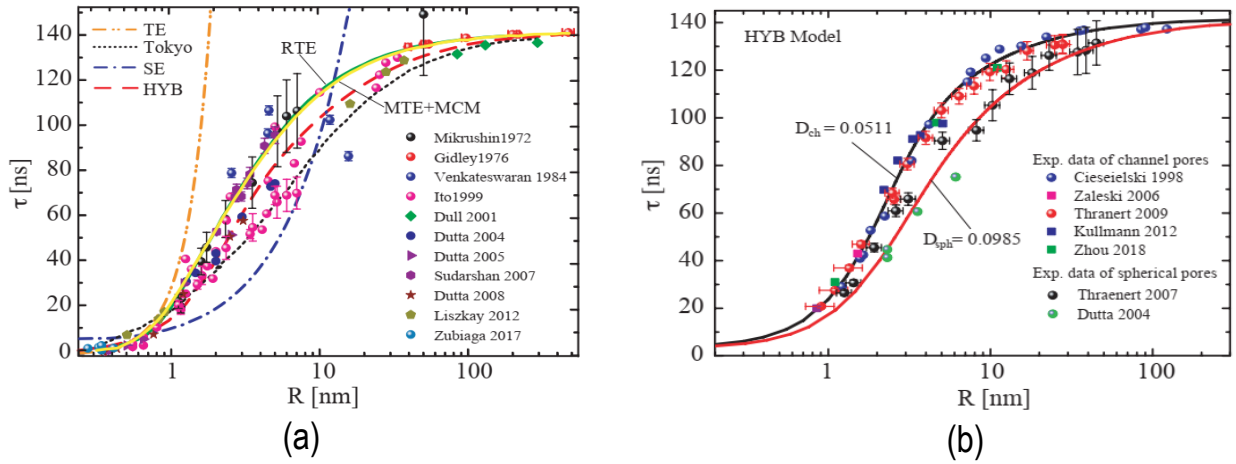


**Figure 1.** (a) The o-Ps lifetimes obtained in TE, SE, Tokyo, RTE, and HYB models compared with experimental data of different porous materials; (b) The o-Ps lifetime obtained in the HYB model compared with the experimental data for the spherical and channel pores.

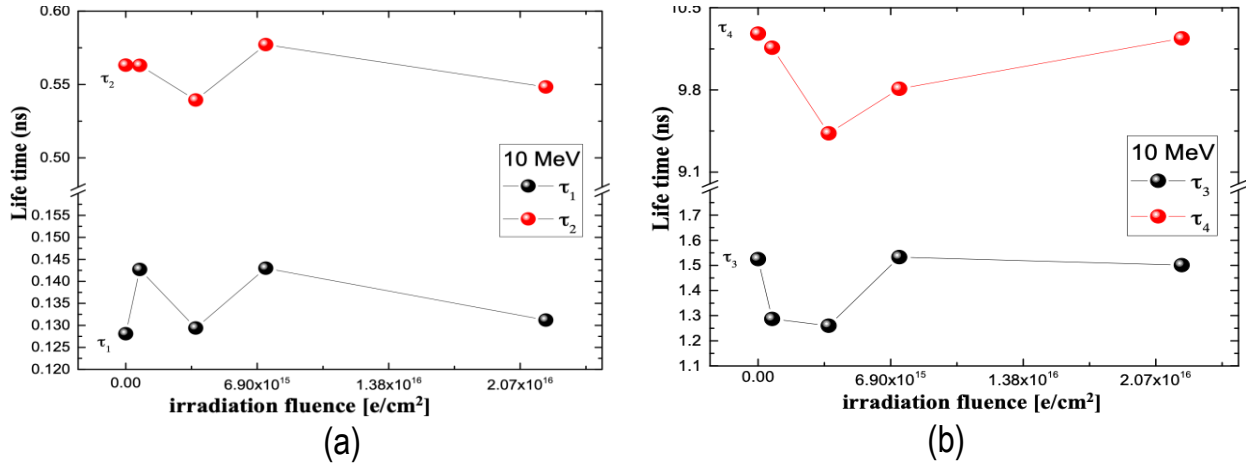


**Figure 2.** Effects of the irradiated fluences and the 10 MeV electron beam energy on short lifetimes (a) and long lifetimes (b) of positron for samples with Si/Al ratio = 50.

The results show that the HYB model not only smoothly connects two regions of the pore but also well agrees with the experimental o-Ps lifetimes collected over the past four decades for the universal region of nano-pore size from 0.2 to 400 nm with spherical and channel pore shapes of most materials, especially materials with porous structures such as zeolite ZSM-5.

The results of X-ray diffraction analysis show that irradiated ZSM-5 using the 10 MeV electron beams is changed the basic lattice structure (unit-cell size) through reduction of the unit-cell volume.

The results of positron-electron annihilation experiments indicate that the unit structure of ZSM-5 is significantly affected by the electron beam irradiation at energies of 8 MeV, 9 MeV and 10 MeV. The decrease of $\tau_1$ versus the irradiation fluences from $7.35\times10^{14}$ e/cm$^2$ to $7.35\times10^{15}$ e/cm$^2$ at electron energies of 8 MeV and 9 MeV shows an increase of perfection in the structure of ZSM-5. At the electron energy of 9 MeV, the irradiation process makes a gradual decrease of $\tau_1$ value. However, this rule does not appear for the electron energy of 10 MeV. This shows that, with the 10 MeV electron beam, in addition to rearrangement of the

crystal structure, the removal of Al atoms can make changes of the average electron density leading to changes in the $\tau_1$ lifetime component following a complicated trend. The $\tau_2$ lifetime component decreases deeply at the irradiation fluence of $3.68\times10^{15}$ e/cm$^2$ for all electron energies. The decrease of $\tau_2$ at the irradiation fluence of $3.68\times10^{15}$ e/cm$^2$ shows that the recovery of structural defects occurred effectively at this irradiation fluence.

The $\tau_3$ lifetime component deepest decreases at the irradiation fluence of $3.68\times10^{15}$ e/cm$^2$ for the electron energies of 9 MeV and 10 MeV. This shows that the removal of Al atoms has moved $Al^{+3}$ ions from the crystal lattice into the space of the characteristic channels of ZSM-5. Whereas, the irradiation process at the 8 MeV electron energy increases the $\tau_3$ lifetime component. This may be related to the formation of defects on the surface of characteristic porous channels. The result shows that the defect formation can occur at different structural positions with different energies. Electron energies of 9 MeV and 10 MeV can cause a defect in the structure center due to the high penetrating ability to remove the atoms in the unit-cell center. In contrast, for the 8 MeV electron energy, the defect can form on the surface of porous channels, where the atoms are loosely bound and easily removed from the crystal lattice.

The study results also showed that, at the ratio of Si/Al = 50, with the highest irradiation fluence of $2.2\times10^{16}$ electron/cm$^2$, the ability of adsorption and treatment of isotope $Pb^{2+}$ can increase 126%. For the petrochemical catalysis results, when using ZSM-5 sample with the ratio of Si/Al = 50, irradiated by the 10 MeV electron energy, as catalysis the olefin performance is 12% higher than that of the unirradiated sample.

However, to assess the structural stability and the catalytic time of the ZSM-5 modified by electron irradiation, further studies need to be conducted in detail and combined with some specific nuclear spectroscopies such as X-ray energy dispersion spectrometer, slow positron beam, solid phase nuclear magnetic resonance, Rutherford backscattering.

# 2.8. RADIOCHEMISTRY AND MATERIALS SCIENCE

# EXPLORATION STUDY ON PREPARATION $TiO_2$ POWDER FROM ILMENITE CONCENTRATE BY SUBLIMATION METHOD

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**Project information:**

- **Project name: Exploration study on preparation $TiO_2$ powder from ilmenite concentrate by sublimation method**
- **Code: CS/20/03-03**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020 - Dec 2020)**
- **Contact email: lxdinh79@gmail.com**
- **Published papers related to the project:**

1. Nguyen Dinh Viet et al., Study on decomposition of ilmenite concentrate by $NH_4F.HF$, Proceedings of the 6th Vietnam Conference on Nuclear Science and Technology for Young Researchers, Ha Noi, Vietnam, 2020, p38.
2. Nguyen Dinh Viet, Nguyen Van Tung, Luu Xuan Dinh. Study on preparation $TiO_2$ powder from ilmenite concentrate by sublimation method. Journal of Chemistry and Application, (in Vietnamese).

Currently, the situation of titanium exploitation and processing in Vietnam is facing difficulties. Titanium mining and processing activities only stop in the field of beneficiation, which doesn't have-technology for deep processing of Ilmenite concentrate. There have been many studies on the preparation of $TiO_2$ from ilmenite concentrate by different methods such as sulfate method, alkali resolution method, ammonium fluoride resolution method ... which have been done in Vietnam. However, most of these solutions have the disadvantages of generating large amounts of wastewater, incurring an additional iron recovery process, and high ammonium fluoride recirculation costs due to additional concentration steps. To reduce costs and expand the line of titanium oxide products of satisfactory quality for pigments and titanium metal production materials, titanium fluoride sublimation technology - the dry method should be researched to reduced wastewater volume and reduced ammonium fluoride recirculating concentration cost. Therefore, the implementation of a scientific and technological research project and processing of ilmenite concentrate using fluoride technology to separate titanium fluoride to produce white $TiO_2$ powder in Vietnam is urgent and completely suitable for the real situation domestic economy.

The objective of the project is an exploration study of the fluoridation of ilmenite concentrate by $NH_4F.HF$, the sublimation of $TiF_4$, and the collection of $TiO_2$ from $TiF_4$ hydrolysis in ammonia solution.

The research process uses an airtight tube furnace device combined with an absorption system by ammonia solution. The ilmenite concentrate was mixed with $NH_4F.HF$ at a given ratio, the reaction mixture was heated in a tube kiln, and the air was blown through the furnace to entrained sublimated $TiF_4$ products as well as steam and $NH_4F.HF$ residual. The whole was absorbed through a hydrolysis tank system containing concentrated $NH_4OH$ solution. Here, the $TiF_4$ would be hydrolyzed, forming $Ti(OH)_4$ precipitation products. The resulting precipitate was then filtered, washed, dried, and calcined to obtain the product $TiO_2$. The reaction processes are as follows:

Decomposition reaction of ilmenite concentrate by $NH_4F.HF$:

$$FeTiO_3 + 5.5NH_4F.HF = (NH_4)_2TiF_6 + (NH_4)_3FeF_5 + 0.5NH_3 + 3H_2O$$

Reaction to form of $TiF_4$ and sublimation of $TiF_4$:

$$(NH_4)_2TiF_6 + (NH_4)_3FeF_5 = 5NH_3 + 5HF + TiF_4 + FeF_2$$

Hydrolysis reaction of $TiF_4$ in $NH_4OH$ solution:

$$TiF_4 + 4NH_4OH = Ti(OH)_4 + 4NH_4F$$

Decomposition reaction of $Ti(OH)_4$ to forms $TiO_2$ product:

$$Ti(OH)_4 = TiO_2 + 2H_2O$$

Binh Thuan ilmenite concentrate was used as the research object of the project. XRF analysis results showed that the $TiO_2$ content in the concentrate was very high, up to 54%. However, the impurity composition, including Mn, Zr could affect the product quality. The particle size of the concentrate was quite large, about 0.5 mm.

**Table 1.** Composition of ilmenite concentrate

| **Compositions** | **% weight** |
|---|---|
| $TiO_2$ | 54 |
| FeO | 20 |
| $Fe_2O_3$ | 16 |
| $ZrO_2$ | 0.1 |
| $V_2O_5$ | 0.09 |

| Compositions | % weight |
|---|---|
| MnO | 0.1 |

The results of the mixture of ilmenite concentrate's thermal analysis and $NH_4F.HF$ showed that the reaction proceeds through many stages (Fig 1), similar to the results of the previous studies.

✓ The decomposition stage of Ilmenite concentrate takes place at the temperature <200ºC with a weight reduction of 15.90%.

✓ $TiF_4$ sublimation stage at about 600ºC with a weight reduction of 49.90%.

However, it is important to note the morphology of the reaction process when calcining the mixture of ilmenite concentrates and $NH_4F.HF$, due to the melting of $NH_4F.HF$ can make it difficult to perform on a large scale.

The effects of the reaction mixture ratio, the reaction temperatures, and the reaction time on the efficiency of ilmenite concentrate decomposition by $NH_4F.HF$ was studied. The optimal technology parameters were obtained as follows:

✓ The reaction ratio of ilmenite concentrate/ $NH_4F.HF$ by weight: 1/2.5

✓ Reaction temperature: 180˚C

✓ Reaction time: 2 hours

The sublimation process of $TiF_4$ has been studied at different temperature and time conditions. Figure 3 showed the decomposition and sublimation efficiency of $TiF_4$. The results showed that the decomposition and sublimation efficiency was up to 94% at 600°C for 2 hours or at 550°C for 3 hours.

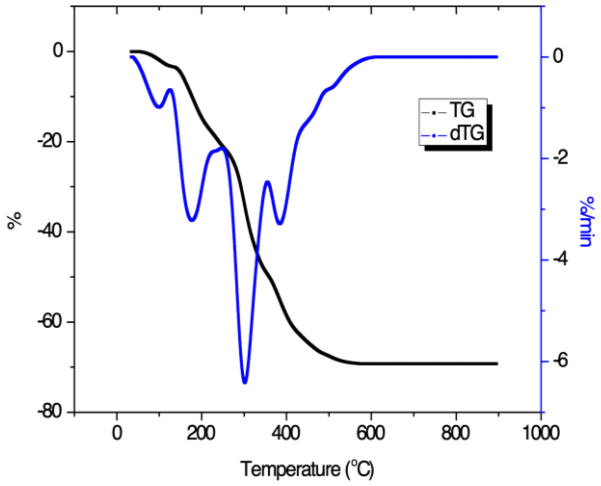


**Figure 1.** The thermal analysis of the mixture of ilmenite concentrate and $NH_4F.HF$

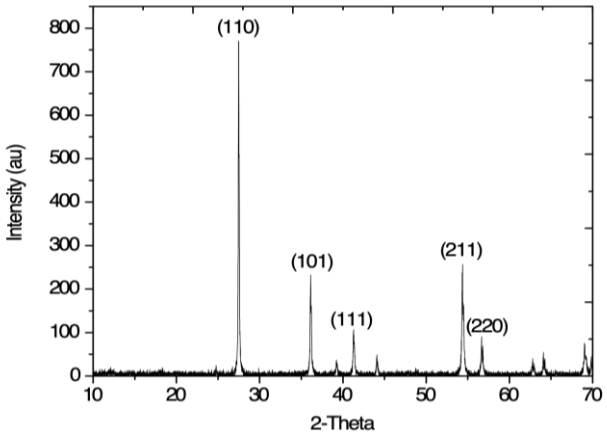


**Figure 2.** XRD diffraction of the $TiO_2$ product

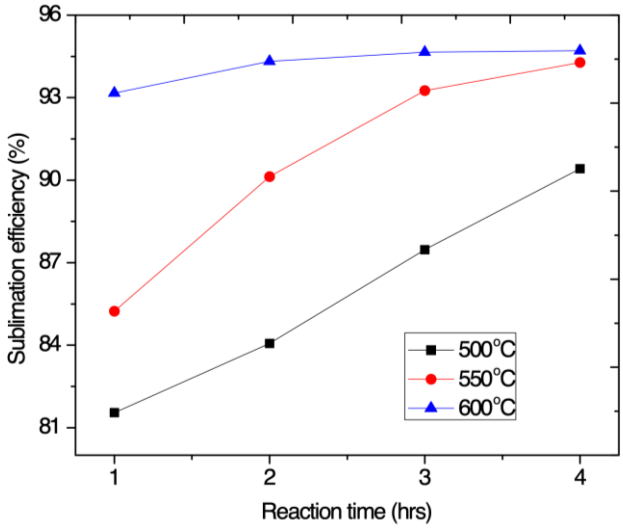


**Figure 3.** Sublimation efficiency of $TiF_4$ under different conditions

$TiF_4$ vapor was absorbed directly into $NH_4OH$ solution; $TiF_4$ hydrolysis products were filtered, washed, dried, and calcined at 800°C in a rotary kiln. The final product was a white, powdered $TiO_2$. XRD results showed that the product has a rutile crystal phase (Fig 2), XRF results showed that the product purity was 99.31%. The product has the potential for practical applications.

Currently, the fluorination method to produce $TiO_2$ from ilmenite concentrates is continuing to be researched and developed in the world. Therefore, it is necessary to continue studying on a larger scale to evaluate the economic efficiency and practical applicability of the above method. Since the reaction generates a lot of emissions, it is also necessary to study the treatment of the flue gas when performing on a large scale to recover and reuse ammonium fluoride.

# STUDYING THE EFFECT OF NEODYMIUM OXIDE/HYDROXIDE SPECIES FORMED IN PLASMA ON THE ANALYSIS OF HEAVY RARE EARTH IMPURITIES TRACE IN THE PURE NEODYMIUM OXIDE USING HPLC - TANDEM ICP - MS

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**Project information:**

- **Project name: "Studying the effect of neodymium oxide/hydroxide species formed in plasma on the analysis of heavy rare earth impurities trace in the pure neodymium oxide using HPLC - Tandem ICP-MS"**
- **Code: CS/20/03-01**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020 - Dec 2020)**
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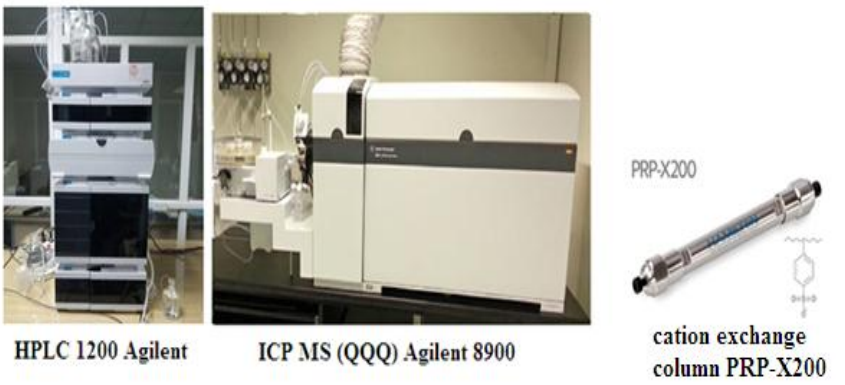
- **Published papers related to the project:**

1. Nguyen Thi Kim Dung, Ngo Quang Huy, Nguyen Thi Lien, Nguyen Thi Men, Ngo Thi Thu Thuy, Do Phuong Thuy, "Determination of some rare earth impurities in high purity $Nd_2O_3$ by ICP-MS/MS using the internal standard and with the hyphenated high pressure liquid chromatography (HPLC)", *Journal of Analytical Sciences, Vol.***25**, No.4, *ISSN-0868-3224 (*in Vietnamese)
2. Ngo Quang Huy, Nguyen Thi Lien, Nguyen Thi Men, Le Quoc Viet, Nguyen Nho Lan, Nguyen Thi Hang, Do Thi Anh Tuyet, Nguyen Thi Kim Dung, "Studying the effect of neodumium oxide/hydroxide in plasma on the analytical process of some trace heavy rare earth impurities in the pure neodym oxide using ICP-MS tandem", reported in the 6th Conference of Nuclear Science and Technology for young staffs, Hanoi 8-9, Oct. 2020 (in Vietnamese).

High-purity rare earth elements are widely used in many fields of the material technology such as in screens, laser media, optical materials (optical isolators) and high-temperature superconductors, etc…. Inductively coupled plasma mass spectrometry (ICP-MS) with the high sensitivity, the low quantifing limit and the ability to simultaneously identify trace or super trace elements, is used to determine the rare earth elements (REE) traces in high purity $Nd_2O_3$. However, the determination of REE impurity in high purity $Nd_2O_3$ were affected by samples that contain high levels of total dissolved solids, the dissolved matrix can deposit on the interface cone orifices, leading to signal loss and instability. Moreover, the mass spectrometry interference arising from polyatomic ions such as oxide or hydroxide of neodymium in the high Nd matrix also affected the accuracy of analytical results. ICP-MS/MS (Tripquad Agilent 8900) hyphanated HPLC (Agilent 1200) at the Institute for Technology of Radioactive and Rare

Elements (Fig.1) was used to study the above-mentioned effects. The study resulted in a proposed method to eliminate the effect of neodymium oxide/hydroxide species such as using the internal standard Rh/Re for the measurement on ICP-MS/MS directly or HPLC - ICP-MS/MS using a cation exchange column PRP-X200. The procedure for determining the heavy rare earth impurities such as Tb and Ho in high purity $Nd_2O_3$ was built by using ICP - MS/MS equipment system.

The research results showed that the instrumental conditions such as radio frequency power, peristaltic pump speed, sample depth, carrier gas flow, and sample matrix directly affected the formation of neodymium oxide/hydroxide species that caused the errors of the heavy rare earth impurities content. Among these interferences, the radiofrequency power directly affected the dissociation, ionization to form oxide/hydroxide species in the plasma (Fig.2). The formed neodymium oxide/hydroxide species occupied less than 1% of the neodymium signal in the sample matrix.




ICP-MS parameters: Radio frequency power (RF) 1550W; Flow rate of carrier gas 1 liter/min; Sample injection flow rate 0.1 rps; Sample depth 10 mm.
HPLC parameters: Cation exchange column PRP-X200 (size 250x4.1 mm; particle size 10 µm); Mobile phase α-HIBA 0.1 mol/L; adjust pH by NH3 to pH = 4.1; Gradien concentration elution program; Flow rate of mobile phase 1ml / min; Sample injection volume 100 µL.

**Figure 1.** ICP-MS/MS couple to HPLC online system

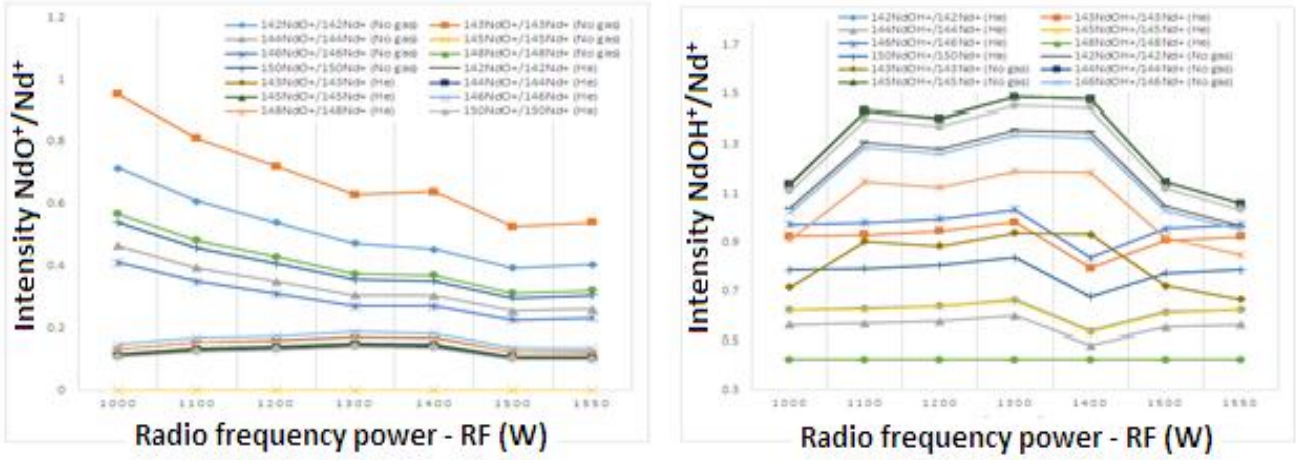



**Figure 2.** Effect of RF on $NdO^+$ and $NdOH^+$ fragmentation

The signal attenuation effect on the heavier REE due to the Nd matrix has been effectively overcome when using the $^{103}Rh$ internal standard. The additive influence caused by the signal intensity of $NdO^+/NdOH^+$ species from Nd matrix on the analytes mass number $^{159}Tb$, $^{163}Dy$, $^{165}Ho$ and $^{166}Er$ increased the concentration of these impurities. Therefore, it is necessary to separate the rare earth impurities (Tb, Dy, Ho, Er) from the Nd matrix and

determine them using a HPLC system hyphenated ICP-MS/MS. The validation of method shows that the quantitative limits (LOQ) of REE impurities were from 0.005 to 0.019 µg/L and from 0.019 to 0.030 µg/L for using the internal standard technique and HPLC-ICP-MS/MS technique, respectively. The sample recovery is from 98 to 107% using both techniques. The ICP-MS/MS method using the internal standard and that hyphanated HPLC is suitable the determination of trace REE impurities in high purity $Nd_2O_3$ over 99.99% (Table 1).

**Table 1.** Recovery, LOD, LOQ of internal standard and HPLC-ICP-MS /MS techniques

| Isotopes | Internal standard method using $^{103}Rh$ | | | | HPLC – ICP-MS/MS method | | | |
|---|---|---|---|---|---|---|---|---|
| | LOD (µg/L) | LOQ (µg/L) | Recovery (%) | RSD (%) | LOD (µg/L) | LOQ (µg/L) | Recovery (%) | RSD (%) |
| $^{159}$ Tb | 0.006 | 0.017 | 99.71 | 1.7 | 0.006 | 0.019 | 98.04 | 1.7 |
| $^{163}$ Dy | 0.006 | 0.019 | 96.16 | 2.4 | 0.009 | 0.026 | 101.17 | 1.9 |
| $^{165}$ Ho | 0.002 | 0.005 | 97.93 | 0.7 | 0.008 | 0.023 | 103.67 | 2.6 |
| $^{166}$ Er | 0.004 | 0.011 | 107.30 | 1.7 | 0.010 | 0.030 | 103.18 | 2.6 |

From the research results 01 paper was accepted for publishing in *Journal of Analytical Sciences* (in Vietnamese) in 2020, and 01 report was presented at the Nuclear Science and Technology Conference of young staffs in Oct. 2020, meanwhile 01 analytical procedure of the Ho and Tb determination in high purity $Nd_2O_3$ sample was issued. Hence, the project achievement has fulfilled the registered content as the contract requirement.

# COMPLETING THE TECHNOLOGY OF PRODUCING $Fe_3O_4$ NANOMATERIALS AND CREATING FILTER PARTICLES FOR ARSENIC TREATMENT ON $Fe_3O_4$ NANO-BASED WITH A CAPACITY OF 20KG/DAY

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**Project information:**

- **Project name: "Completing the technology of producing $Fe_3O_4$ nanomaterials and creating filter particles for Arsenic treatment on $Fe_3O_4$ nano-based with a capacity of 20kg/day"**
- **Code: DASXTN.15/19/VCNXH**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan 2019 - Dec 2020)**
- **Contact email: huonghvcc@gmail.com**
- **Published papers related to the project:**

1. Do Quoc Hung, Nguyen Van Tien, Bui Cong Trinh, Le Thi Mai Huong, et al. (2020) "Synthesis of magnetic nanoparticles $Fe_3O_4$ solution in aqueous saturated lome solution at laboratory and pilot scale", J, Internauka, № 43(172), V. 2, pp. 49-54
2. Nguyen Van Tien, Bui Cong Trinh, Le Thi Mai Huong, et al. (2020) "RESEARCH AND PRODUCTION MATERIALS FOR ASEN TREATMENT BY NANO $Fe_3O_4$", Proceeding of the 13th Conference on Nuclear Science and Technology, VINATOM, Ha Noi, Vietnam.

The wide applicability of $Fe_3O_4$ nano is shown in industries such as i) printing industry, rubber, paint (stealth coating), ceramics; ii) biotechnology, health; iii) magnetic materials, magnetic liquids; iv) water treatment materials; v) catalyst, catalyst carrier; vi) Magnetic liquid to recover spilled oil, separate oil from water, magnetic liquid in mineral extraction... In water treatment, nano $Fe_3O_4$ has been proven to be an effective adsorbent for the treatment of impurities as toxic heavy metals in water.

Large-scale arsenic pollution has poisoned large numbers of the population. A study in 2007 reported that over 137 million people in more than 70 countries could be affected by arsenic poisoning in drinking water. In Vietnam, about 13.5% of the population (10-15 million people) are using drinking water from well water, which is very susceptible to arsenic contamination. According to incomplete statistics, the whole country currently has more than 1 million drilled wells, of which many wells have arsenic concentrations 20-50 times higher than the allowable arsenic concentration (0.01mg/L), adversely affecting the environment, the health of the community.

There have been many studies on $Fe_3O_4$ nanofabrication. However, the results shows that the technological processes, materials, and manufacturing equipments are often very complicated and therefore, practical applicability, and production on a large scale are not yet feasible. Currently, Vietnam has no places where produces $Fe_3O_4$ nanomaterials, even on a pilot or industrial scale.

The research group of Assoc. Prof. Dr. Le Thi Mai Huong has published research on the fabrication of $Fe_3O_4$ nano-material by oxidation - precipitation method and at the same time using $FeCl_2$ solution mixed with $Ca(OH)_2$ solution. This is a new patented method of utility solution. The essence of the method is expressed through the reaction (1):

$$3FeCl_2 + 3Ca(OH)_2 + 1/2O_2 \rightarrow Fe_3O_4\downarrow + 3H_2O + 3CaCl_2 \quad (1)$$

The survey results have shown that the parameters of the $Fe_3O_4$ nano synthesis process are as follows:

i) Raw materials: $FeCl_2$ solution has a concentration in the range of 2-3M (actually 2.2M). The precipitating agent is a saturated solution of $Ca(OH)_2$ at a normal temperature of 30$^oC$.

ii) The reactor has a volume of 1$m^3$ and is equipped with a stirrer with a speed of ~ 200 - 300 rpm, a ratio of impeller area/bottom area 1/5 - 1/3, stirring time from 30-40 minutes.

iii) The 2-step settling mode, each step is of 10 hours, and product filtration and washing are performed on a fabric frame of size The total number of washing times is 6.

iv) The obtained product is vacuum-dried at low temperature < 70$^oC$, then milled and packaged.

To evaluate the Arsenic adsorption capacity of $Fe_3O_4$ nanopowder, experiments were conducted under the following conditions: 0.50g $Fe_3O_4$ nanopowder was added to 1000mL of Arsenic (V) solution 100mg/l, stirring speed 120 rpm, room temperature. After 90 minutes, the adsorption capacity of the sample reached a value of 111.6 mg/g.

**Table 1.** Characteristic properties of nano $Fe_3O_4$ powder products

| **Product** | **Specifications** | | | |
|---|---|---|---|---|
| | **Grain size (nm)** | **Surface area ($m^2$/g)** | **Magnetic saturation (emu/g)** | **Arsenic adsorption capacity (mg/g)** |
| Nano $Fe_3O_4$ | 20-60 | ≥ 40 | ≥ 40 | ≥ 100 |

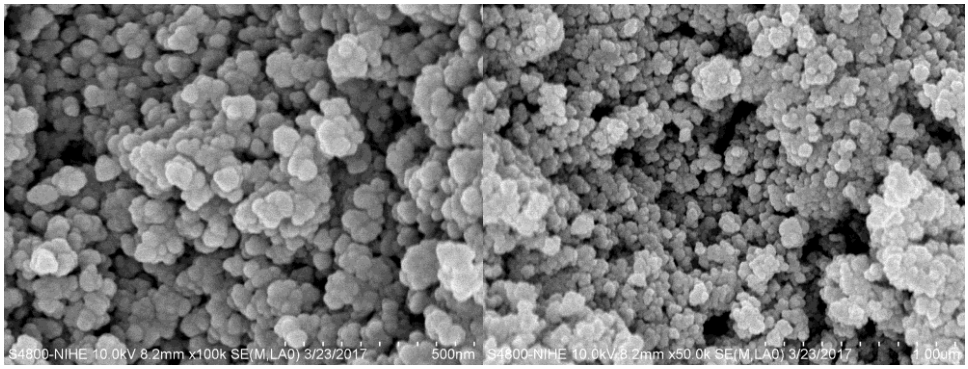


**Figure 1.** FE-SEM images of $Fe_3O_4$ synthesized from $FeCl_2$ salt

The above research results only prove the effective Arsenic treatment ability of powdered materials. However, for $Fe_3O_4$ nanomaterials to be effective in practical conditions, it is necessary to make the material in the form of a porous particle structure. This process is performed when adding bentonite additives, $MnO_2$, activated carbon to $Fe_3O_4$ nanopowder. Survey results according to density, compressive strength, ability to decontaminate water...have shown two types of materials: Mag-B-Mn 3 and Mag-BC 3. In which, Mag-B-Mn 3 is fully distributed in the following ratio (%w/w): W($Fe_3O_4$): W(Bentonite):W($MnO_2$):W($H_2O$) is: 40:40:10:10; and Mag-BC 3 with the ratio (%w/w):W($Fe_3O_4$):W(Bentonite):W($MnO_2$):W(active C):W($H_2O$) is: 20:40:5:20:15, the adsorption capacity (after 90 minutes) of the two samples reached the value of 84.4(mg/g), 52.1(mg/g) respectively.

The arsenic (V) adsorption capacity of the two materials above is shown in Figure 1. It shows that:

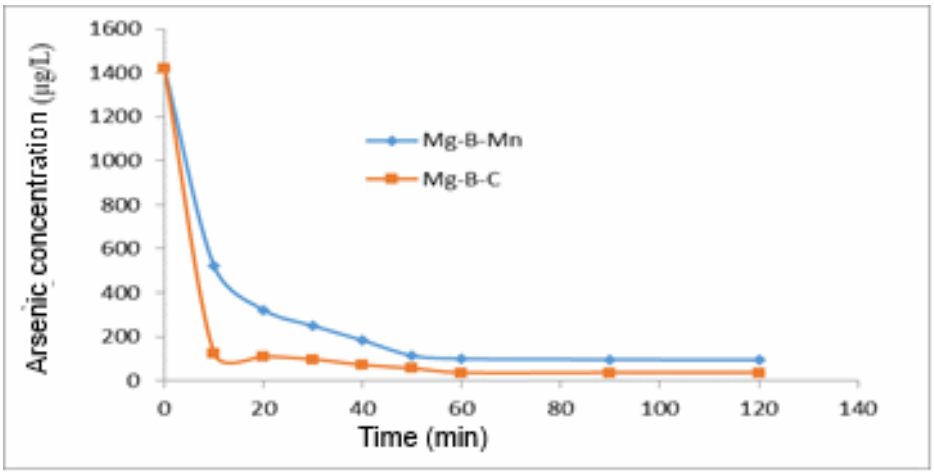


**Figure 2.** Effect of exposure time on arsenic removal efficiency

The results Figure 2 shows:

- The adsorbed Mag-B-C material sample reached equilibrium within 10 minutes of contact, while the Mag-B-Mn material sample needed a period of 30 minutes.

Thus, the Mag-B-Mn sample has a higher adsorption capacity (84.4 mg/g) but a slower rate than that of the Mag-BC sample, but the adsorption capacity of Mag-BC is lower (52, 1 mg/g). The results are consistent with the project team's idea: Fabrication of the selected

Arsenic adsorbent for the purpose of dividing the adsorption process into 2 stages: The first stage of crude adsorption - using the material has a large adsorption capacity, but the speed does not need to be too fast, it is the type of Mag-B-Mn; stage 2 fine adsorption - use a material with moderate adsorption capacity but high adsorption speed, which is Mag-B-C type to quickly reduce Arsenic concentration to meet treatment standards

To evaluate the adsorption of materials over time, we surveyed the Bed - Volume model. Mass of material was packed into a column of 1L volume, at a flow rate of 10 mL/min.

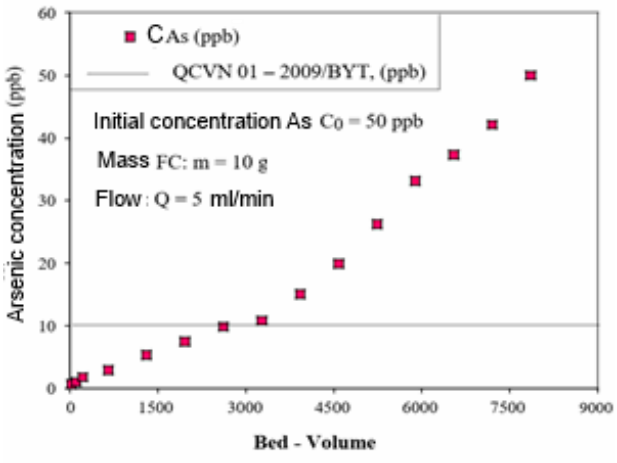


**Figure 3.** Arsenic output concentration according to Bed – Volume model

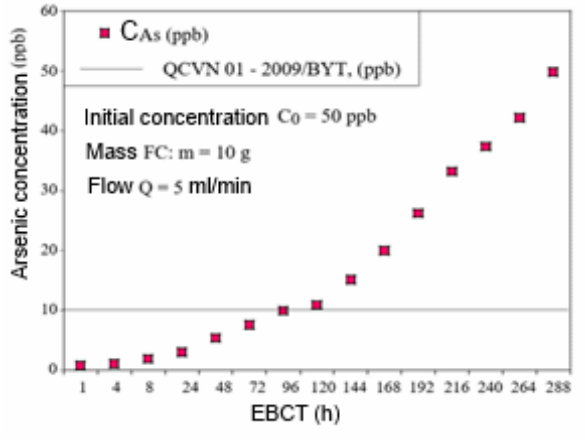


**Figure 4.** Equilibrium adsorption time according to Bed – Volume model

The modified $Fe_3O_4$ material has an adsorption capacity equivalent to some zeolite (one of the popular Arsenic adsorbents being applied to Arsenic adsorption), the water after treatment meets standards QCVN 01-2009 /BYT on arsenic content. Therefore, $Fe_3O_4$ nano fabricated from this study can be used as an Arsenic adsorbent in aqueous medium. Optimal parameters are: Maximum filtration rate (litre/hour): 80L/h; Arsenic concentration reached: <0.01mg/L. The treatment speed is 80 L/hour to meet the water treatment needs for a household of 5-8 people.

Replace core every 3 months for areas with As contamination from 100 μg/L and every 6 months for areas with lower As contamination.

In terms of technical features, the treatment project's filter equipment meets the specified standards, but has a cheaper price than similar ones on the market (RO and Nano form) and is suitable for application of arsenic-contaminated water treatment in remote areas without access to water supply systems.

- Setting up process of granulating a porous carrier and impregnating $Fe_3O_4$ nanoparticles to create adsorbent granules used in arsenic treatment with a capacity of 20 kg / day".

- The product cost has been preliminarily calculated as 280 thousand VNĐ/core and the expected selling price is 350 thousand VNĐ/core.

- Produced 10.5 kg of $Fe_3O_4$ powder; trial installation for 50 households; commercial production of 500 filter cartridges.

**Table 2.** Specifications of adsorbent particles in 500 filter cartridges

| Product | Specifications | | | |
|---|---|---|---|---|
| | **Grain size (mm)** | **Dump weight (g/cm3)** | **Surface area ($m^2/g$)** | **Arsenic adsorption capacity (mg/g)** |
| Arsenic adsorption particles | 0.5-2.0 | Type 1: 1-1,4<br>Type 2: 0.6-0.8 | Type 1: ≥ 40<br>Type 2: ≥ 100 | Type 1: ≥ 80<br>Type 2: ≥ 40 |

Thus, the precipitation method combining oxidation by $FeCl_2$ solution with saturated $Ca(OH)_2$ solution in air environment (the raw material is industrial) allows to fabricate $Fe_3O_4$ nanoparticles with size 20- 60 nm and specific surface not less than 40 $m^2/g$ and magnetic saturation not less than 40 emu, and obtained $Fe_3O_4$ nanopowder mixed with bentonite, $MnO_2$, activated carbon can make Arsenic adsorbent particles with The adsorption capacity is greater than 40 and 80 mg/g and is applied in the treatment of arsenic-contaminated water for households in remote areas that do not have access to the water supply system.

# STUDY ON THE EFFECT OF GRINDING TO THE SOLUBILITY OF THE TAN RAI ALUMINUM HYDROXIDE IN HCL SOLUTION

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**Project information:**

- **Project name: "Study on the effect of grinding process on the solubility of Tan Rai aluminum hydroxide in HCl solution"**
- **Code: CS/20/03-02**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020- Dec 2020)**
- **Contact email: phungvuphong@yahoo.com**
- **Published papers related to the project:**

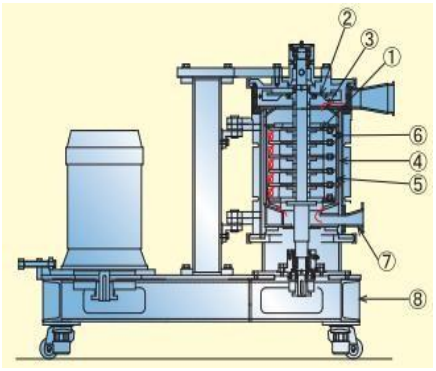
1. Phung Vu Phong, Le Thi Mai Huong, Nguyen Thi Lien, Bui Cong Trinh, Effect of grinding principle on Tanrai aluminum hydroxide dissolution efficiency in HCl acid", Internauka science Jounal, (2020), No 42 (171), T2, pp 47-54
2. Phung Vu Phong, Le Thi Mai Huong, Nguyen Thi Lien, Bui Cong Trinh, Different characteristics of Tan Rai Aluminum hydroxide dissolution process in acid and base media", Journal of Science and Technology, Viet Tri University of Industry, No 2, T1/2021 (in Vietnamese)
3. Nguyen Thi Lien, Phung Vu Phong, Le Thi Mai Huong, Bui Cong Trinh, Nguyen Van Tien, Luong Manh Hung, Study on the effect of grinding on the ability of dissolution of the Tan Rai aluminum hydroxide in HCl solution, Proceeding of the 6th Conference of Nuclear Science anf Technology for young reseacher, Ha Noi, Vietnam, 8-9 Oct 2020,pp 38-39.

Currently, Polyaluminium chloride (PAC) is a flocculation chemical that is widely used in the market for the wastewater treatment. It has many advantages compared to other traditional chemicals such as active in a wide pH range, less pH reduction of water, fast flocculation speed, less impact on the environment...So, the domestic demand for PACs is higher and higher. However, the current PAC domestic production from the aluminum hydroxide dissolution process in HCl solution is carried out at a high temperature and high pressure, leading to higher production costs than the products imported from China. Therefore, the problem is how to improve the dissolution conditions, production costs reduction, and increasing the competitiveness with imported products. One of the methods to enhance the dissolution efficiency is to grind the samples before the dissolution. The grinding process will

change the morphology of the particle, increase the surface area, help accelerate the reaction (higher efficiency) and lower the required conditions (temperature, pressure).

Based on the real requirements and research capability, we proposed the project "Study on the effect of grinding on the solubility of Tan Rai aluminum hydroxide in HCl solution" to improve the efficiency of the production.

The dissolution investigating of the pre and post grinding samples using three grinding techniques (the ultraspeed hammer centrifugal grinding 3000rpm, ball milling, planetary ball milling) (Fig.1-3).




1. Hopper of material; 2. Grinding chamber; 3. Mesh sieve; 4. Exhaust fan; 5. Material pipe to separating chamber; 6.Collection pan return to hopper; 7. Product container; 8. Separating Xyclon

**Figure 1.** The hammer centrifugal grinder

**Figure 2.** The ball mill

**Figure 3.** The planetary ball mill

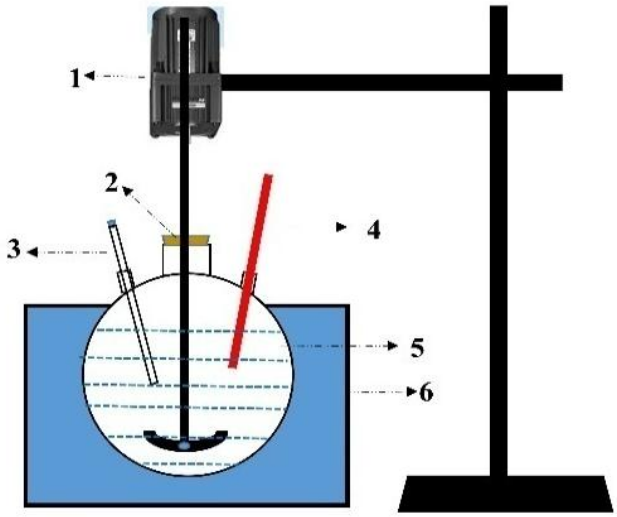
The results showed that the phase composition (Gibbsite) of raw and grinded samples have not been changed, but the particle size and the specific surface area of the ground samples had been changed significantly compared to the raw sample were shown in Table 1.

**Table 1.** The results of particle size and surface area of Tan Rai $Al(OH)_3$ samples

| **Surface area ($m^2/g$)** | | | | **Average particle size (μm)** | | | |
|---|---|---|---|---|---|---|---|
| **Raw sample** | **Hammer centrifugal grinding sample** | **Ball milling sample** | **Planetary ball milling sample** | **Raw sample** | **Hammer centrifugal grinding sample** | **Ball milling sample** | **Planetary ball milling sample** |
| 0.089 | 1.232 | 1.433 | 9.92 | 107.21 | 12.38 | 25.69 | 15.43 |

By the hammer centrifugal grinding, ball milling and planetary ball milling processes the surface area was increased about 13.84 times, 16.10 times, 111.44 times compared to the raw samples, respectively. It can be explained that the grinding process broke the raw samples into the particles, which tends to create many defects in the samples' surfaces.

The dissolution experiments of pre and post Tan Rai aluminum hydroxide grinding samples were carried out in HCl solution with 3M, 5M concentrations at 65°C, 75°C, 85°C, 95°C under the following conditions: sample weight: 10 g, solution volume: 500 ml, stirring speed: 250 rpm, reaction time: 90 minutes. The experiments were carried out in a glass bottle placed in a heated water bath (Fig.4). After the reaction, the samples are filtered. Part of the filtrate is analyzed for the concentration of aluminum ($Al^{3+}$); The solid residue was washed and dried to measure the surface area (BET), analyzed by scanning electron microscopy (SEM), X-ray diffraction (XRD) and the particle size distribution.




1. Stirring motor with speed ranged from 0 to 1000 rpm, total cross section of paddles are $3cm^2$ covered with epoxy.
2. The heat-resistant plastic button reduces the amount of air released.
3. Sampling tube;
4. Thermometer;
5. Heat-resistant round bottom flask (1liter);
6. Water bath:heater rate $4^oC$/min. Thermal dispersion is done by cyclic pump.

**Figure 4.** The equipments system of the dissolving of $Al(OH)_3$ in HCl solution

The influence of the grinding process on the dissolution efficiency of $Al(OH)_3$ Tan Rai in HCl solution is presented in Table 2. At the same dissolution conditions (temperature, reaction time, stirring speed, HCl concentration), the $Al(OH)_3$ dissolution efficiency of the grinded samples were higher than the raw sample and the dissolution efficiency of the planetary ball milling and the hammer centrifugal grinding samples were higher than the ball milling samples.

**Table 2.** Dissolution efficiency of raw and grinded Tan Rai $Al(OH)_3$ samples

| Temperature (°C) | HCl concentration | Efficiency (%) | | | |
|---|---|---|---|---|---|
| | | Raw sample | Ball milling sample | Planetary ball milling sample | Hammer centrifugal grinding sample |
| 65 | 3M | 6.73 | 22.59 | 58.06 | 34.61 |
| | 5M | 19.41 | 34.82 | 70.13 | 49.06 |
| 75 | 3M | 14.12 | 34.58 | 68.45 | 45.78 |
| | 5M | 26.28 | 48.31 | 82.77 | 68.43 |
| 85 | 3M | 27.01 | 44.04 | 78.57 | 65.07 |
| | 5M | 37.86 | 56.96 | 87.52 | 83.81 |
| 95 | 3M | 33.99 | 60.51 | 87.99 | 73.64 |
| | 5M | 50.69 | 79.73 | 95.26 | 95.25 |

On the other hand, the estimation of energy cost for the 1kg $Al(OH)_3$grinding of a hammer centrifugal grinding is lowest: engine capacity (15kW), equipment productivity (150 kg/h), retention time (5s), electricity cost (0.1kWh/kg). Therefore, the centrifugal grinding method is more suitable for $Al(OH)_3$ activation in HCl acid solution than other methods.

In summary, in the project framework, our studies have clarified the influence of the grinding processes (the hammer centrifugal grinding, ball milling, planetary ball milling) on the solubility of Tan Rai $Al(OH)_3$ in HCl solution and we have been selected a suitable grinding method for the $Al(OH)_3$ dissolution process.

In the future, we will continue to study further in the process of $Al(OH)_3$ Tan Rai dissolution in the HCl solution using the hammer centrifugal grinding to activate the raw material and to research on the application capability of the hammer centrifugal grinding in the PAC production processes in Vietnam.

# RESEARCH ON EVALUATING THE POSSIBILITY OF USING RED MUD AS A COAL-FIRED ADDITIVE OF THERMAL POWER PLANT IN THE ALUMIN-TAN RAI COMPLEX

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**Project information:**

- **Project name: "Research on evaluating the possibility of using red mud as a coal fired additive of thermal power plant in the Alumin – Tan Rai"**
- **Code: DTCB.16/19/VCNXH**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan 2019 - Dec 2020)**
- **Contact email: thucphuong82@gmail.com**
- **Published papers related to the project:**

1. Phuong N.T.T, Duc H.V., Dinh L.X., Huong L.T.M. "Study on the influence of additives containing elements of Na, Fe, Al, Ca to anthracite coal combustion efficiency; Sci. J. Internauka. 2021". № 24(200)
2. Nguyen Thi Thuc Phuong, Hoang Van Duc, Tran Ngoc Ha, Hoang Thi Tuyen, et al. (2019) "Study on the influence of additives containing separate elements of Na, Fe, Al, Ca to coal combustion efficiency (in Vietnamese)", Journal of Chemistry and Application, 2019
3. Nguyen Thi Thuc Phuong, Hoang Van Duc, Pham Tuan Anh (2019) "Study on the influence of additives containing separate elements of Na, Fe, Al, Ca to coal combustion efficiency applied on coal samples of thermal power plant (in Vietnamese)", Vietnam Conference on Nuclear Science and Technology–VINANST XIII-VINATOM 08/2019
4. Nguyen Thi Thuc Phuong, Hoang Thi Tuyen, Pham Tuan Anh (2020) "Study on the influence of multi-element additives containing Na, Fe, Al, Ca to coal combustion efficiency (in Vietnamese)", Vietnam Conference on Nuclear Science and Technology for young researchers (2020) – VINATOM 10/2020
5. Nguyen Thi Thuc Phuong, Le Thi Mai Huong, Hoang Nhuan, Luu Xuan Dinh, Hoang Van Duc, Ta Ngoc Dung, and Nguyen Van Tung (2021) "Studies on the effects of red mud on the combustion characteristics of Vietnam pulverized coal", Korean Domestic Journal (submitted and under review).

With an aim to promote the combustion of pulverized coal, lots of experiments have been carried out by adding various inorganic compounds. In these studies, the most commonly used

coal combustion catalysts include metal oxides (e.g. $MnO_2$, CaO, $CeO_2$, $Fe_2O_3$, CuO, and ZnO), alkaline metal salts (e.g. $NaNO_3$, $NClO_4$, $KNO_3$, $KClO_3$, and $K_2CO_3$), industrial wastes rich in these effective metal components as coal combustion promoters (e.g. steel slag, steel wastes,) …, which are both pure chemical reagents. The results indicated that the ignition temperature decreased and burnout index simultaneously increased with catalysts. The mentioned studies showed that alkaline earth metals, alkali metals, transition metal oxides, and other compounds, such as salts, can serve as supporting agents for coal combustion.

In this study, red mud, and industrial waste rich in Na, Fe, Ca, and Al or bauxite residue which is a side-product of the Bayer process, is employed as the catalyst, and the effects of catalyst on the combustion performance of anthracite coal are investigated. It is played an important rolein reducing the environmental hazard from red mud. If red mud is used as coal-combustion-supporting agents, additional resources would be available and energy and costs will be conserved. The waste as red mud is extremely cheap, effective, and highly suitable for large-scale industrial applications.

Red mud was obtained from Tan Rai factory in Lamdong, Vietnam. The chemical components of red mud are presented in Table 1, which mainly are $Fe_2O_3$, $Al_2O_3$, and a small amount of gangue such as $Na_2O$, $SiO_2$, CaO, and $TiO_2$.

**Table 1.** Chemical composition of red mud, wt%

| $Fe_2O_3$ | CaO | $Al_2O_3$ | $SiO_2$ | $Na_2O$ | $TiO_2$ | Other |
|---|---|---|---|---|---|---|
| 52.10 | 2.83 | 33.71 | 2.32 | 2.98 | 5.83 | 0.23 |

The anthracite employed was obtained from a company in Quang Ninh province, Vietnam. The chemical properties of the raw anthracite are shown in Table 2.

**Table 2.** The properties of Vietnam Anthracite

| Components | Vietnam Anthracite |
|---|---|
| Proximate analysis (%) | |
| Moisture | 2.44 |
| Ash | 30.78 |
| Volatile matter | 5.61 |
| Fixed carbon | 61.08 |

| | |
|---|---|
| Ultimate analysis (%) | |
| C | 63.25 |
| N | 0.89 |
| S | 0.21 |
| O | 4.13 |
| The ingredient of ash (%) | |
| $SiO_2$ | 47.72 |
| CaO | 5.65 |
| $Al_2O_3$ | 31.49 |
| $Fe_2O_3$ | 10.01 |
| MgO | 1.12 |
| Other | 4.01 |

The ignition temperature, $T_i$, is measured by thermogravimetry and the Derivative thermogravimetry (TG-DTG) method. Burnout efficiency, $B_c$, can be calculated based on the weights, the ash weight contents (%) of the raw anthracite coal, red mud, and anthracite coal with red mud, the carbon content by weight (%) in of the raw anthracite coal and anthracite coal with red mud; the maximum weight loss by the percentage of the sample after the burning process (%). TG-DTG curves of anthracite coal with optimal addition of red mud are shown in Figure 1, the different indexes of coal combustion from TG-DTG are obtained and shown in Table 3.

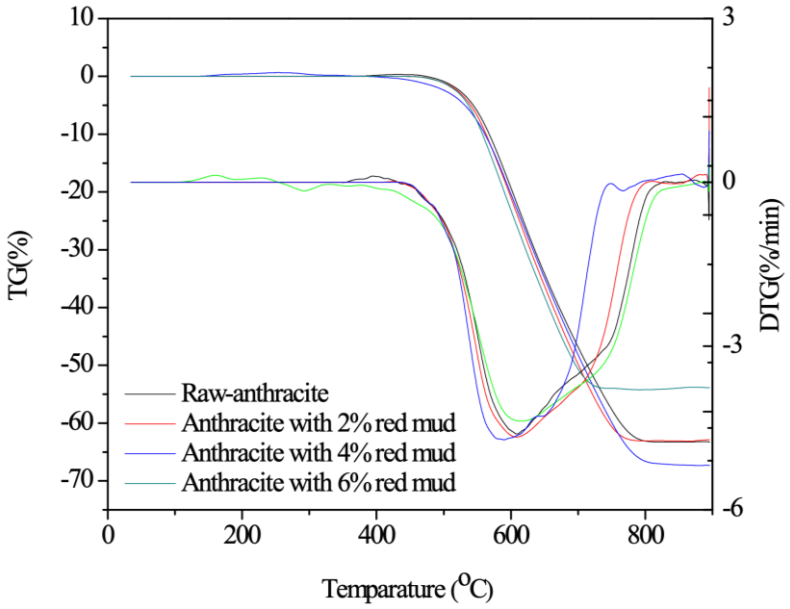


**Figure 1.** TG-DTG curve of anthracite with red mud.

**Table 3.** Effects of the red mud on coal ignition temperature and burnout efficiency

| Samples | Ignition temperature (°C) | Burnout efficiency (%) |
|---|---|---|
| Raw-anthracite | 540 | 90.54 |
| Anthracite with 2% red mud | 533 | 91.67 |
| Anthracite with 4% red mud | 531 | 92.35 |
| Anthracite with 6% red mud | 528 | 93.13 |

The combustion reactivity of pulverized coal is influenced by particle size, the content of volatile and oxygen concentration. From Table 3, as can be seen, that the *Ti* of the initial sample for anthracite coal is 540°C. However, the *Ti* of anthracite coal with 2%, 4%, and 6% red mud is 533°C, 531°C, and 528°C, respectively.

The results indicate with the red mud addition, the ignition temperature of anthracite coal is decreased 7°C, 9°C, and 12°C, respectively. The red mud has a greater influence on anthracite coal on decreasing ignition temperate. The ignition temperature decreases as the red mud content increases. As can be seen from Table 3 that the burnout efficiency is increased 1.13%, 1.81%, and 2.59% with 2%, 4%, and 6% red mud, respectively. The red mud has a greater influence on anthracite coal on increasing burnout efficiency. It further indicates that the red mud has a significant effect on improving pulverized coal combustion.

# ESTABLISHING THE PROCEDURE TO MEASURE Cd, Pb, Zn, AND Cu CONCENTRATIONS BY ICP-MS SYSTEM

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**Project information:**

- **Project name: Establishing the procedure to measure Cd, Pb, Zn, and Cu concentrations by ICP-MS system**
- **Code: CS/20/04-05**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020 - Dec 2020)**
- **Contact email: dvthangnb@gmail.com**
- **Published papers related to the project:**

1. Pham Tuan Nam, Nguyen Van Khanh, Nguyen Thi Oanh, Le Thi Hoa, Determination of Co and Cs concentration ratio and distribution coefficient using ICP-MS system, Young Researcher Conference on Nuclear Science and Technology – 6th, Hanoi, 2020.

Over the past few decades, the environment has been polluted by pollutants originating from agriculture and industry. Heavy metal contamination has been identified as a concern in the environment, due to the discharges from the industrialization and urbanized processes in developing countries. The problem affected the biological system and human health. To investigate the heavy metal concentration, the establishing a procedure for measurements of Cd, Pb, Zn, and Cu in sediment by the ICP-MS system was carried out under the frame of this project.

Five sediment samples were collected along Day river, Vietnam. The sampling was under TCVN 6663-1:2011 (ISO 5667-1:1980) Water quality - Sampling - Part 1: Guidance on the design of sampling programs and sampling techniques; and the sediment preservation and handling process followed up TCVN 6663-15:2004 (ISO 5667-15:1999) Water quality – Sampling - Part 15: Guidance on preservation and handling of sludge and sediment samples.

The sediment samples were removed leaves, rock, and gravel; dried at 60$^{o}$C until its mass has not changed; ground to fine powder form; and preserved in the desiccator. The sample digesting is carried out with a microwave and acid by EPA method 3052 (Microwave assisted acid digestion of siliceous and organically based matrices): 0.2 g of samples being digested in 15 mL of nitric acid (63%) and hydrochloric acid (37%) for using microwave heating. After cooling, the sample solution in the vessel was transferred to 50 mL volumetric

flask, then diluted to level with deionized water. The sample solution was diluted 10 times before measurement in the ICP-MS system.

ICP-MS system was started following the manufacture guideline, and optimized by tuning solution, Pb concentration was measured by No Gas mode, Cd, Cu and Zn concentrations were measured by He Gas mode. The linear range and calibration curve have been established by the tuning solutions with concentrations d 0.1 ppb; 1.0 ppb; 5.0 ppb; 10.0 ppb; 50.0 ppb, and 100.0 ppb, concentrations of Initial calibration verification (ICV) and d calibration verification (CCV) are 6.0 ppb and 20.0 ppb. The Cd calibration curve is shown in Figure 2. LOD and LOQ are measured with a blank (a blank is a sample with a similar composition to the test sample but without the analyte) to find the theoretical LOD and LOQ and the standard is diluted to concentrations around the theoretical LOD and LOQ to confirm the actual LOD and LOQ.

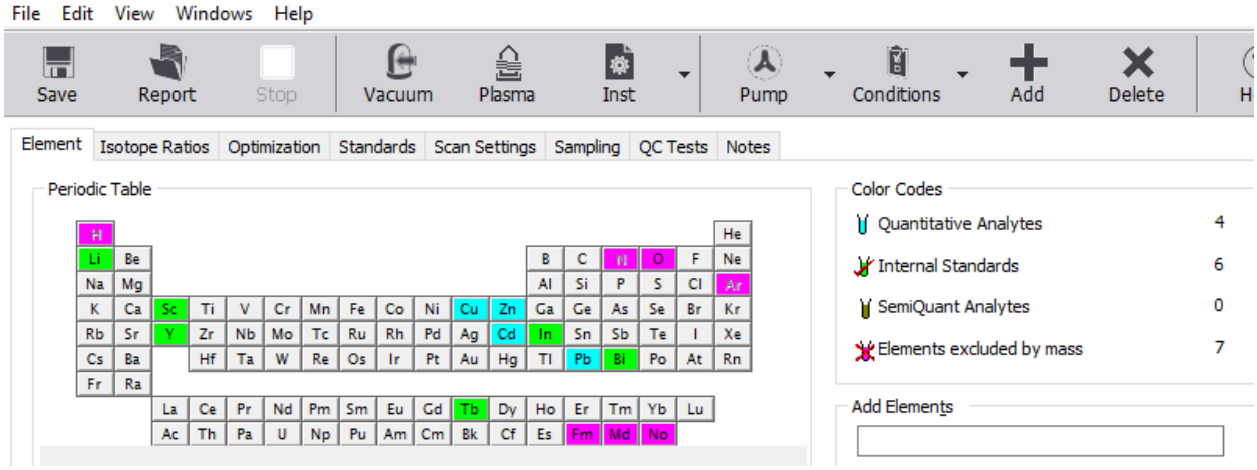
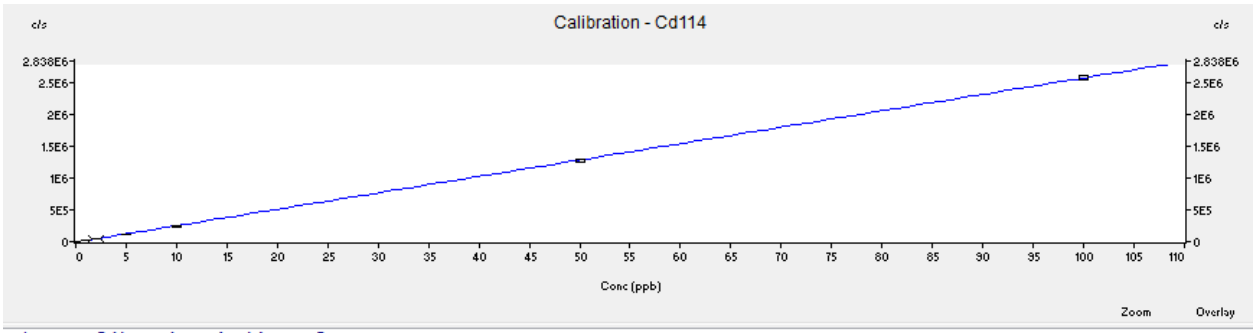



**Figure 1.** Setting the worksheet and selection of elements in ICP-MS




Cd114 Calibration (ppb), Cal Set 1, 2020-11-08 12:48:16

| Soln Type | c/s | SD(c/s) | %RSD | Std Conc | Calc Conc | Error | %Error | Flags |
|---|---|---|---|---|---|---|---|---|
| Blank | 442 | 51.3 | 11.62 | 0.0000 | 0.2830 | 0.2830 | - | |
| Standard 1 | 24581 | 62.2 | 0.25 | 1.0000 | 1.2210 | 0.2210 | 22.10 | |
| Standard 2 | 49679 | 372.8 | 0.75 | 2.0000 | 2.1662 | 0.1662 | 8.31 | |
| Standard 3 | 125125 | 542.5 | 0.43 | 5.0000 | 5.0320 | 0.0320 | 0.64 | |
| Standard 4 | 251965 | 3463.0 | 1.37 | 10.0000 | 9.4922 | -0.5078 | -5.08 | |
| Standard 5 | 1309404 | 30729.3 | 2.35 | 50.0000 | 49.5237 | -0.4763 | -0.95 | |
| Standard 6 | 2662742 | 41116.4 | 1.54 | 100.0000 | 100.2818 | 0.2818 | 0.28 | |

Curve Fit: Linear, Weighted Fit: No, Thru Blank: No
Correlation Coefficient: 0.999958
Limit of detection: 0.0060 ppb
Limit of quantitation: 0.0199 ppb
Blank Equivalent Concentration: 0.0171 ppb
Calibration Equation: c/s = (441.7 - 7301 + 25800*conc)*[I/S Ratio]

**Figure 2.** The calibration curve for Cd

The instrument uses hydrogen and helium gas to eliminate interference caused by the influence of the sample and the gas background. The result relative errors are in the range -0.05% to +0.04%, below the AOAC criteria (relative error for trace element concentration are from -20% to +10%), this ICP-MS method has good trueness. The resulting relative standard deviations (RSD) are in the range 0.69% - 0.90%, also below RSD criteria from 15% to 30% for ppb concentration level, the results indicated that the experiment precision is acceptable.

Table 1 shows the concentrations of 4 metals in sediment, which are arranged in the following order: Cd < Cu < Pb < Zn. The 5$^{th}$ sample has the highest metal concentration. The concentration of 4 heavy metals in the sediment samples is within the allowable limits according to QCVN 43:2017/BTNMT - National technical regulation on sediment quality. The limit of detections (LOD) ranges below the project requirement of 0.1 mg/kg.

**Table 1.** Result of the Cd, Pb, Zn, and Cu concentration in the sediment samples (mg/kg-dry)

| **Mẫu** | **Cd** | | **Pb** | | **Zn** | | **Cu** | |
|---|---|---|---|---|---|---|---|---|
| LOD | 1,5E-3 | | 2,3E-3 | | 81,0E-3 | | 50,1E-3 | |
| LOQ | 5,0E-3 | | 7,6E-3 | | 270,0E-3 | | 167,0E-3 | |
| TT1 | 0,336 | ±0,196 | 16,088 | ±0,917 | 54,017 | ±11,992 | 12,042 | ±1,144 |
| TT2 | 0,412 | ±0,234 | 22,219 | ±1,407 | 65,125 | ±14,220 | 21,415 | ±1,568 |
| TT3 | 0,457 | ±0,221 | 41,395 | ±1,477 | 101,572 | ±13,669 | 37,330 | ±1,777 |
| TT4 | 0,701 | ±0,216 | 47,654 | ±1,067 | 112,965 | ±13,155 | 52,253 | ±1,306 |
| TT5 | 0,781 | ±0,206 | 90,877 | ±2,454 | 125,593 | ±13,313 | 67,974 | ±2,107 |

The establishing of the procedure for some heavy metal concentration determination has been completed in this project by using the ICP-MS system, and the results have met the requirements. With the advantages of the ICP-MS method, more studies will be carried out to apply this procedure in environmental analysis.

# TECHNOLOGY IMPROVEMENT AND ESTABLISHMENT OF A PRODUCTION LINE FOR BASIC ZINC CARBONATE WITH ZINC CONTENT ≥ 57% AND A CAPACITY OF 150 TONS/YEAR BY ACID METHOD USING $NH_4HCO_3$ AS PRECIPITATING AGENT FROM ZINC CONTAINING SCRAPS

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**Project information:**

- **Project name: Technology improvement and construction of a production line for basic zinc carbonate with zinc content ≥ 57% and a capacity of 150 tons/year by acid method using $NH_4HCO_3$ as precipitating agent from zinc containing scraps.**
- **Code: DASXTN.10/18/VCNXH**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan 2018 - Jun 2019)**
- **Contact email: tranvuong87@gmail.com**

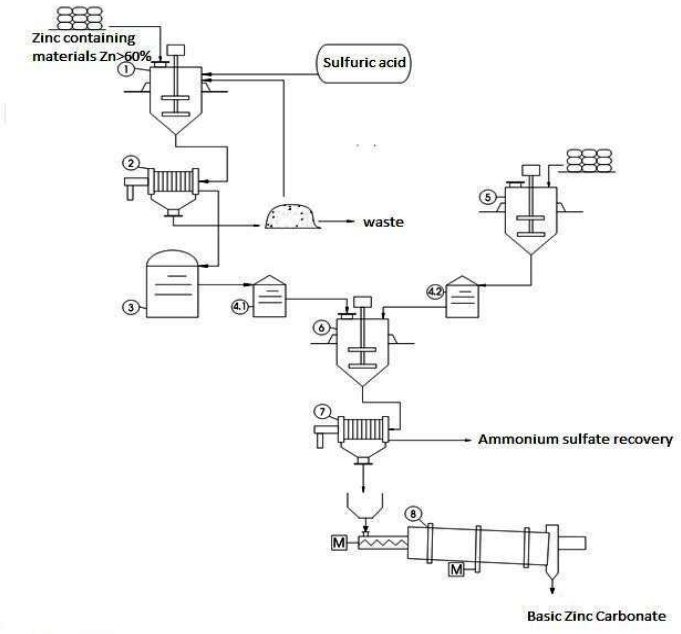
Basic zinc carbonate is widely used in the industry, but currently in our country there is almost no industrial facilities to supply this product. Basic zinc carbonate has been used in the rubber industry as well as in many other industries such as paint, petroleum drilling fluids, animal feed, pharmaceuticals, etc. It is also used as a precursor to produce activated zinc oxide, zinc oxide nano-particles and other zinc-containing chemicals. The production technology of basic zinc carbonate is not complicated because it consists of only several stages and requires no sophisticated machinery and equipment. Additionally, the production line is often quite compact, occupies little space, and the initial investment is low. The production technology of basic zinc carbonate almost does not emit harmful wastes into the environment. The main tailings are $(NH_4)_2SO_4$ which can be recovered as a by-product.

The production of basic zinc carbonate by precipitation method using zinc sulfate and ammonium bicarbonate solutions is preferable on industrial scale. In the framework of this project, basic zinc carbonate was produced by using zinc-containing waste material as a by-product of the zinc oxide production by reduction-oxidation process. The technological process for basic zinc carbonate consists of the stages such as: zinc dissolution by sulfuric acid, purification of zinc sulfate solution, precipitation of basic zinc carbonate, filtration of precipitate and drying the product. The zinc-containing material is dissolved with sulfuric acid (the solution has Zn concentration 100-120g/l). The impurities such as Fe, Mn were removed from the solution by hydrolysis precipitation (adjust the pH of the solution from 5-5.5 and use $H_2O_2$ as oxidizing agent). The impurities (Pb, Cd, Cu) were separated from the solution by cementation method by using metallic zinc powder. The purified zinc sulfate solution has a high purity (zinc

content 100-120g/l, the impurities such as Pb, Cu, Mn, Cd, Fe in trace amount) was supplied to basic zinc carbonate precipitation by using ammonium bicarbonate solution as a precipitating agent.

Basic zinc carbonate precipitation process was conducted by gradually introducing ammonium bicarbonate solution into zinc sulfate solution. The optimal molar ratio $NH_4HCO_3/ZnSO_4$ was 1.10 at room temperature. The optimal concentration of zinc sulfate solution was 150 - 200g/l, the concentration of ammonium bicarbonate solution was 250-300g/l and the reaction time was 60 mins. The solution obtained after precipitation of basic zinc carbonate contains about 11% ammonium sulfate with pH 7.3 - 7.8. This solution is neutralized to pH 5.5 - 6.0 by using sulfuric acid 5% for removing the excess of ammonium bi-carbonate, then it is concentrated to ammonium sulfate concentration of 40% and transferred to a crystallization tank with mixing and allowed to cool to room temperature. An amount of ethyl alcohol with the same weight of ammonium sulfate solution is added to crystallize the ammonium sulfate. The obtained ammonium sulfate crystals are washed with 96° ethyl alcohol and dried. The obtained product has a content of 99% of ammonium sulfate. The yield of recovery was around 93 - 95%.

The production line was built as described in the below figure.




| | |
|---|---|
| 1 | Zinc leaching |
| 2 | Press filter |
| 3 | Zinc sulfate leaaching solution |
| 4.1 | Zinc sulfate purified solution |
| 4.2 | Ammonium bicarbonate solution |
| 5 | Ammonium bicarbonate dissolving |
| 6 | Precipitator |
| 7 | Press filter |
| 8 | Dryer |

**The installed equipment for trial production of basic zinc carbonate**

The installed production line for basic zinc carbonate consists of:

- 02 zinc leaching tanks, capacity 2x2m$^3$
- 02 precipitators, capacity 2x5m$^3$
- 01 reactor with mixer for zinc sulfate purification.
- 01 mixing tank for ammonium bicarbonate dissolution
- 01 press filter with capacity of 564 kg/batch.
- 01 rotary drum dryer with moisture evaporation capacity of 100kg/h.

In addition, the auxiliary systems such as storage tanks, feeding heating systems is also installed.

After setting up the technological process and equipment system, 6 trial batches were carried out to testing the equipment system, re-test the technology process and train the

operator. The technology parameters are shown in Table 1. The product quality was characterized by chemical analysis and XRD, DTA-TG.

**Table 1.** The trial production of basic zinc carbonate

| Batch No. | Reagents | | | Reaction time, h | Basic zinc carbonate, kg | Product specs., % | | |
|---|---|---|---|---|---|---|---|---|
| | $ZnSO_4$, l | $NH_4HCO_3$, kg | Water, l | | | Zn | Pb | $SO_4^{2-}$ |
| 1 | 2000 | 500 | 2500 | 4 | 370 | 55.1 | 0.03 | 1.2 |
| 2 | 2000 | 500 | 2500 | 4 | 375 | 55.7 | 0.02 | 0.8 |
| 3 | 2000 | 500 | 2500 | 3 | 365 | 56.2 | 0.03 | 0.5 |
| 4 | 2000 | 500 | 2500 | 3 | 370 | 56.5 | 0.03 | 0.5 |
| 5 | 2000 | 500 | 2500 | 3 | 360 | 57.1 | 0.03 | 0.5 |
| 6 | 2000 | 500 | 2500 | 3 | 350 | 57.5 | 0.03 | 0.2 |

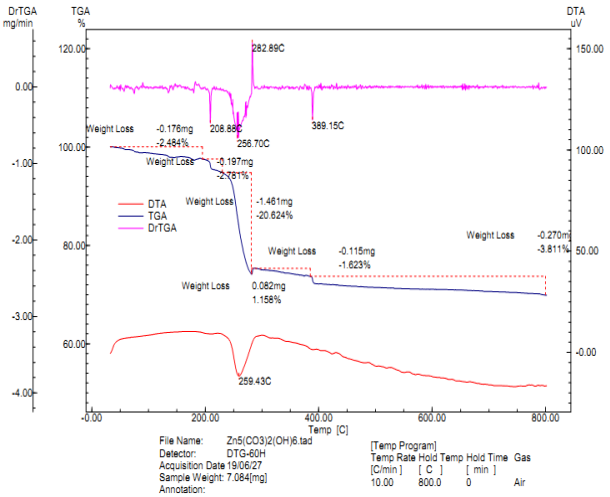



**Figure 1.** TGA- DGA of basic zinc carbonate product

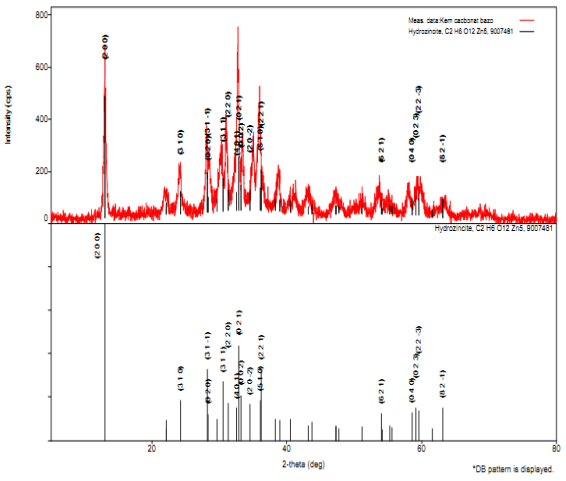



**Figure 2.** XRD of of basic zinc carbonate product

In the project, a chemical precipitation process has been thoroughly studied for the synthesis of basic zinc carbonate. By introducing ammonium bicarbonate solution of 200-250 g/L into zinc sulfate solution of 150 g/l $ZnSO_4$ at room temperature, the molar ratio $NH_4HCO_3/ZnSO_4$ = 1.1, reaction time 3-4h, the obtained basic zinc carbonate precipitate met

the quality requirements such as zinc content Zn >57%, $SO_4^{2-}$ ≤ 0.8%, Pb ≤ 0.08% with the zinc recovery up to 97 - 98%. A production line for zinc carbonate with a capacity of 150 tons/year has been built, 75 tons of basic zinc carbonate has been produced with a quality fully met the technical requirements such as chemical composition, particle size, and moisture content.

In addition, the process for recovery of ammonium sulfate as a by-product with the purity of 98% by crystallization in ethyl alcohol was also successfully studied.

# STUDY ON BUILDING THE QUALITY MANAGEMENT SYSTEM FOR THE LABORATORY IN ACCORDANCE WITH ISO/IEC 17025 TO OBTAIN THE CERTIFICATE OF ELIGIBILITY FOR ENVIRONMENTAL MONITORING SERVICES

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**Project information**:

- **Project name: Study on building a quality management system for the laboratory in accordance with ISO/IEC 17025 standard to obtain the certificate of eligibility for environmental monitoring services**
- **Code: DTCB.09/18/VCNXH**
- **Managerial level: Ministry**
- **Implementation time: 30 months (Jan 2018 - June 2020)**
- **Contact email: nguyentkdz91@gmail.com**
- **Published papers related to the project:**

1. Nguyen Thi Kim Dung, Le Quoc Viet, Ngo Quang Huy, Doan Thanh Son, Nguyen Nho Lan, Nguyen Thi Hang, Nguyen Thi Lien, Nguyen Thi Men, Do Thi Anh Tuyet "Some recently studied results on environmental Radioactivity and heavy elements content in Rare earth mine area at Dong-Pao, Lai-Chau" reported in the 13rd Conference of Nuclear Science and Technology, Halong 7-9, Aug. 2019 *(in English)*
2. Nguyen Thi Kim Dung, Nguyen Thi Men, Nguyen Thi Lien (2019) "Study on determining of the Li isotopic ratio in geological water samples using inductively coupled plasma mass spectrometry (ICP-MS)", *Journal of Analytical Sciences, Vol.* 24, No.3, 137-143, *ISSN-0868-3224 (in English).*

Laboratory of Center for Analytical Chemistry-CACE (belonging to the Institute for Technology of Radioactive and Rare Elements-ITRRE) has been accredited by Bureau of Accreditation (BoA) on the base of ISO/IEC 17025:2005 from October 2011 as VILAS 524 consisting of 20 standard test methods, and re-accredited according to new version of ISO/IEC 17025:2017 from May 2020. However, there are only 6 of 20 accredited procedures concerning the environmental tests: (I) estimation of the gross alpha activity in water samples according to TCVN 6053:2011, (II) estimation of the gross beta activity in water samples according to TCVN 6219:2011, (III) quantification of some natural radioactive nuclides in water samples according to TCVN 7175:2011, (IV) quantifying some natural radioactive nuclides in soil samples according to TCVN 9420:2012, (V) analysis of 05 anions in the water samples according to TCVN 6494-1:2011 and (VI) determination of the heavy metal ions in water

according to ASTM D5673:2016; therefore, the capability of the environmental monitoring service of this laboratory did not supply the demand of customers in the environmental field of mining, ore processing, material production, etc. Furthermore, the Vietnam Environment Administration-VEA (belonging to Ministry of Natural Resources and Environment-MONRE) on the basic of the Vietnam Environment protection Law has a right to issue the certificate of eligibility for environmental monitoring services (VIMCERTS) to the organizations, in which the quality management system of the laboratory complies with ISO/IEC 17025:2017 standard and the technical capability meets the requirements assigned by 24/2017/TT-BTNMT Circulars under 127/2014/NĐ-CP Decree. In order to improve the capability of Lab. of CACE in ITRRE for implementing the environmental monitoring service, the ministerial project entitled "*Study on building a quality management system for the laboratory in accordance with ISO/IEC 17025 standard to obtain the certificate of eligibility for environmental monitoring services*" was granted by the VINATOM.

The capability profile on environmental monitoring and analysis according to 127/2014/NĐ-CP Decree and later instructed by 19/2015/TT-BTNMT Circulars was established and submitted to the VEA. The capability profile consisted of two parts: (i) the profile of laboratory management system complying ISO/IEC 17025:2017 standard together with the quality manual, procedures system, and quality management forms; and (ii) the technical profile of approved test methods by the laboratory. The profile of laboratory management contained (a) the staff list with their specific working experience's duration and their educational certificates, (b) the list of equipment accompanied the test methods together with their instrumental calibration certificates, and (c) the diagram of the laboratory. The technical profile of test methods consisted of the applied standards, the standard operating procedure (SOP), and the reports on the validation of the testing method for the approval together with the originally obtained data.

21 SOPs of the environmental analysis on site and in the laboratory, which covered the various objectives such as air, soil, water, the environment affected by the radioactive factors, hazardous waste was experimentally established, validated according to the guideline of 24/2017/TT-BTNMT Circulars and approved by the Laboratory of CACE in accordance with ISO/IEC 17025:2017. The list of approved SOPs was as the following.

- Sampling, preservation and handling of surface water samples according to TCVN 6663-6:2018;
- Sampling, preservation and handling of waste water according to TCVN 5999:1995;
- Sampling, preservation and handling of soil samples according to TCVN 7538-2:2005;
- Measurement of the turbidity in surface water, underground water, waste water on site according to SMEWW 2130B:2017, the limit of detection LOD = 0,019NTU;
- Determination of metal ions (As, Cd, Cr, Cu, Pb, Mn, Ni, Zn) in surface water, underground water, waste water according to US EPA Method 200.8, the method detection limit for each element MDL is 0,584; 0,711; 0,595; 1,317; 0,589; 0,607; 0,614; 1,012 µg/L, respectively;

- Analysis of 06 heavy metals (As, Cd, Cr, Cu, Pb, Zn) in environmental soil samples according to US EPA Method 200.8, the method detection limit for each element MDL is 0,202; 0,407; 0,303; 0,388; 0,259; 0,385 mg/kg, respectively;

- Analysis of 8 heavy metals (As, Ba, Cd, Pb, Zn, Ni, Se, V) in solid waste (the absolute content) according to TCVN 8963:2011 and US EPA Method 200.8, the method detection limit for each element MDL is 0,812; 0,940; 0,451; 0,606; 0,504; 0,511; 0,691; 0,418 mg/kg, respectively;

- Measurement of Rn activity in soil sample on site according to TCVN 9416:2012 (the minimum detection concentration MDC = 0,1pCi/L);

- Measurement of Rn activity in air sample on site according to TCVN 9416:2012 (the minimum detection concentration MDC = 0,1pCi/L);

- Measurement of gamma dose in air sample on site according to TCVN 9414:2012 (the minimum detection concentration MDC = 0,01μSv/h);

- Determination of dissolved oxygen in surface water, underground water, waste water using multi-functionally electrochemical instrument in the laboratory according to TCVN 7325:2016 (the minimum detection concentration MDC = 0,01mg/L);

- Determination of ammonium concentration in surface water, underground water, waste water using Ion Selected Electrode instrument in the laboratory (LOD = 0,7 mg/L);

- Measurement of Rn activity in water sample on site according to TCVN 9614:2012 (the minimum detection concentration MDC = 0,1pCi/L);

- Measurement of NOx and $H_2S$ contents on site using Optima 7 instrument (MDC= 0,01 ppm);

- Measurement of COx và $SO_2$ contents on site using Optima 7 instrument according to TCVN 7725:2007 ($CO_x$) and TCVN 7726:2007 ($SO_2$) (MDC = 0,01 ppm);

- Analysis of dust, PM10, PM2.5, TSP in air sample on site using CEL712 MICRODUSTPRO instrument according to TCVN 5977:2005 (MDC = 0,001mg/$m^3$);

- Analysis of radionuclides in solid waste (industrial, hazardous waste) using gamma spectrometry according to TCVN 9420:2012 (MDL is 0,43; 0,42; 0,31; 3,18; 0,44 Bq/kg corresponding to $^{238}U$, $^{226}Ra$, $^{235}U$, $^{40}K$, $^{232}Th$, respectively);

- Determination of temperature according to SMEWW 2550B:2017 (LOD = 0,01$^oC$), pH according to TCVN 6492:2011 (LOD = 0,01pH) in surface water, underground water, waste water on site;

- Determination of 8 chemical parameters: Alkalinity (SMEWW 2320B:2017), Acidity (SMEWW 2310B: 2017), Conductivity (SMEWW 2510B:2017), Total Dissolved Substance-TDS (SMEWW 2540C:2017), Total Suspended Substance-TSS (SMEWW 2540C:2017), Total Hardness (SMEWW 2340C:2017), Permanganate Index (TCVN 6186:1996), Chemical Oxygen Demand-COD (SMEWW 5220C:2012) in surface water, underground water, waste water in the laboratory;

- Determination of exchangeable P in environmental soil samples according to TCVN 5256:2009 (MDL = 0,1 mg $P_2O_5$/kg);

- Determination of exchangeable K in environmental soil samples according to TCVN 5254:1990 (MDL = 6,9 mg $K_2O$/kg);

The laboratory participated in the IAEA proficiency tests (IAEA-TEL-2018-03, IAEA-TEL-2019-03 World wide open proficiency test exercise) on the determination of natural radionuclides and gross alpha, beta in water, soil samples with the results as 85% data accepted with Z-score of $\pm$ 2 range. The inter-laboratory test with the North Center for environmental monitoring-CEM (belonging to VEA) was carried out on the determination of 8 metal ions in waste water matrix in the year 2019 with 100% data was accepted.

5 accredited procedures of VILAS 524 (No.I-V) was re-validated (MDL of the test methods I and II is 0,02 và 0,03 Bq/L, respectively; MDL of the test method III is 2,27; 0,41; 3,45 Bq/L corresponding to $^{40}K$, $^{226}Ra$, $^{232}Th$, respectively; MDL of the test method IV is 6,71; 0,34; 5,36; 1,11; 0,43; 0,55; 0,55; 0,29 Bq/kg corresponding to $^{40}K$, $^{137}Cs$, $^{226}Ra$, $^{228}Ac$, $^{212}Pb$, $^{214}Pb$, $^{214}Bi$, $^{208}Tl$, respectively; MDL of the test method V is 0,014; 0,048; 0,078; 0,074; 0,072 mg/L corresponding to $F^-$, $Cl^-$, $NO_3^-$, $PO_4^{3-}$, $SO_4^{2-}$, respectively, and 10 approved SOPs (1-10) in the above list were selected for the registration in the testing capability profile due to the strict requirements on the qualified performance of accompanied equipment for the test methods according to 24/2017/ BTNMT Circulars.

The audit delegation from VEA evaluated the compliance level of the procedures, profiles and testing capability of the laboratory on 15 approved test methods at ITRRE on 29$^{th}$ of July, 2020. However, the SOPs of the nuclear analytical techniques were not audited due to the newest regulations (2020) from VEA, except for that of Alpha and Beta Activity analysis. Hence, the list of the audited test method, which needed to take the reparative action was 7 SOPs (No.1-3, 5-7, V) besides 3 accepted SOPs (No.4, I and II) for accreditation. The meeting of expertise on the reparative profiles was organized at the headquarters of VEA on November 13$^{th}$ 2020 and 3 SOPs (No.1-3) of 7 were accepted for accreditation but 4 remained SOPs were further required to complete the quality documentation and the technical profile. The additional experiments were carried out and the completed technical profile was sent to the audit delegation on November, 20$^{th}$ 2020. The VEA considered the whole profiles and issued the certificate of eligibility for environmental monitoring services to ITRRE on January 5$^{th}$ 2021 with the code VIMCERTS 274

The quality management system for environmental monitoring and analysis with the quality management profile and technical profile of testing methods have been built at the laboratory of the CACE, ITRRE. The products of this project included a test method profile with 15 SOPs (87 parameters) approved by the leader of the CACE in accordance with ISO/IEC17025:2017, and the certificate of eligibility for environmental monitoring services VIMCERTS 274 has been issued by the VEA (the type II product) beside of the type III products (a published article in the journal of Analytical Sciences in English, a poster presentation in VINANST-13, and a successfully defended Master thesis).

# STUDY ON TECHNOLOGY FOR PREPARATION OF DYSPROSIUM METAL FROM THE OXIDE BY METALLOTHERMIC REDUCTION METHOD

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**Project information:**

- **Project name: "Study on technology for preparation of Dysprosium metal from the oxide by metallothermic reduction method"**
- **Code: DTCB.11/19/VCNXH**
- **Managerial level: Ministry**
- **Implementation time: 24 months (Jan 2019 - Dec 2020), extended six months, by 30 Jun. 2021**
- **Contact email: nthungvaec@gmail.com**
- **Published papers related to the project:**

1. Nguyen Trong Hung, Le Ba Thuan, Nguyen Thanh Thuy, Nguyen Van Tung, et al. (2020) "Optimization of sulfuric acid leaching of a Vietnamese rare earth concentrate", Hydrometallurgy 191, 105195.
2. Trong Hung Nguyen, Ba Thuan Le, Thanh Thuy Nguyen (2021), "Study on the fluorination of dysprosium oxide by ammonium bifluoride for the preparation of dysprosium fluoride", Vietnam Journal of Science, Technology and Engineering, MOST (Article in press).
3. Nguyen Trong Hung, Nguyen Thanh Thuy, Nguyen Van Tung (2019), "Study on the preparation and dehydration of rare earth fluoride salts for the rare earth metals processing" Proceeding of the 13th Conference on Nuclear Science and Technology, VINATOM, Ha Noi, Vietnam.
4. Trong Hung Nguyen, Ba Thuan Le, Thanh Thuy Nguyen (2021), "Study on calcinothermic reduction of dysprosium fluoride to prepare metalic dysprosium", Vietnam Journal of Science, Technology and Engineering, MOST (Article under review).
5. Nguyen Thanh Thuy, Nguyen Van Tung, Nguyen Trong Hung, Le Ba Thuan, et al. (2020) "Spectroscopic Studies of Mössbauer, Infrared, and Laser-InducedLuminescence for Classifying Rare-Earth Minerals Enriched in Iron-Rich Deposits", ACS Omega 5, 7096-7105.

Dysprosium (Dy) is one of the valuable heavy rare earth elements. It is one of the components of Terfenol-D ($\underline{Tb}_x\underline{Dy}_{1-x}\underline{Fe}_2$; x=~0.3), of high energy Nd-Fe-B ($Nd_{13.4-x}Dy_{0.2+x}Fe_{79.7}M_{0.4}B_6$; x=0-0.3; M is Al or Ga, Co, Cu) permanent magnets. Dysprosium, such as

most HREEs, is currently almost exclusively supplied by ion adsorption clays (IACs) and xenotime. Ben Den IAC and Yen Phu xenotime (Vietnam) have high Dy contents of 2.7 % và 3.1 %, respectively.

There are two main techniques to prepare rare earth metals, including molten salt electrolysis and metallothermic reduction. Both techniques used anhydrous chloride or fluoride rare earth salt as raw material. Metalic Dy is prepared by metalothermic reduction of dysprosium fluoride ($DyF_3$) or dysprosium chloride ($DyCl_3$), using calcium (Ca) or lithium (Li) as a reductant. This study carried out the metallic Dy preparation by calcinothermic reduction of $DyF_3$.

Dy compounds used in this study are pure dysprosium oxide ($Dy_2O_3$) and $DyCl_3$ solution, being a product from Yen Phu xenotime concentrate processing in Institute for Technology of Radioactive and Rare Elements (ITRRE); chemicals such as Ca, ammonium bifluoride ($NH_4HF_2$), hydrofluoric (HF) acid, etc. are pure ones.

Two vacuum tube furnaces were selt-made, one of these has a maximum operating temperature of 1000$^o$C that is used for the preparation of anhydrous $DyF_3$ and the other has a maximum operating temperature of 1600$^o$C that is used for calcinothermic reduction of $DyF_3$ and cast to prepare metallic Dy.

The studies on the preparation of anhydrous $DyF_3$ were implemented. Thermogravimetric analysis (TGA) and differential thermal analysis (DTA) using SETARAM Thermal Analyzer were used to determine the temperature arrange of the $Dy_2O_3$ fluorination by $NH_4HF_2$. Phase identification was analyzed by the XRD method using SIEMENS D5005 instrument. Element composition in the fluorinated samples was identified by the EDS method using the JEOL JSM-IT100LV instrument. A mixture of ammonium bifluoride with dysprosium oxide containing $NH_4HF_2$ and $Dy_2O_3$ in $Dy^{3+}/NH_4^+$ mole ratio of 1/3.5 was analyzed by DTA-TGA. The results indicated that the fluorination temperature is at more than 250$^o$C. Based on this mass variation let's assume that the fluorination can proceed through two following reactions:

$$Dy_2O_3 + 4NH_4HF_2 = 2DyF_3{\cdot}NH_4F + 2NH_3\uparrow + 3H_2O\uparrow$$

$$DyF_3{\cdot}NH_4F = DyF_3 + NH_4F\uparrow$$

Based on the thermal analysis, the fluorination temperature range was determined from 350 to 450$^o$C. So, the studies were carried out at these temperatures for 2h and 3h and results indicated that optimum parameters for the preparation of anhydrous $DyF_3$ were: fluorination temperature and time of 450$^o$C and 3h, respectively. Fig. 1 showed the EDS pattern of $DyF_3$.

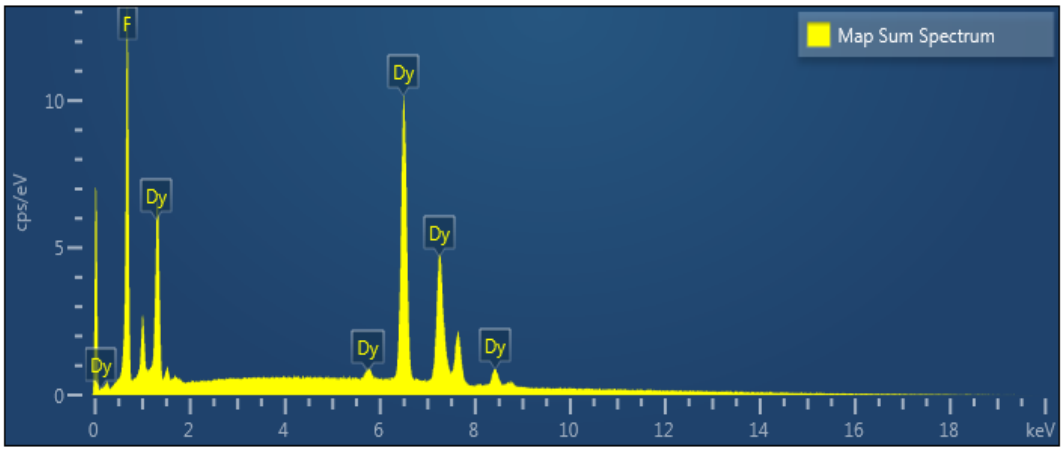



**Figure 1.** The EDS pattern of $DyF_3$.

The anhydrous $DyF_3$ is used as a material for the calcinothermic reduction to prepare the metallic Dy. The studies on the calcinothermic reduction were implemented. Three factors are affecting the calcinothermic reduction of $DyF_3$, including calcinothermic temperature and time, and the molar ratio of $Ca/DyF_3$. The response surface methodology (RSM) based on a central composite face-centered (CCF) design was empirically used to model the interactive effect of the independent variables on the dependent response. The calcinothermic reduction yield (Y, %) was considered the dependent response, and the temperature ($X_1$, $^oC$), $Ca/DyF_3$ molar ratio ($X_2$, mol/mol), and time ($X_3$, h) were considered independent variables (factors). The variables' levels in coded and actual values are presented in Table 1. The total number of required experimental runs was $2^k+2k+n_0=15$, where k is the number of factors (k=3) and $n_0$ is the number of replications at the center points ($n_0=1$). The experimental matrix in the planning experimental region is also presented in Table 1. The CCF regression model can be described in the form given in Eq. (1).

$$Y = b_0 + \sum_{i=1}^{k} b_i X_i + \sum_{i=1}^{k} b_{ii} X_i^2 + \sum_{i,j=1(i\neq j)}^{k} b_{ij} X_i X_j \,, \quad (1)$$

Where: Y is the dependent response;

$b_0$ is the constant coefficient; $b_i$, $b_{ii,}$ and $b_{ij}$ are the linear, quadratic, and interaction coefficients, respectively;

$X_i$ and $X_j$ are the coded values of the independent variables; $X_iX_j$ and $X_i^2$ represent the interaction and quadratic terms, respectively.

The experimental studies were determined the planning experimental region, including the temperature $X_1$ of 1400 – 1500$^o$C, $Ca/DyF_3$ molar ratio $X_2$ 1.95 – 2.25 and time $X_3$ 0.5 – 1h. The effects of the independent variables on the dependent response were studied based on a CCF design. The results of 15 experimental runs are presented in Table 1. The results were also entered into the MODDE 5.0 software to determine the model by multiple linear regressions. The final calculated equation for the calcinothermic reduction of $DyF_3$ to prepare metallic Dy is:

$$Y=84,34+2,21X_1+2,95X_2+1,22X_3-3,47X_1^2-1,97X_2^2-0,62X_3^2+0,11X_1X_2-0,01X_1X_3-0,39X_2X_3 \quad (2)$$

**Table 1.** Central composite rotatable design arrangement and results

| Run | Independent variables ($X_i$) | | | | | | Responses (Y) | |
|---|---|---|---|---|---|---|---|---|
| | Coded levels | | | Real values | | | Experimental in % | Calculated in % |
| | $X_1$ | $X_2$ | $X_3$ | $X_1$ | $X_2$ | $X_3$ | | |
| 1 | -1 | -1 | -1 | 1400 | 1.95 | 0.5 | 71.4 | 71.60359 |
| 2 | 1 | -1 | -1 | 1500 | 1.95 | 0.5 | 75.3 | 75.82360 |
| 3 | -1 | 1 | -1 | 1400 | 2.25 | 0.5 | 78.1 | 78.05364 |
| 4 | 1 | 1 | -1 | 1500 | 2.25 | 0.5 | 82.7 | 82.72362 |
| 5 | -1 | -1 | 1 | 1400 | 1.95 | 1 | 74.8 | 74.84360 |
| 6 | 1 | -1 | 1 | 1500 | 1.95 | 1 | 78.9 | 79.01362 |
| 7 | -1 | 1 | 1 | 1400 | 2.25 | 1 | 80.2 | 79.74362 |
| 8 | 1 | 1 | 1 | 1500 | 2.25 | 1 | 84.5 | 84.36361 |
| 9 | -1 | 0 | 0 | 1400 | 2.1 | 0.75 | 78.4 | 78.65558 |
| 10 | 1 | 0 | 0 | 1500 | 2.1 | 0.75 | 83.6 | 83.07558 |
| 11 | 0 | -1 | 0 | 1450 | 1.95 | 0.75 | 80.3 | 79.41556 |
| 12 | 0 | 1 | 0 | 1450 | 2.25 | 0.75 | 84.7 | 85.31558 |
| 13 | 0 | 0 | -1 | 1450 | 2.1 | 0.5 | 83.2 | 82.49556 |
| 14 | 0 | 0 | 1 | 1450 | 2.1 | 1 | 84.5 | 84.93556 |
| 15 | 0 | 0 | 0 | 1450 | 2.1 | 0.75 | 83.8 | 84.33780 |

Based on the proposed model (Eq. 2) and considering the energy consumption, low chemical consumption, further waste treatment, and better calcinothermic reduction yield, the factors affecting the calcinothermic reduction of $DyF_3$ were optimized as follows: the reduction temperature and time are 1450-1460$^o$C and 50 min., respectively, and the Ca/$DyF_3$ molar ratio is 2.15. The purity of metallic Dy product obtained from the above calcinothermic reduction is 90%; so the cast processes need to be done to obtain the product of high purity $\geq$ 95%. The experimental studies on the effect of factors, namely content of melting support $CaCl_2$ and, temperature and time, on the casting process, were implemented and the results have shown that the optimum parameters for the casting process are: content of melting supporting $CaCl_2$ of 5-6 wt.% and, temperature and time of 1460-1500$^o$C and 60 min.

Thus, a technique for the metallic Dy preparation from the oxide was established from the above results; and 1000g of ≥95% metallic Dy was prepared from the oxide.

# 2.9. COMPUTATION AND OTHER RELATED TOPICS

# STUDY OF THE COMPARTMENT MODELING METHOD ON THE BASIC NON-REACTIVE TANK

**Tran Trong Hieu, Huynh Thi Thu Huong, Nguyen Huu Quang**

*Centre for Applications of Nuclear Technique in Industry (CANTI), 01 DT 723, ward 12, Dalat city, Lamdong province*

**Project information:**

- **Project name: Study of the compartment modeling method on the basic non-reactive tank.**
- **Code: CS/20/06-02**
- **Managerial level: Institute**
- **Implementation time: 12 months**
- **Contact email: hieutt@canti.vn**
- **Published papers related to the project:**

1. Tran Trong Hieu, Huynh Thi Thu Huong, Nguyen Thanh Chau, Le Van Son. Approaching the compartmental model based on CFD simulation combined with RTD analysis to describe flow behavior in a basic tank. Nuclear Science and Technology conference for young scientists. (In Vietnamese).

The tanks are widely used in many industrial fields such as wastewater treatment, aquaculture, or mixing multi-phase processes. Understanding the characteristics of flow in a tank including bypass zone, mixing zone and dead zone with the parameters such as mean velocity, mean residence time and volume has an importance in controlling the optimal operation of the system. Two conventional methods are used to describe the flow of a closed tank including computational flow dynamics (CFD) and analysis of Residence Time Distribution (RTD). The CFD method based on numerically solving Navier – Stokes equations provides detailed velocity distribution in the system but often requires large computational times, and the analysis of the RTD method based on tracer test is simple to calculate but does not locate flow zones in the system. In recent years, Compartmental Model (CM) has been developing as an alternative approach to compromise the advantages of the RTD and CFD methods in localization of the basic flow models. In the CM method, the flow system is characterized by multiple compartments corresponding to the basic flow zones such as ideal mixing, plug flow, dead volume, etc. with the zoning criterion based on the velocity field of the system obtained from CFD. To initially approach the CM method, this research project established the CM model on the likely 2D, non-chemical reactive tank and determined the relationship between the compartment configuration and the system parameters.

Referring to the results of other researchers [1, 2, 3], the Project Team selected the 2D tank (ignored the velocity distribution according to z-direction) having the dimension of 100 cm (L) x 100 cm (W) x 10 cm (H) with one inlet and one outlet for experimenting. The tracer

experiment was conducted on the tank with the water flow of 4.5 L/minute, salt tracer NaCl was released at the inlet during 5 s with a volume of 0.5 L and concentration of 12.14 g/L. At the outlet, salt concentration C was observed by using conductivity sensor HANNA HI98197 (Romania) to determine the experimental retention time distribution curve.

The spatial velocity distribution and tracer response curve of the tank was calculated on the numerical model corresponding to the experimental parameters using FLUENT software (ANSYS ACADEMIC 2020R2, USA). The zoning program built on MATLAB 2014b software classified 3 main flow zones in the tank including convection flow zone (2 - 5.9 cm/s), cyclic flow zone (0.5 - 2 cm/s) and slow exchange zone (0 - 0.5 cm/s) as illustrated in Figure 1a. The parameters such as volume and exchange rate between zones calculated from Reference [4] were used to determine the CM model with the compartments corresponding to the basic flow zones determined by using Progepi RTD 4.2.1.0 software as illustrated in Figure 1b.

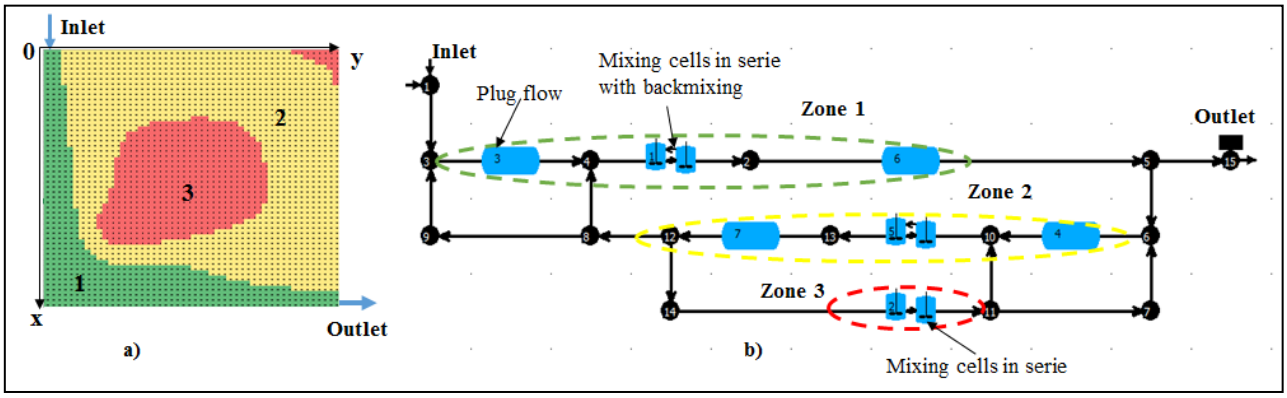



**Figure 1.** Zoning system (a) and CM model (b)

The results show that the tracer curve obtained from the CM model agrees with the figure obtained from CFD and experiment with the root-mean-square error below 0.1 ($RMSE_{CM\text{-}CFD}$ = 0.04 and $RMSE_{CM\ –\ experimental\ data}$ = 0.08) as depicted in Figure 2. The RMSE is used to measure the differences between two sets of data, particularly, the smaller the RMSE indicates the less difference between the two sets of data.

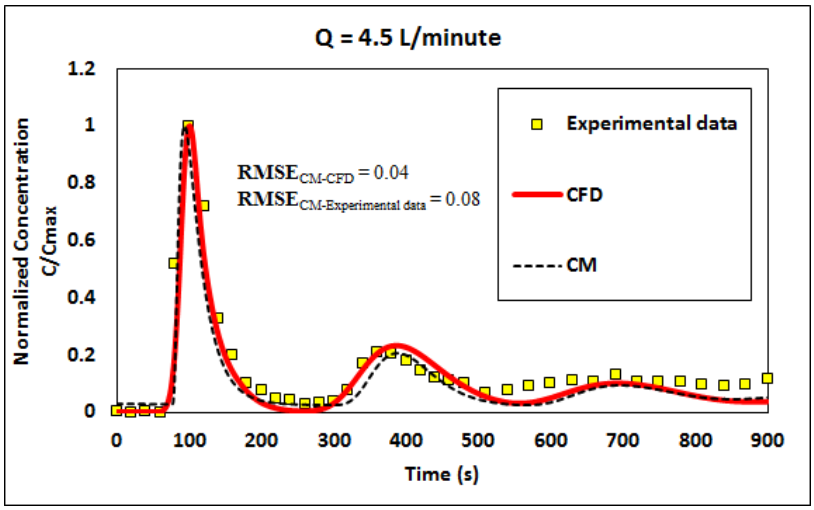



**Figure 2.** Tracer curves obtained from the numerical model and the CM model agree with the experimental curve ($RMSE_{CM\text{-}CFD}$ = 0.04 and $RMSE_{CM\ –\ experimental\ data}$ = 0.08).

In addition, testing a wide range of inlet flow on the CFD and CM model shows that the volume and exchange flow of the cyclic flow zone are proportional to the inflow. This is of particular importance in optimizing the tank's performance.

The obtained results obtained in this research work show that it is initially successful to approach the compartmental model on the basic non-reactive tank. The further study will focus on developing the method on stirred-tanks with reactions and a 3D tank.

## REFERENCES

[1] Alvarado et al, “A compartmental model to describe hydraulics in a full scale waste stabilization pond”, *Water Research 46*: 521-530. 2012.

[2] Bezzo, F., and S. Macchietto, “A General Methodology for Hybrid multizonal/CFD Models: Part II.” *Automatic Zoning Computation Chemical Engineering* 28: 513–525. 2004.

[3] Le Moullec et al, “Comparision of Symtemic, compartmental and CFD modelling approaches: Application to the simulation of the biological reactor of wastewater treatment”, *Chemical Engineering Sciences 65*: 343-350. 2010.

[4] Jérémie Haag et al, “Modelling of Chemical Reactors: From Symtemic approach to Compartmental modelling”, *International Journal of Chemical Reactors Engineering*, Vol 16, Issue 8, 20170172. 2018.

# RESEARCH ON BIODEGRABLE OF CHLORPYRIFOS BY AEROBIC ORGANISM FROM AGRICULTURAL SOIL IN LAM DONG

**Luong Thi Tham, Nguyen Thi Hong Tham, Nguyen Tien Dat, Dang Trung Tin, Ta Thi Tuyet Nhung, Nguyen Thuy Huong Trang**

*Center of Analytical Techniques, Nuclear Research Institute, 01 Nguyen Tu Luc, Ward 8, Da Lat City, Lam Dong Province*

**Project information**:

- **Project name: Luong Thi Tham**
- **Code: CS/20/01-01**
- **Managerial level: Institute**
- **Implementation time: 12 months (Jan 2020 - Dec 2020)**
- **Contact email: luongtham0710917@gmail.com**
- **Published papers related to the project:**

1. Luong Thi Tham, Nguyen Tien Dat, Nguyen Thi Hong Tham, Nguyen Thuy Huong Trang, Ta Thi Tuyet Nhung, Dang Trung Tin, Le Thanh Do, Ho Thanh Tam. Investigation of chlorpyrifos degradation by 3 aerobic bacteria strains from Soils in Da Lat city. DTU Journal of Science & Technology, Vol 6(43), (2020), (in Vietnamese).

Lam Dong is leading the country in high-tech agriculture. However, the overuse of pesticides, as well as their residues in soil and agricultural products is a concern today. Chlorpyrifos is a broad-spectrum organophosphate pesticide that is frequently used by farmers to kill a wide variety of insects. This pesticide was most mentioned for its health impacts on farmers who were mixing, transporting, and spraying chlorpyrifos. The application of bioremediation of pesticides has become one of the good solutions to treat pesticide residues in soil. Chlorpyrifos can be degraded by bacteria and fungi species found in the soil. However, the application of microorganisms for this purpose still has certain limitations due to the difficulty in selected chlorpyrifos-degrading strains. Isolation of indigenous bacteria strains to treat chlorpyrifos contaminated soil will be favorable because they are well adapted to the local conditions. Therefore, this study aimed to isolate indigenous aerobic bacteria strains that is effectively decompose chlorpyrifos in Lam Dong province.

In this study, we used MSM broth medium, supplemented with chlorpyrifos at a concentration of 20 ppm to increase the bacterium is capable of decomposing chlorpyrifos. Screening of the isolates was carried out based on colony morphology, then streaked on MSM agar to create pure colonies. For determining the degradation potential of bacterial strains, based on the residual CP concentration was determined by remaining in the culture medium by gas chromatography, then selected the bacterial strain with the decomposition rate above 50% of the chlorpyrifos content in the culture medium. The use of 16S rRNA gene

sequencing method was used to identify bacteria species fastest capable of decomposing chlorpyrifos.

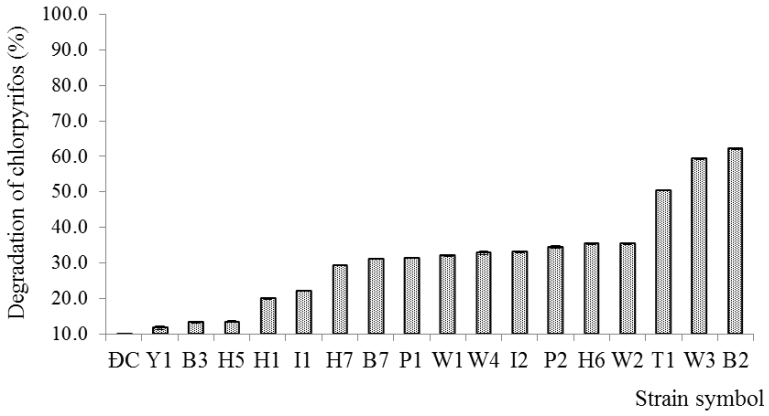



**Figure 1.** 17 bacteria strains were capable of degrading chlorpyrifos efficiently within 14 days in MSM + 20mg/L medium. ĐC: control sample (without bacteria strains)

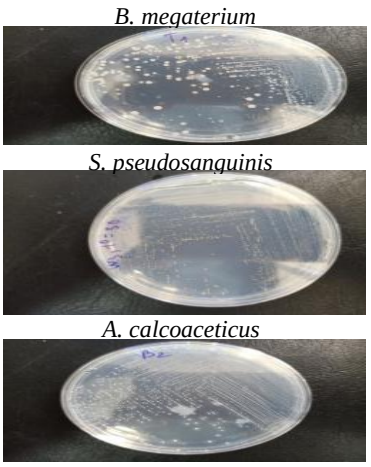



**Figure 2.** Colony morphology of T1, B2, and W3 strains isolated on MSM agar medium

After density enrichment and isolating bacteria degrading chlorpyrifos in MSM broth medium, from 21 soil samples total of 17 aerobic were isolated on MSM agar. Investigating the ability to decompose chlorpyrifos in MSM broth medium (adding chlorpyrifos to 20 ppm) of 17 aerobic strains, the initial density added to the culture medium was in the range of $10^5$ CFU/ml. Results of analyzing the remaining chlorpyrifos content in the medium after 14 days, we have selected 3 strains T1, W3, and B2 for the decomposition efficiency of over 50% of chlorpyrifos content in the culture medium (Fig.1, Fig.2). The growth and decomposition efficiency of chlorpyrifos of 3 bacteria strains reached optimal values in MSM broth at 30°C, pH = 7, the concentration of chlorpyrifos added in the medium 10 mg/L - 40 mg/L. These three strains were identified as *Bacillus megaterium, Sphingomonas pseudosanguims* and *Acinetobacter calcoaceticus*. Previous reports revealed on the biodegradation of chlorpyrifos showed that strains exhibited the ability to degrade chlorpyrifos in liquid culture medium will also be able to degrade chlorpyrifos in soil. In addition to the decomposition chlorpyrifos, *A. calcoaceticus* was also found for phosphate solubilizing, nitrogen fixation and biosynthesis of IAA under in vitro conditions. *Sphingomonas* sp. has an ability hydrolyzing chlorpyrifos to 3,5,6-trichloro-2-pyridinol (TCP).

It could also decompose parathion, parathion methyl, fenitrothion and profenofos. *B. megaterium* is well known for its role in stimulates the growth and prevent plant diseases.

Therefore, it is necessary to have more experiments investigating the ability to decompose other pesticides, biosynthesis of IAA, phosphate solubilizing, and nitrogen fixation, of 3 strains *Bacillus megaterium, Sphingomonas pseudosanguims* and *Acinetobacter calcoaceticus*. Then, research on producing microbial fertilizer to help treat pesticide residues in agricultural soil and stimulate the growth of the plant.

# 3- FOTOBOOK

## A Wrap-up of VINATOM significant events

## in 2020

## 3.1 - NUCLEAR RESEARCH INSTITUTE, DA LAT

I-131 solution production line meets WHO-GMP standards
at Dalat Nuclear Research Institute (DNRI)

Operating the freeze-dryer in KITs production at DNRI

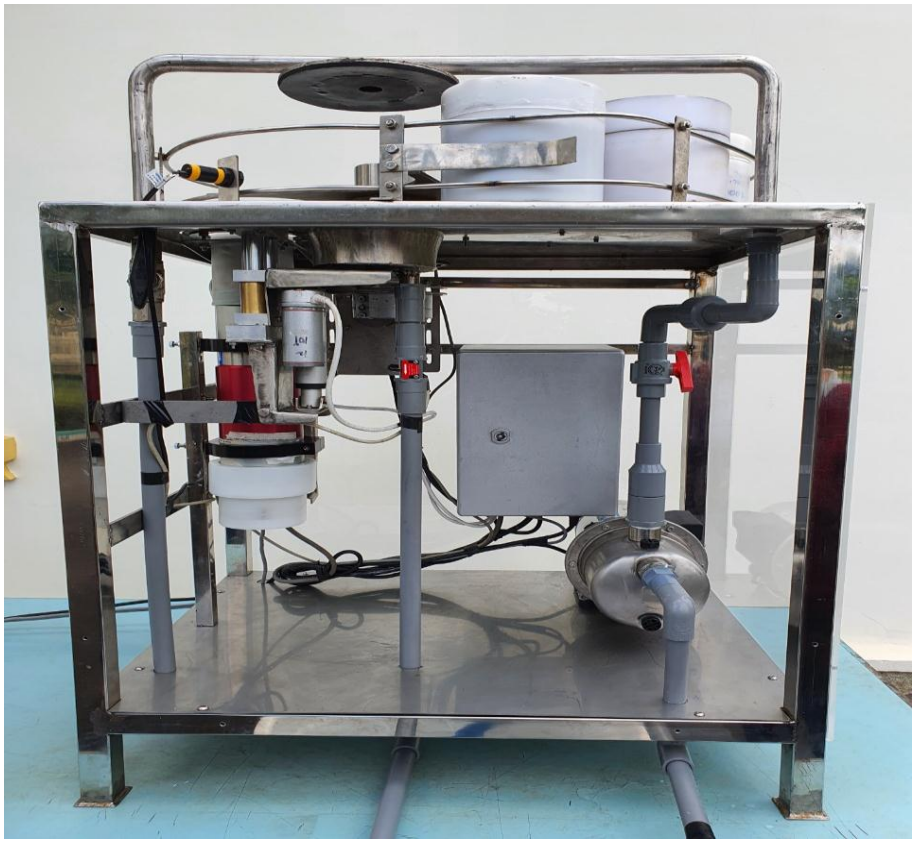
DNRI participating in the exercise on nuclear and radiological emergency response in Lam Dong Province


Lecturers and participants at the Training course: “Improving qualification for research reactor projects managers” at DNRI


Prof. Le Hong Khiem presented at the Workshop on new Research Reactor of Center for Nuclear and Science Technology held at DNRI (March 2021)

Delegates participated in the Workshop on new Research Reactor of Center for Nuclear and Science Technology at DNRI (March 2021)


Dr. Tran Chi Thanh presented certificates of merit to DNRI's scientists whose scientific works have been published in prestigious international journals

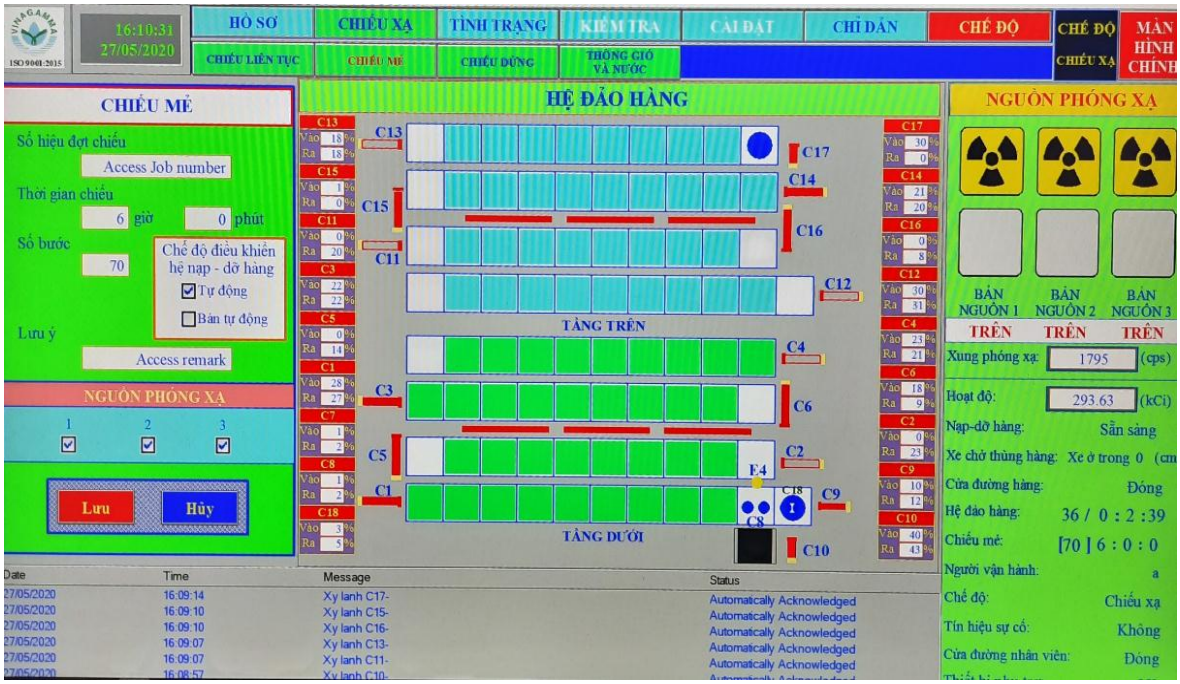


Automatic marine environmental monitoring and warning system (DNRI
(The product of State-level project KC.05.17/16-20 implemented by DNRI)

Digital gamma-gamma coincident spectrometer system, 4 channels 16K input
(The product of State-level Project KC05.08/16-20 implemented by DNRI)

## 3.2 - RESEARCH AND DEVELOPMENT CENTER FOR RADIATION TECHNOLOGY, HO CHI MINH CITY & DA NANG

Group photo of the Center's leaders and guests at its 20th Anniversary Celebration (14/02/2000 – 14/02/2020)




Software interface of new control system of SVST-Co60/B irradiator, replaced and put into operation since January 2020


The Board of Directors and local leaders gave gifts to support difficult situations affected by the Covid-19 epidemic (April 2020)

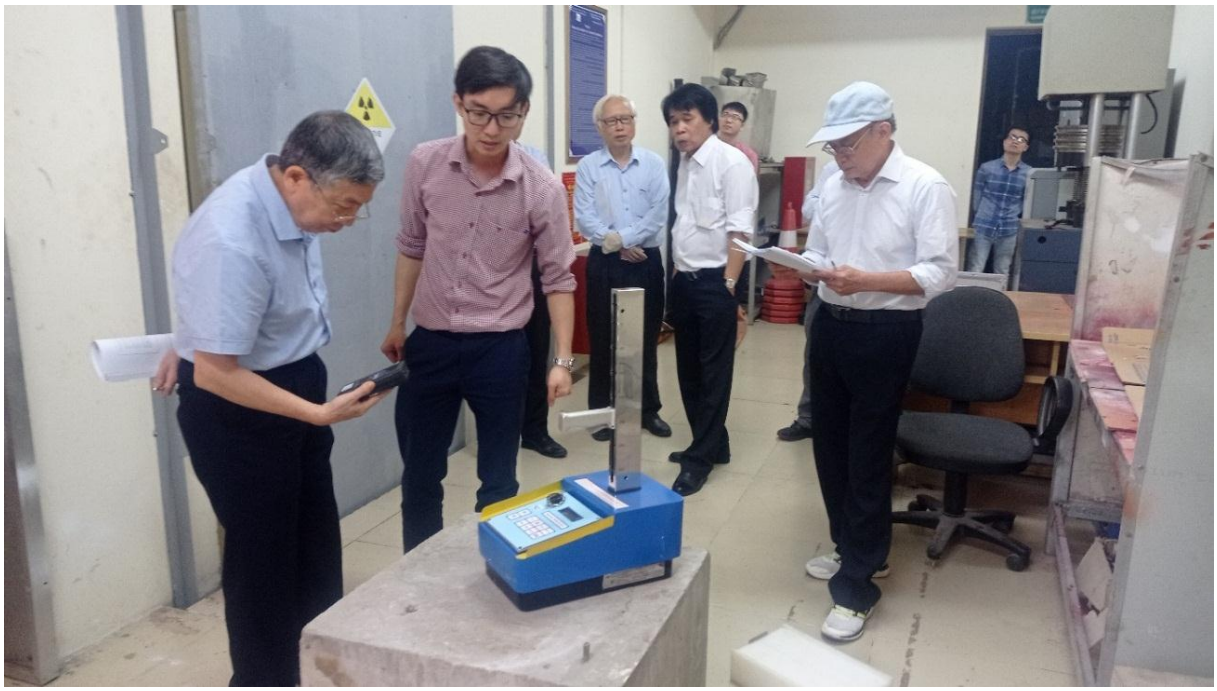

Delegates congratulated the success of the Center's Party Congress, the term 2020-2025 (May 2020)

Training on operating the industrial irradiation equipment (September 2020)

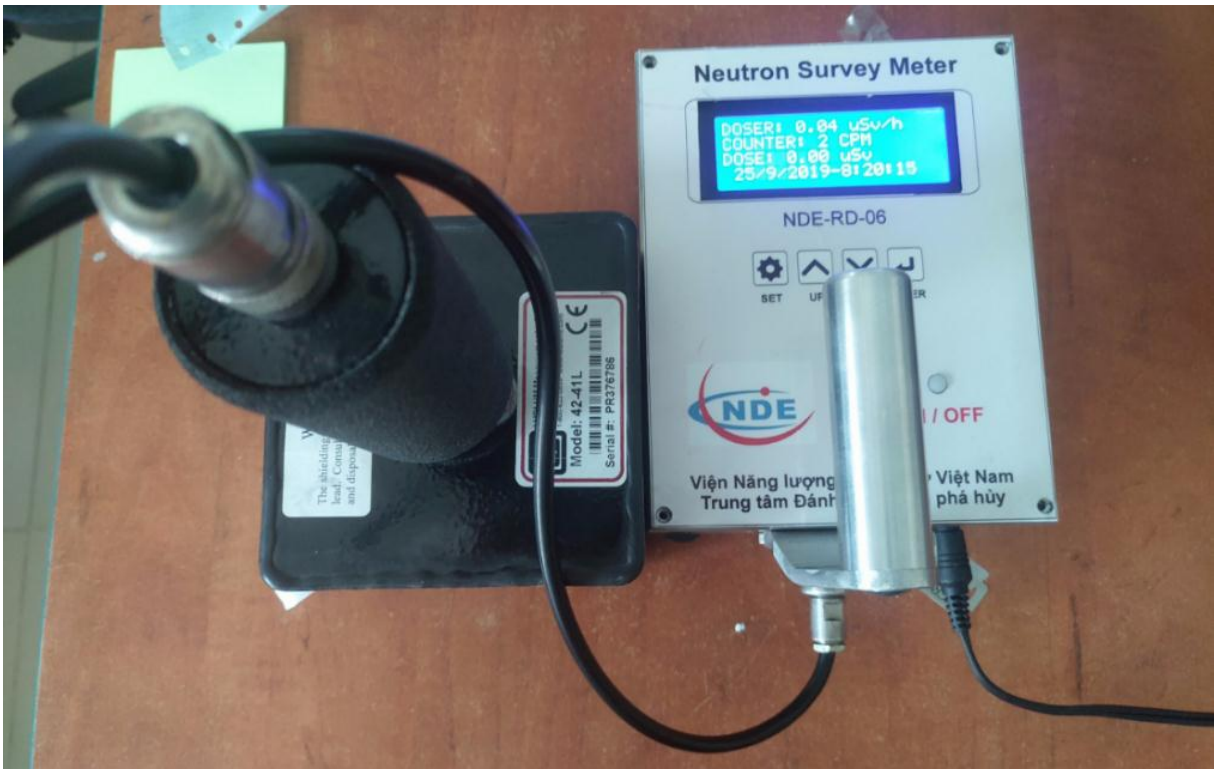

Scientific seminar on Irradiation method in fabrication of
modified Graphene oxide materials and applications (October 2020)

The Center joined hands to help people affected by floods and storms
in central provinces (Quang Tho, Quang Dien, Thua Thien Hue, October 2020)

## 3.3 - NON-DESTRUCTIVE EVALUATION CENTER, HA NOI

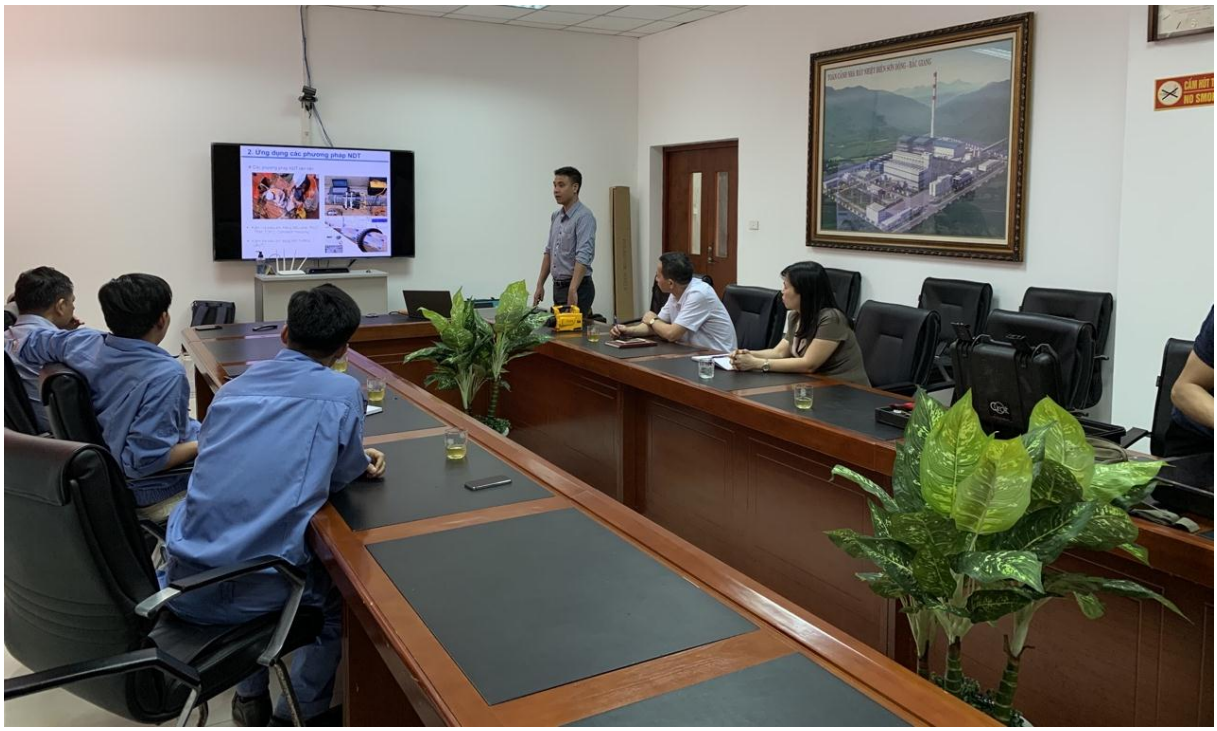


The expert group appraised the equipment measuring moisture and density in the project under the protocol NDT.41.LA/18




Neutron dosimeter device to control the dose of neutron radiation in industry in the Ministry-level project DTCB.02/17/TTNDE

Applying the results of the ministerial-level project 2019-2020 to carry out the inspection at Tien Hai gas distribution station of Hai Phong gas branch, Vietnam gas corporation



Applying the results of the ministerial-level project 2019-2020 to carry out the inspection at Son Dong Thermal Power Plant

Training course in the ministry-level project: "Building the quality system for training NDT technicians according to ISO 9001: 2015"


Attending the 4th National Nuclear Regulatory Conference for serving the institutional project in 2020 "Developing a training program on security of radioactive source in use, transportation and storage""

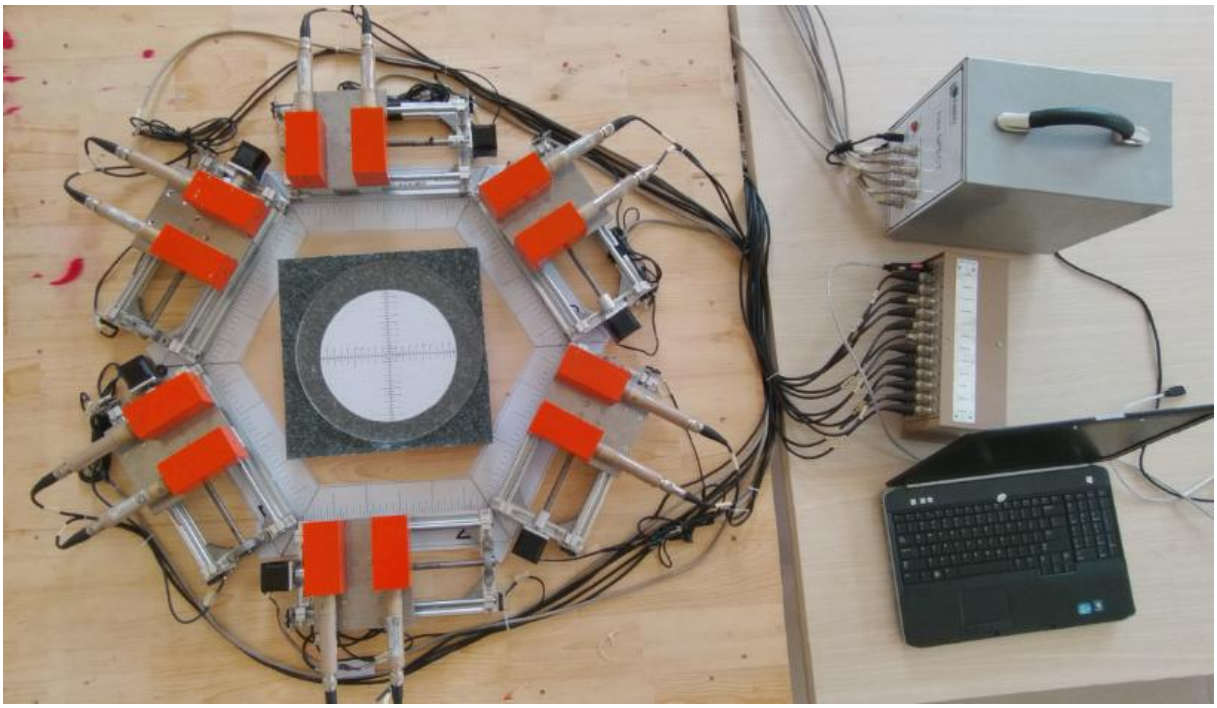
Attending the scientific conference of young researchers at
Vietnam Institute for Building Materials

NDT training for international organizations in Vietnam


Training on Advanced RT Method for Defense Industry Units


Guidance on non-destructive testing for the students of Hanoi University of Science and Technology

## 3.4 - CENTER FOR APPLICATION OF NUCLEAR TECHNIQUES IN INDUSTRY (CANTI), DA LAT



The configuration called HexSPECT to investigate objects with a maximum diameter of 200mm, a resolution of up to 2.6cm with a relative error of about 12%,the time for a slice from 20 to 30 seconds.

CANTI'S equipment on PTSC G&S's robots – CANTI & PTSC G&S's technician staff working offshore


Conducting research and manufacturing IMI gauges for detecting carbon steel in stainless welds

## 3.5 - NUCLEAR TRAINING CENTER, HA NOI


The Signing Ceremony of Memorandum of Understanding on cooperation in scientific research, application and training in the field of water resources among NTC, CANTI and CEVIWRPI – Da Lat, October 23, 2020

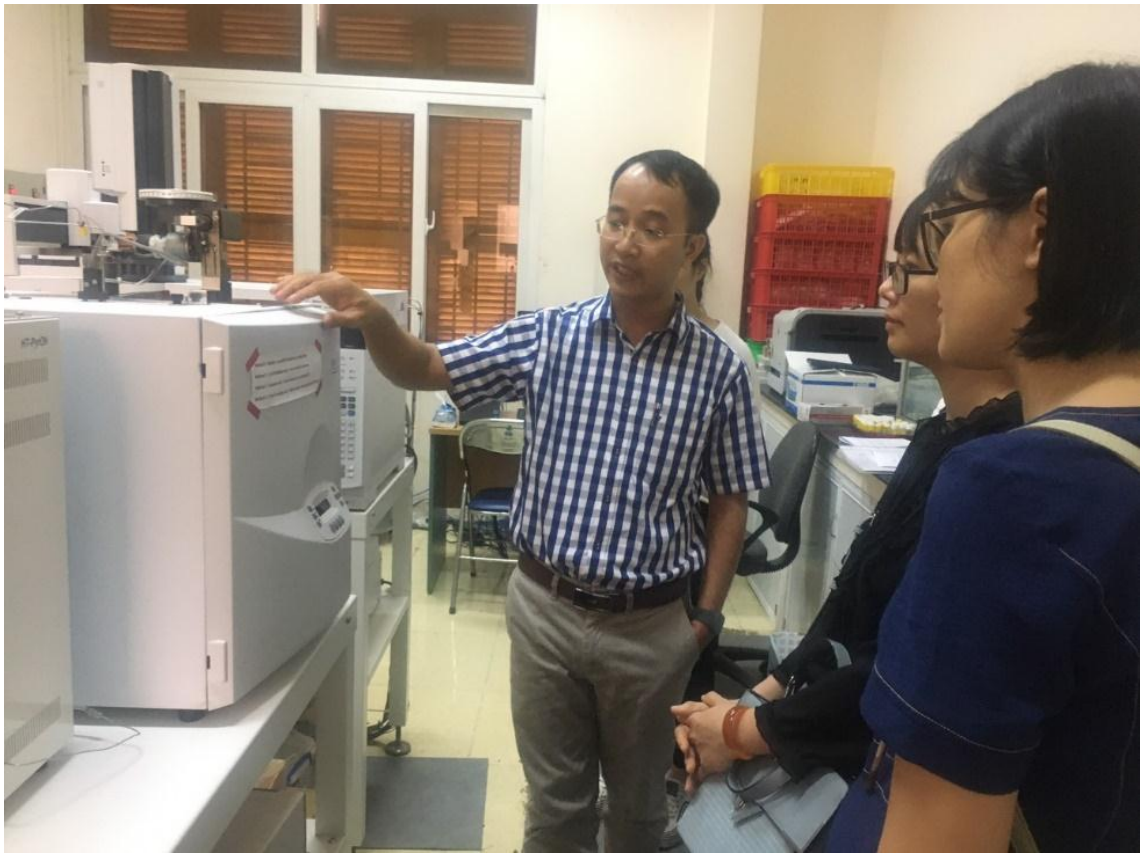

Graduation and PhD Award Ceremony in 2020 – January 17, 2020


(he defense ceremony of Institute-level PhD thesis of PhD student Dinh Tien Hung - Hanoi, December 19, 2020


The defense ceremony of Institute-level PhD thesis of PhD student Ho Van Doanh – Ho Chi Minh City, November 11, 2020


The defense ceremony of Institute-level PhD thesis of PhD student Pham Dang Quyet – Dalat, August 01, 2020


Organizing orientation internships and professional internships for University students in 2020



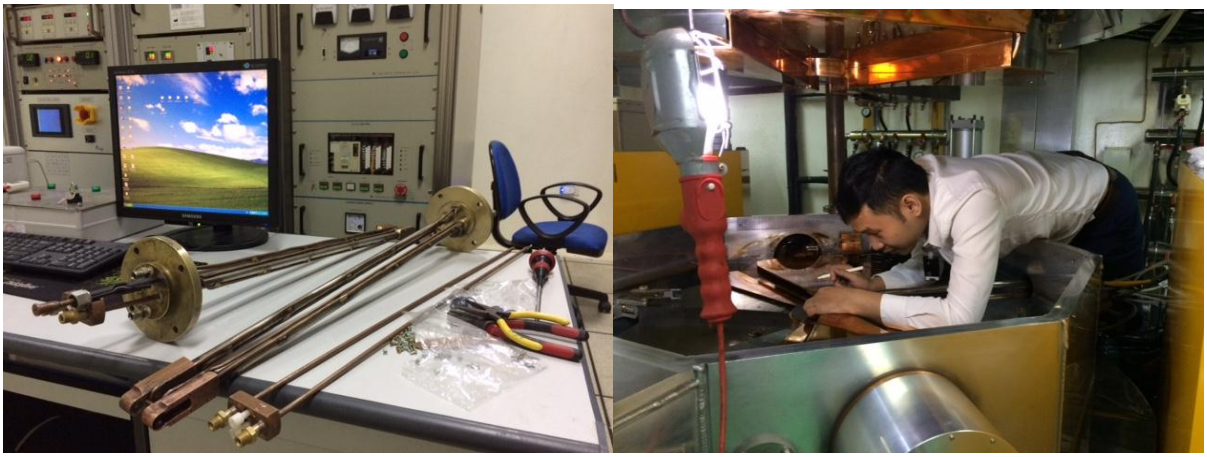
Training course on Application of isotope techniques in environmental and agricultural r esearch (Participants at Stable Isotope Laboratory, VNU University of Sciences) – Hanoi, September 28-October 2, 2020


Advanced Training course on Radiation measurement – November 16-20, 2020


Training Course on Advanced Non-Destructive Testing Methods from November 30 to December 04, 2020

## 3.6 - HANOI IRRADIATION CENTER

Maintenance and operation of the KOTRON-13 Accelerator

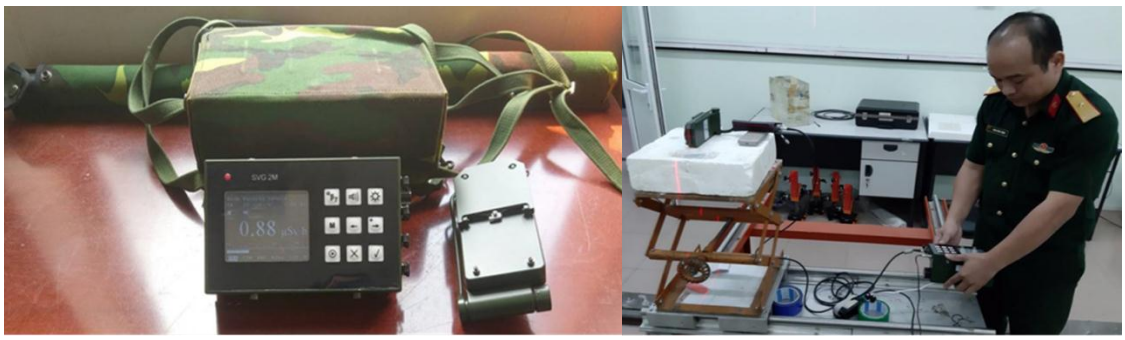


Manufacture and installation of an ion source for the KOTRON-13 Accelerator under a ministerial project


Manufacturing of 18F-NaF radiopharmaceutical production automatic module and preclinical test of 18F-NaF radiopharmaceutical produced at Hanoi Irradiation Center


Manufacture and installation of environmental radiation monitoring equipment in Lao Cai province under the KC05 project


Manufacturing and testing of the POCKET MCA multichannel analyzer under a project in cooperation with the Institute of Nuclear Science and Technology



Manufacturing and calibrating of the multi-purpose radiometric device under a project in collaboration with the Military Institute of Chemistry and Environment

Maintenance and repair of nuclear electronic equipment


Preparation of microbiological testing medium for setting standardized microbiology laboratory ISO 17025:2017 (The project of DTCB.01/21/TTCX)

Treating rice straw on paddy field using Trichoderma probiotic
(The project of DTCB.01/18/TTCX )

Cultivation of Cordyceps Militaris for extracting of radioprotector at Radiation Technology Research Laboratory - Hanoi Irradiation Centrer (The project of DTCS.01/20/TTCX)

Preparation of bead based biofertilizers
from Bacillus megaterium and radiation modified starch as carrier


Application of resulting products in production of vegetable at Hoai Duc, Ha Noi


Irradiation of fresh fruit for export

## 3.7 - INSTITUTE OF NUCLEAR SCIENCE AND TECHNOLOGY, HA NOI

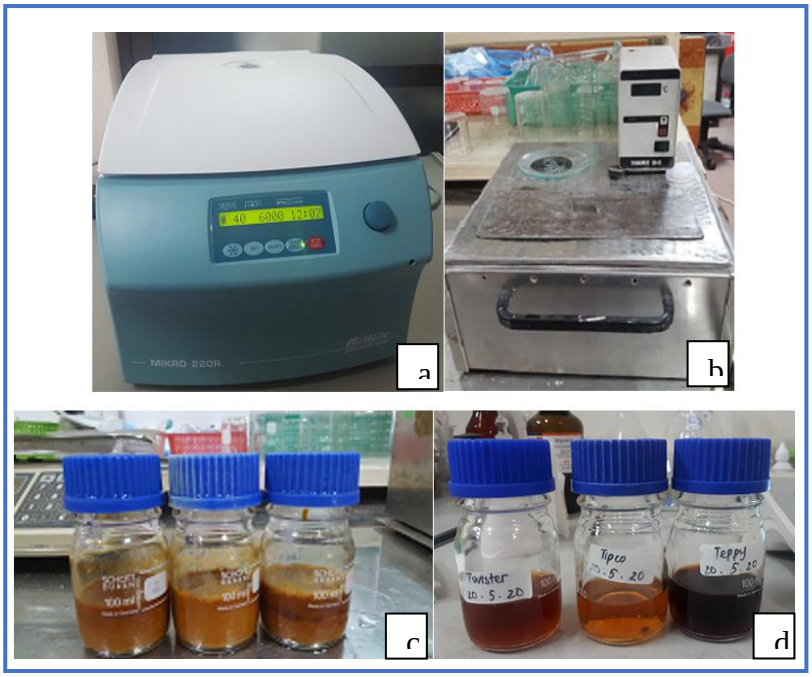

Radiation Safety Calibration of an Elekta Medical LINAC
(Image credit: Center for Radiation Protection, INST)


Radiation Safety Calibration of Varian TrueBeam LINAC
(Image credit: Center for Radiation Protection, INST)

Sampling in Ba Lat river, Nam Dinh province
(Image credit: Center for Environmental Radioactivity Monitoring and Impact Assessment, INST)

Setting up a sampling device at Co To Island (Image credit: Center for Environmental Radioactivity Monitoring and Impact Assessment, INST)

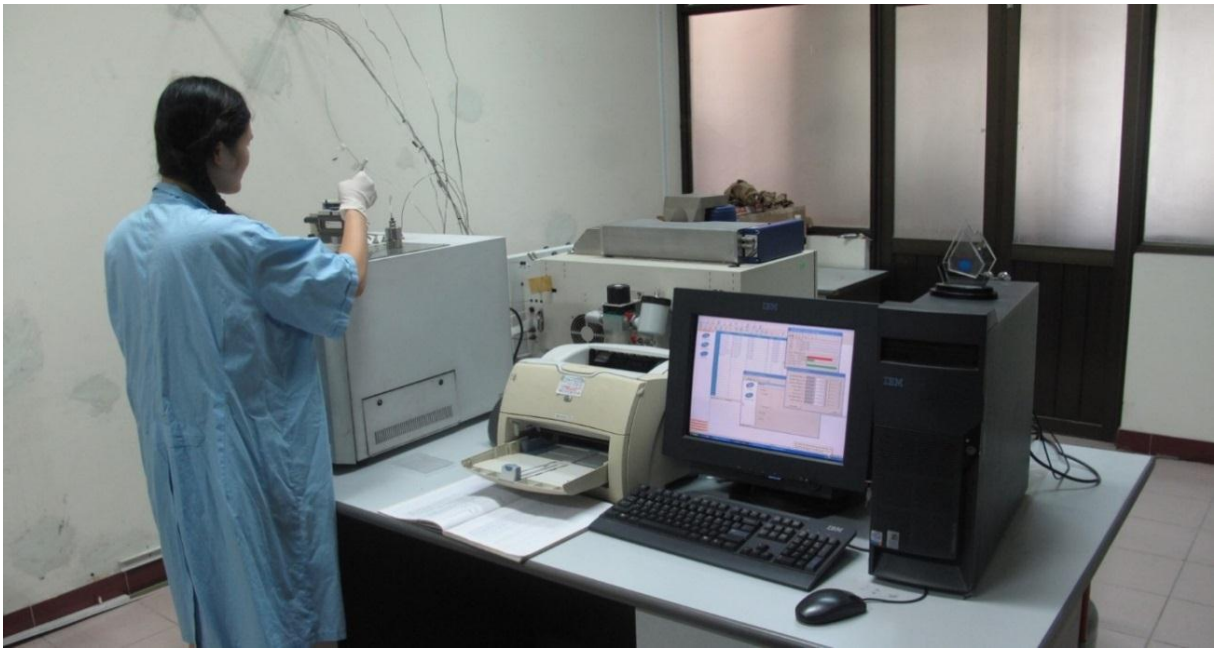

Testing and maintaining the online radiation monitoring station
(Image credit: Center for Environmental Radioactivity Monitoring and Impact Assessment, INST)




Setting up a sample preparation procedure for fruit juice authentication

a) Centrifuge, b) Thermostat water tank,
c) Samples before treatment d) Samples after treatment

(Image credit: Center for Nuclear Technique Application, INST)



Performing experiments on the Isotope Ratio Mass Spectrometer
(Image credit: Center for Nuclear Technique Application, INST)


The Institute for Nuclear Science and Technology organised the 8th Follow-up Training Course (FTC) on Reactor Engineering (Image credit: Center for Nuclear Energy, INST)

Hindawi
Science and Technology of Nuclear Installations
Volume 2020, Article ID 8847897, 7 pages
https://doi.org/10.1155/2020/8847897

*Research Article*

**Core Design of a Small Pressurized Water Reactor with AP1000 Fuel Assembly Using SRAC and COBRA-EN Codes**

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*Cau Giay, Hanoi 100000, Vietnam*

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Received 21 August 2020; Revised 19 October 2020; Accepted 31 October 2

Academic Editor: Leon Cizelj



This paper presents the core design and performance characteristics of
assemblies of the AP1000 reactor. Numerical calculations have been perf
loading pattern using the SRAC code system with the JENDL-4.0 data
temperature coefficients including fuel temperature, coolant temperature,
equate negative reactivity feedbacks. Use thermal-hydraulic analysis reveal

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Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Investigation of the VVER-1000 reactor pressure vessel neutron fluence and displacement per atom using MCNP6

Nguyen Huu Tiep[a,b,**], Sy Minh Tuan Hoang[c,a], Donny Hartanto[d], Kyung Doo Kim[b], Jong Kyung Kim[e], Nguyen Minh Tuan[f], Pham Nhu Viet Ha[a,*]

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epublic of Korea
g, 670000, Viet Nam
iet Nam

A C T

ie integrity of the reactor pressure vessel (RPV) during the operating life of nuclear reactors is of importance, and hence the harmful effects of irradiation on the steels of the RPVs have been cx-udied especially the irradiation embrittlement effects. However, improvements in the calculation e still necessary to further reduce the discrepancy between calculations and experiments. This study ned to examine the neutron fluence and respective rate of displacement per atom (DPA), an important describing the irradiation-induced damage, in the VVER-1000 RPV steel based on the criticality , instead of the common fixed source approach, with the MCNP6 Monte Carlo code, and identify the ive locations in the VVER-1000 RPV. The MCNP6 modeling of the VVER-1000 reactor was verified OpenMC calculations in addition to the confirmation of the convergence of the effective neutron ion factor and the Shannon entropy of the fission source distribution in the MCNP6 criticality cal-ensure reliable tally results of the neutron fluence. Consequently, the maximum neutron fluence in .000 RPV was found at the positions adjacent to the peripheral fuel assemblies, and the respective as analyzed in correlation with the neutron fluence and energy spectrum.

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Evolutionary simulated annealing for fuel loading optimization of VVER-1000 reactor

Viet-Phu Tran[a], Giang T.T. Phan[b,c], Van-Khanh Hoang[a], Pham Nhu Viet Ha[a], Akio Yamamoto[d], Hoai-Nam Tran[b,c,*]

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VVER-1000

ABSTRACT

An evolutionary simulated annealing (ESA) method has been developed for the problem of fuel loading optimization of VVER-1000 reactor. The ESA method improves original simulated annealing by using crossover and mutation operators to generate new trial loading patterns (LPs). A core physics calculation code for fuel LP optimization of VVER reactors (LPO-V) has been developed and verified based on a VVER-1000 MOX benchmark core in comparison with MCNP4c calculations. Calculations for optimizing fuel LP of the VVER-1000 MOX core have been conducted using the ESA method in comparison with simulated annealing (SA) and adaptive simulated annealing (ASA). Statistical differences between these methods were also evaluated based on the Mann–Whitney U test. The results show that the ESA method is advantageous over the SA and ASA.



Typical research publications in 2020
(Image credit: Center for Nuclear Energy, INST)

INST and VNU-HUS research team, and experimental setup at the Pelletron Accelerator Laboratory, Hanoi University of Science Image credit: Center for Nuclear Physics, INST)

Nuclear Physics experiments at the 5SDH Pelletron Accelerator
(Image credit: Center for Nuclear Physics, INST)


Prof. Dao Tien Khoa attended the Intellectuals, Scientists, Writers and Artists Meeting on the occasion of the 90th Anniversary Day of the Communication and Education Sector of the Communist Party of Vietnam (Image credit: Center for Nuclear Physics, INST)

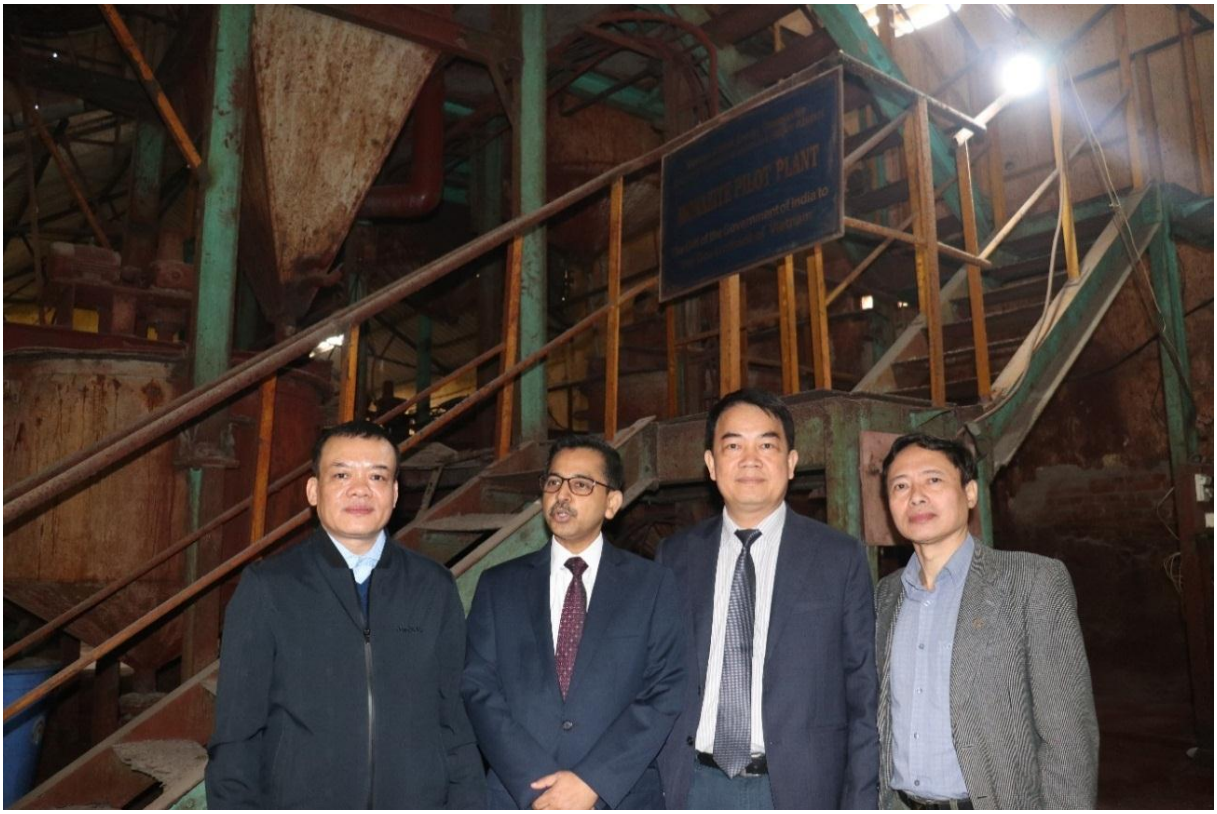

Dr. Le Xuan Chung attended the 10th National Patriotic Emulation Congress (Image credit: Center for Nuclear Physics, INST)

## 3.8 - INSTITUTE FOR TECHNOLOGY OF RADIOACTIVE WASTE AND RARE ELEMENTS, HA NOI



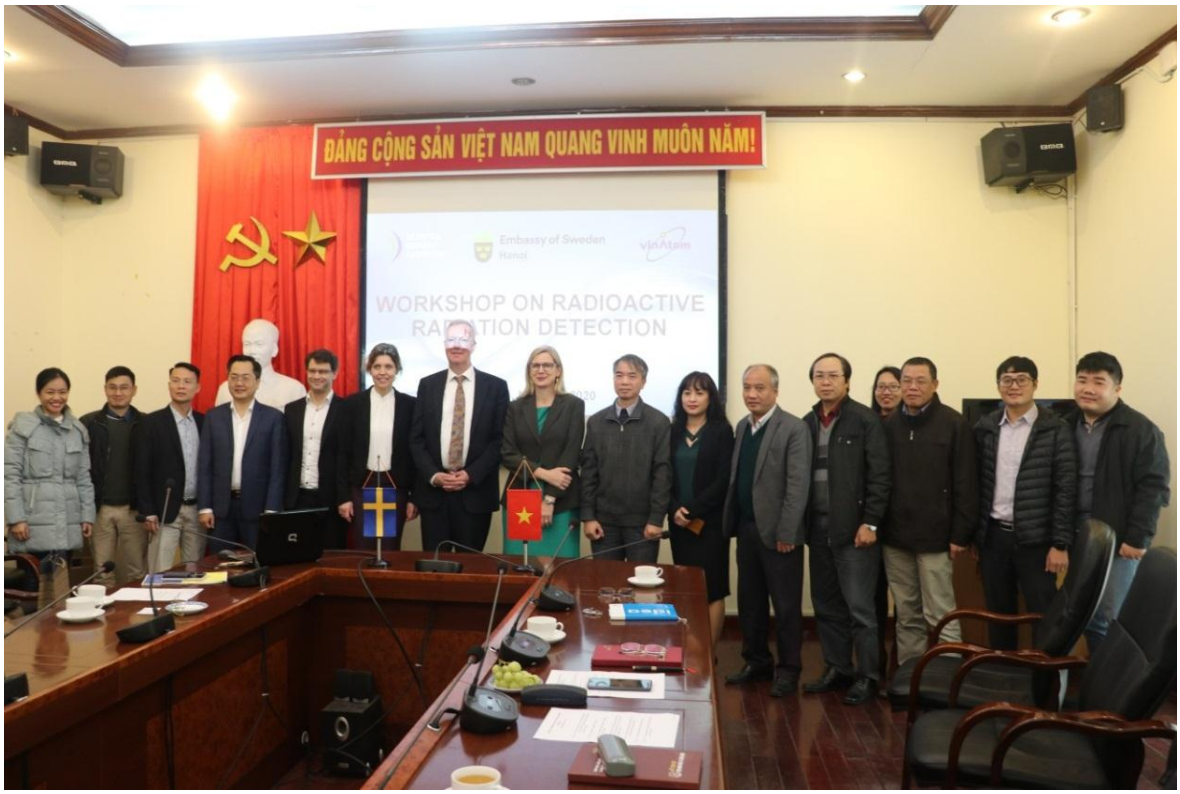
Working session of Russian and VINATOM's experts and on the application of electron beam technology at Vietnam Atomic Energy Institute

Series of following images: The Indian Ambassador paying a visit and working at ITRRE on cooperation in research and treatment of monazite ore



## 3.9 - HEADQUARTERS, HA NOI

Meeting Acting Ambassador of Ukraine to Vietnam to discuss cooperation opportunities between the two countries




Workshop on Radioactive Radiation Detection

The Finnish Ambassador to Vietnam paying a visit to Vietnam Atomic Energy Institute

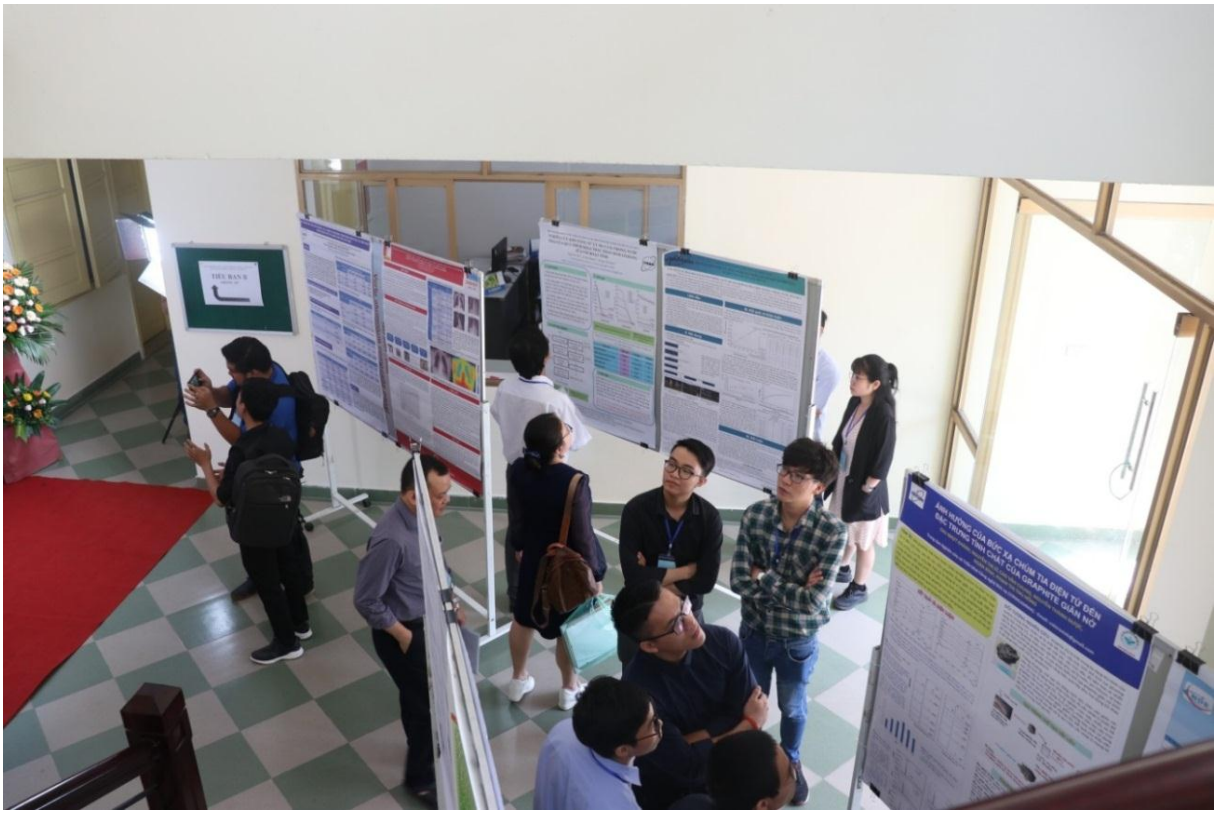

Group photo on the occasion of the visit of Mr. Kari Kahiluoto and the Finish Embassy's delegation to Vietnam Atomic Energy Institute


The meeting honored outstanding individuals and units in 2020


The signing ceremony of cooperation agreement between Vietnam Atomic Energy Institute and the Institute of Natural Product Chemistry


Opening ceremony of the 6th Conference on Nuclear Science and Technology for Young Researchers


Science & Technology Exhibition with the youth at the 6th Conference on Nuclear Science and Technology for Young Researchers



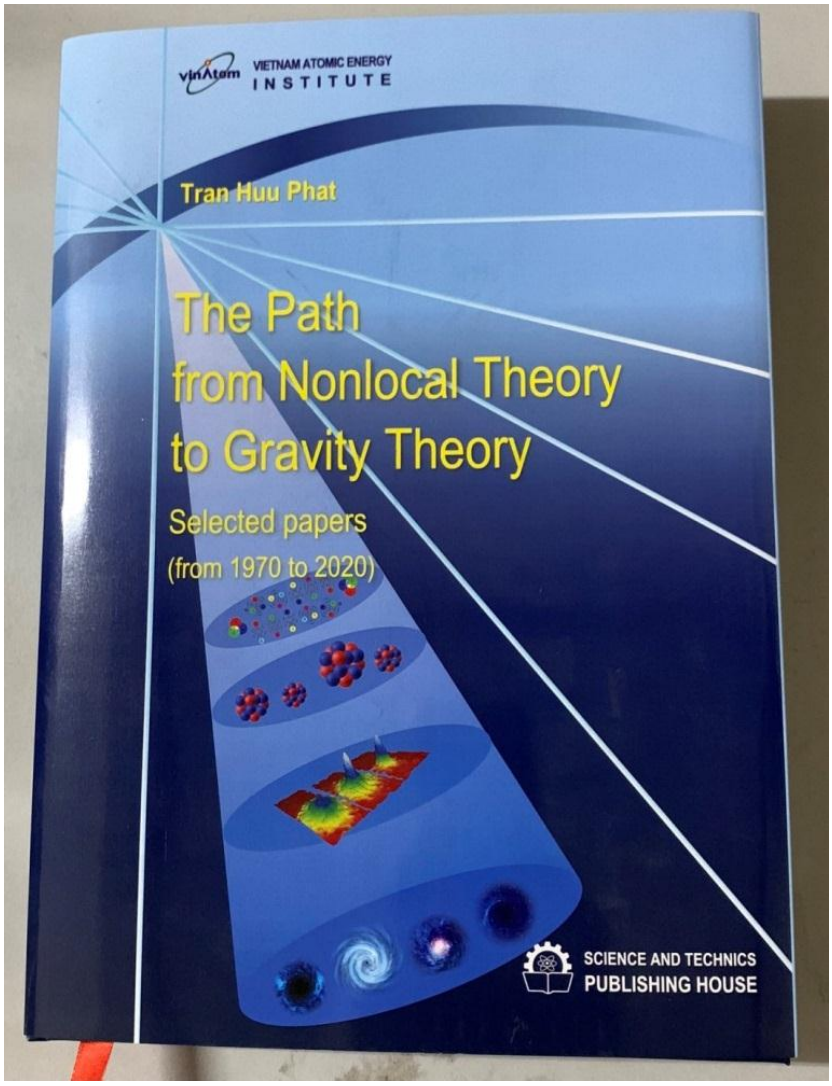
Poster Session at the 6th Conference on Nuclear Science and Technology for Young Researchers


Awarding excellent reporters at the 6th Conference on Nuclear Science and Technology for Young Researchers


The Meeting of Council of Science, Technology and Training in 2020


The release of the book "The Path from non-local theory to gravity theory" written by Prof. Dr. Tran Huu Phat

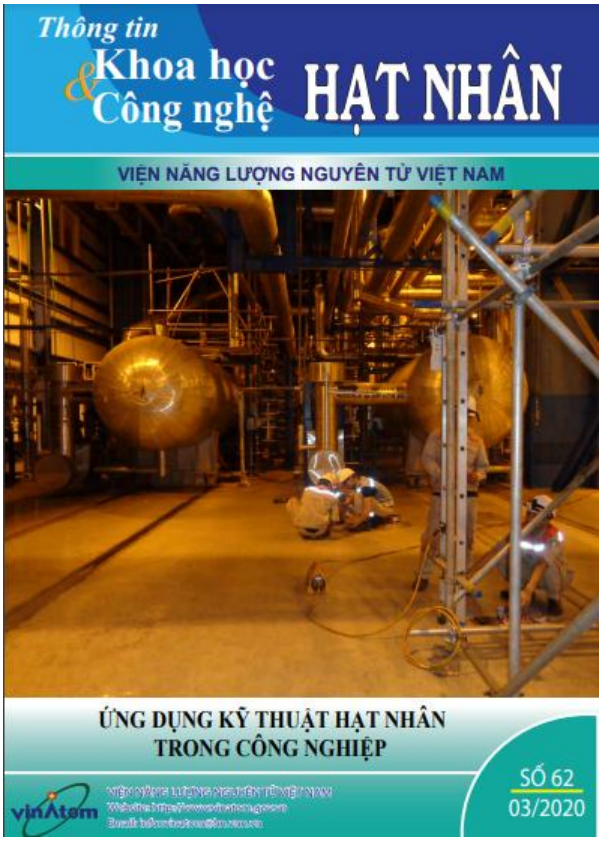
Participants in the book release ceremony

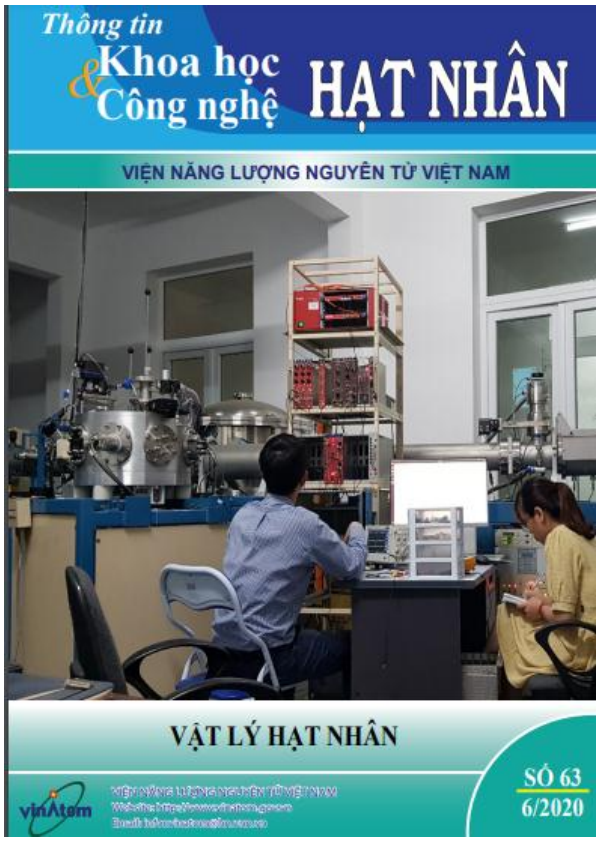


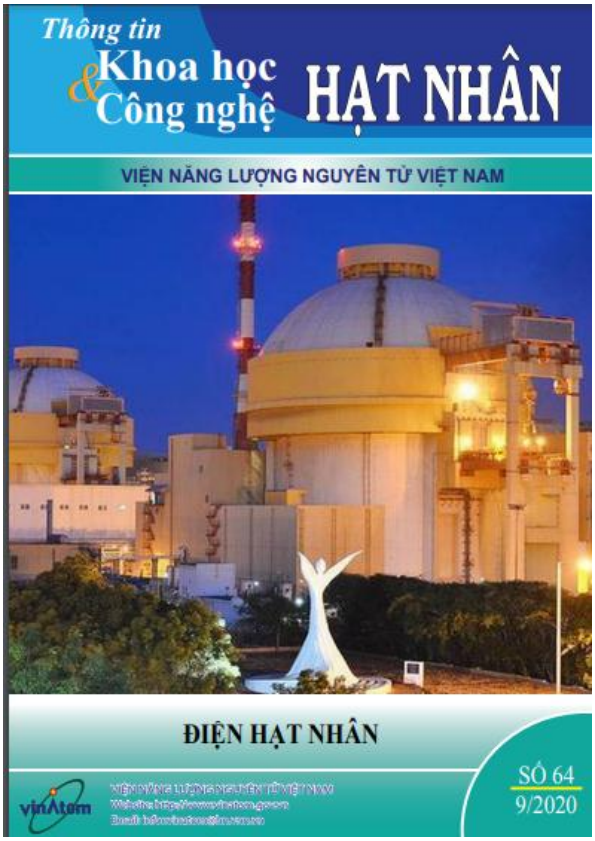

The book written by Prof. Dr. Tran Huu Phat and published by Science and Technics Publishing House


Minister of Science and Technology Huynh Thanh Dat made speech at the Meeting of Summarizing the work in 2020 and Orientation of the key tasks in 2021

The President of Vietnam Atomic Energy Institute Tran Chi Thanh made speech at the Meeting of Summarizing the work in 2020 and Orientation of the key tasks in 2021

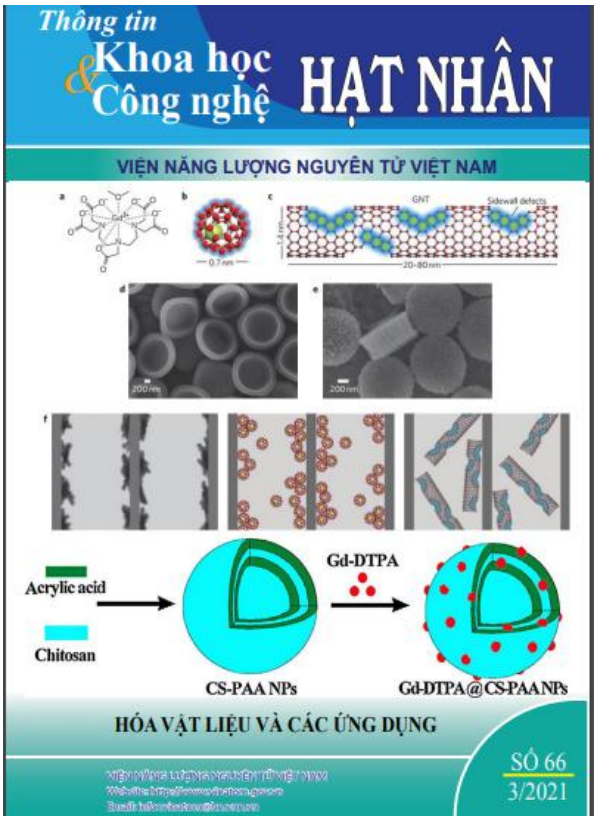


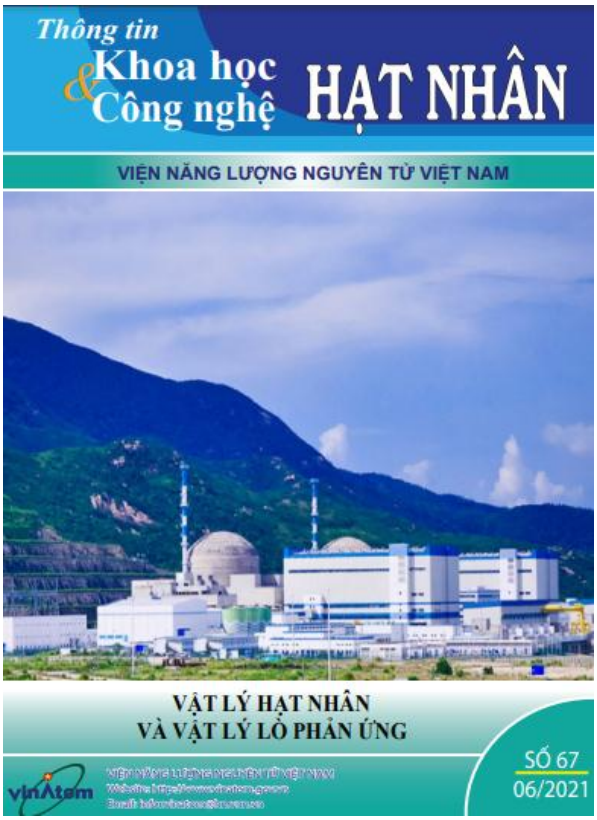



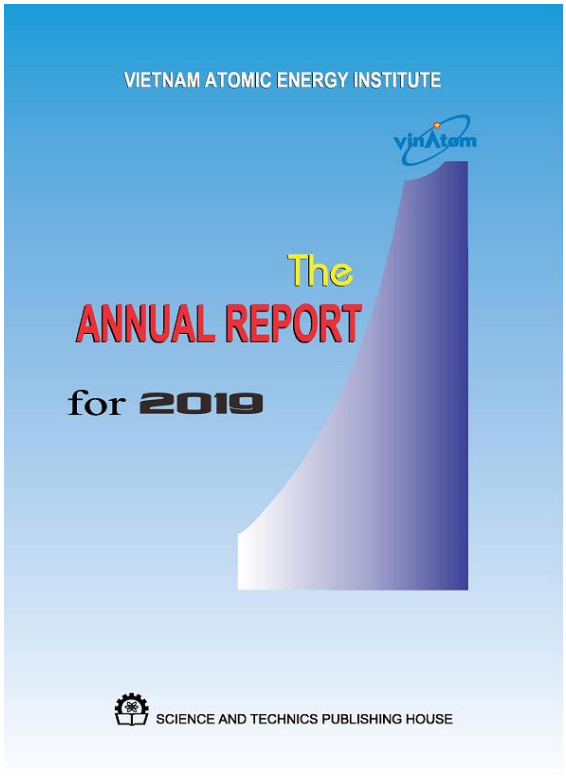


Nuclear Science and Technology Information in Vietnamese made by VINATOM. Available from https://vinatom.gov.vn/an-pham-tai-lieu/ (to be continued…)




Nuclear Science and Technology Information in Vietnamese made by VINATOM. Available from https://vinatom.gov.vn/an-pham-tai-lieu/




VINATOM Annual Report for 2019 published in 2020 (printed version). Available at Division of Information, Department of Planning and R&D Management, VINATOM





Journal of Nuclear Science and Technology published by VINATOM and Vietnam Atomic Energy Society. Available from https://vinatom.gov.vn/an-pham-tai-lieu/

# 4- APPENDICES

## 4.1. LIST OF VINATOM'S INTERNATIONAL SCIENTIFIC PUBLICATIONS IN 2020

| No | Name of publications | Authors | Journals |
|---|---|---|---|
| 1 | Restoration of the natural $E(1/2^+_1)$ - $E(3/2^+_1)$ energy splitting in odd-Kisotopes towards N = 40 | **Y.L. Sun, …, L.X. Chung, B.D. Linh, et al.** | **Physics Letters B** ISSN: 0370-2693 |
| 2 | Metastable States of $^{92,94}$Se: Identification of an Oblate K Isomer of $^{94}$Se and the GroundState Shape Transition between N = 58 and 60 | **C. Lizarazo, L.X. Chung, B.D. Linh, et al.** | **Physical Review Letters** ISSN: 0031-9007 (Print) ISSN: 1079-7114 |
| 3 | Sequential Nature of (p,3p) Two-Proton Knockout from Neutron-Rich Nuclei | **A. Frotscher, L.X. Chung, B.D. Linh, et al.** | **Physical Review Letters** ISSN: 0031-9007 (Print) ISSN: 1079-7114 (Online) ISSN: 1092-0145 (CD-ROM) |
| 4 | Shell structure of the neutron-rich isotopes $^{69,71,73}$Co | **T Lokotko, L.X. Chung, et al.** | **Physical Review C** ISSN: 2469-9985 (Print) ISSN: 2469-9993 (Online) |
| 5 | Coupled-reaction channel study of the $^{12}$C(α,$^{8}$Be) reaction and the $^{8}$Be+$^{8}$Be optical potential | **Do Cong Cuong, Pierre Descouvemont, Dao T. Khoa, and Nguyen Hoang Phuc** | **Physical Review C** ISSN: 2469-9985 (Print) ISSN: 2469-9993 (Online) |
| 6 | Spin-polarized β-stable neutron star matter: The nuclear symmetry energy and GW170817 constraint | **Ngo Hai Tan, Dao T. Khoa, and Doan Thi Loan** | **Physical Review C** ISSN: 2469-9985 (Print) ISSN: 2469-9993 (Online) |

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| 7 | Synthesis of lithium aluminate for application in radiation dosimetry | **Nguyen Thi Thu Ha, Trinh Van Giap, Nguyen Trong Thanh** | **Material Letters**<br>ISSN: 0167-577X |
| 8 | Evolutionary simulated annealing for fuel loading optimization of VVER-1000 reactor | **Viet-Phu Tran, Giang T.T. Phan, Van-Khanh Hoang, Pham Nhu Viet Ha, Akio Yamamoto, Hoai-Nam Tran** | **Annals of Nuclear Energy**<br>ISSN: 0306-4549 |
| 9 | Natural radionuclides and assessment of radiological hazards in MuongHum, Lao Cai, Vietnam | **Nguyen Thanh Duong, Duong Van Hao,Van Loat Bui, Duc Thang Duong, Trong Trinh Phan, Hoan Le Xuan** | **Chemosphere Available**<br>ISSN: 0045-6535 (Print)<br>ISSN: 1879-1298 (Online) |
| 10 | Folding model approach to the elastic p+$^{12,13}$C scattering at low energies and radiative capture $^{12,13}$C(p,γ) reactions | **Nguyen Le Anh, Nguyen Hoang Phuc, Dao T. Khoa , Le Hoang Chien , Nguyen Tri Toan Phuc** | **Nuclear Physics A**<br>ISSN: 0375-9474 (Online) |
| 11 | Measurement of yield ratios for the isomeric pair $^{137m,g}$Ce in the $^{141}$Pr(γ,X)$^{137m,g}$Ce reactions with bremsstrahlung end-point energies of 50-, 60-, and 70-MeV | **Nguyen Van Do, Nguyen Thanh Luan, Nguyen Thi Xuan, Pham Duc Khue, Nguyen Thi Hien, Guinyun Kim, Kwangsoo Kim, Sung-Gyun Shin, Yong-uk Kye, Moo-Hyun Cho** | **Radiation Physics and Chemistry**<br>ISSN: 0969-806X (Online) |
| 12 | Investigation of the VVER-1000 reactor pressure vessel neutron fluence anddisplacement per atom using MCNP6 | **Nguyen Huu Tiep, Sy Minh Tuan Hoang, Donny Hartanto, Kyung Doo Kim, Jong Kyung Kim, Nguyen Minh Tuan, Pham Nhu Viet Ha** | **Radiation Physics and Chemistry**<br>ISSN: 0969-806X |

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| 13 | Assessment of atmospheric deposition of metals in Ha Noi using the moss bio-monitoring technique and proton induced X-ray emission | **L. H. Khiem, K. Sera, T. Hosokawa, N. H. Quyet, M. V. Frontasyeva, T. T. M. Trinh, N. T. B. My, N. T. Nghia, T. D. Trung, L. D. Nam, K. T. Hong, N. N. Mai, D. V. Thang, N. A. Son, T. T. Thanh & D. P. T. Tien** | **Journal of Radioanalytical and Nuclear Chemistry** ISSN: 0236-5731 (Print) |
| 14 | Core design of a small-pressurized water reactor with AP1000 fuel assembly using SRAC and COBRA-EN codes | **Van Khanh Hoang** | **Science and Technology of Nuclear Installations** ISSN: 1687-6075 (Print) ISSN: 1687-6083 (Online) |
| 15 | Active moss biomonitoring technique for atmospheric elemental contamination in Hanoi using proton induced X-ray emission | **Le Hong Khiem, Nguyen Huu Quyet, Nguyen Thi Bao My, Duong Van Thang, Nguyen An Son, Tran Thien Thanh, Sonexay Xayheungsy and et al.** | **Journal of Radioanalytical and Nuclear Chemistry** ISSN: 0236-5731 (Print) |
| 16 | Natural radioactivity measurement and radiological hazard evaluation in surface soils in a gold mining area and surrounding regions in Bolikhamxay province, Laos | **Somsavath Leuangtakoun, Giang T. T. Phan, Thang Duc Duong, Ngoc Thiem Le, and et al.** | **Journal of Radioanalytical and Nuclear Chemistry** ISSN: 0236-5731 (Print) ISSN: 1588-2780 (online) |
| 17 | Calibration of a neutron dose rate meter in various neutron standard fields | **Tuan Khai Nguyen, Hoai-Nam Tran, Quynh Ngoc Nguyen, Thi My Linh Dang, Van Loat Bui, Thiansin Liamsuwan, Ngoc-Thiem Le** | **Nuclear Science and Techniques** ISSN: 2210-3147 (elec.) ISSN: 1001-8042 (print) |

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| 18 | Spectroscopy of neutron-rich scandium isotopes | **P. Koseoglou, …, L.X. Chung, B.D. Linh, et al.** | **Journal of Physics: Conference Series**<br>Online ISSN: 1742-6596<br>Print ISSN: 1742-6588 |
| 19 | Establishment of Neutron Reference Fields in Vietnam: A Review | **LE Ngoc-Thiem** | **Philippine Journal of Science**<br>ISSN: 0031-7683 |
| 20 | Validation of UNIST Monte Carlo code MCS for criticality safety calculations with burnup credit through MOX criticality benchmark problems | **Duy Long Ta, Ser Gi Hong, Deokjung Lee** | **Nuclear Engineering and Technology**<br>ISSN / eISSN: 1738-5733 |
| 21 | Silver-Doped LiI Crystal: A Sensitive Thermal Neutron Detector With Pulse Shape Discrimination | **PQ Vuong, HJ Kim, A Khan, S Khan, SH Kim, H Park, J Kim** | **IEEE Transactions on Nuclear Science**<br>ISSN/eISSN: 0018-9499/1558-1578 |
| 22 | Crystal growth and $Ce^{3+}$ concentration optimization in $Tl_2LaCl_5$: An excellent scintillator for the radiation detection | **A Khan, PQ Vuong, G Rooh, HJ Kim, S Kim** | **Journal of Alloys and Compounds**<br>ISSN/eISSN: 0925-8388/1873-4669 |
| 23 | Lithium-doped two-dimensional perovskite scintillator for wide-range radiation detection | **Victor Springham, Phan Quoc Vuong, Muhammad Danang Birowosuto, Cuong Dang and et al** | **Nature - Communications Materials**<br>ISSN: 2662-4443 (online) |
| 24 | Thallium lead iodide ($TlPbI_3$) single crystal inorganic perovskite: Electrical and optical characterization for gamma radiation detection | **Ibrahim Hany, Ge Yang, Quoc Vuong Phan, Hong Joo Kim** | **Materials Science in Semiconductor Processing**<br>ISSN/eISSN:1369-8001/1873-4081 |

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| 25 | Discovery, Crystal Growth, and Scintillation Properties of Novel Tl-Based Scintillators | **HongJoo Kim, Gul Rooh, Arshad Khan, Phan Quoc Vuong, Sunghwan Kim** | **Crystal Research and Technology** ISSN/eISSN: 0232-1300/1521-4079 |
| 26 | Development of Tin-based Single Crystal Scintillator for Double-beta Decay Experiments | **P Aryal, A Khan, HJ Kim, PQ Vuong, J Kaewkhao, S Kothan, S Kaewjaeng** | **IEEE Transactions on Nuclear Science** ISSN/eISSN: 0018-9499/1558-1578 |
| 27 | Evaluation of energy and impulse generated by superheated steam bubble collapse in subcooled water | **Melikhov V I, Melikhov O I, Yakush S E and Le Tran Chung** | **Nuclear Engineering and Design** ISSN/eISSN: 0029-5493/1872-759X |
| 28 | Collapse of a hot vapor bubble in subcooled liquid | **Le T. Chung, Melikhov V.I., Melikhov O.I. and Yakush S.E** | **Journal of Physics: Conference Series** ISSN: 1742-6588, 1742-6596 |
| 29 | Impact effects due to hot vapor bubble collapse in subcooled liquid | **Le T. C., Melikhov V.I., Melikhov O.I. and Yakush S.E** | **Journal of Physics: Conference Series** ISSN: 1742-6588, 1742-6596 |
| 30 | Spectroscopic Studies of Mössbauer, Infrared, and Laser-Induced Luminescence for Classifying Rare-Earth Minerals Enriched in Iron-Rich Deposits | **Aoyagi Noboru, Thuy NT., Tung NV. Hung NT. Thuan LB. et al** | **ACS Omega** ISSN: 2470-1343 |
| 31 | Separation of thorium and uranium from xenotime leach solutions by solvent extraction using primary and tertiary amines | **Nguyen Trong Hung, Le Ba Thuan, Tran Chi Thanh, Masayuki Watanabe, Do Van Khoai, Nguyen Thanh Thuy, Hoang Nhuan, Pham Quang Minh, Tran Hoang Mai, Nguyen Van Tung,** | **Hydrometallurgy** ISSN: 0304-386X |

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| | | **Doan Thi Thu Tra, Manis Kumar Jha, Jin Young Lee, Rajesh Kumar Jyothi** | |
| 32 | Study on the Adsorption and Activation Behaviours of Carbon Dioxide over Copper Cluster ($Cu_4$) and Alumina-Supported Copper Catalyst ($Cu_4/Al_2O_3$) by means of Density Functional Theory | **Nguyen Thi Thu Ha, Van Thi Minh Hue, Bui Cong Trinh, Nguyen Ngoc Ha, Le Minh Cam** | **Hindawi, Journal of Chemistry** ISSN 2090-9071 |
| 33 | Synthesis of magnetic nanoparticles $Fe_3O_4$ from $FeCl_2$solution in aqueous saturated lime solution at laboratory and pilot scale | **Do Q.H., Vu X.M., Nguyen V.T., et al.** | **Internauka, Sci. J.** |
| 34 | Effect of grinding principle on tanrai aluminum hydroxide dissolution efficiency in HCl acid | **Phung V. P., Le T. M. H., Nguyen T. L., Bui C. T.** | **Internauka, Sci. J.** |
| 35 | Evidence for the First Excited State of $^{7}$H | **A.A. Bezbakh, V. Chudoba* …, Mai Quynh Anh** | **Physical Review Letters** ISSN/eISSN: 0031-9007/1079-7114 |
| 36 | A fully microscopic model of total level density in spherical nuclei | **N. Quang Hung*, N. Dinh Dang, L. Tan Phuc, Nguyen Ngoc Anh, et al** | **Physics Letters B** ISSN/eISSN: 0370-2693/1873-2445 |
| 37 | Cu/$Fe_3O_4$@carboxylate-rich carbon composite: One-pot synthesis, characterization, adsorption and photo-Fenton catalytic activities | **Van Thuan Le, Van Dat Doan, Dai Lam Tran, Pham Thanh Minh, et al.** | **Materials Research Bulletin** ISSN/eISSN: 0025-5408/1873-4227 |

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| 38 | Facile fabrication of highly flexible and floatable $Cu_2O$/rGO on Vietnamese traditional paper toward high-performance solar-light-driven photocatalytic degradation of ciprofloxacin antibiotic | **Le Thi Thanh Nhi, Le Van Thuan, Dao My Uyen, Nguyen Minh Hiep** | **RSC Advances** ISSN/eISSN: 2046-2069 |
| 39 | Activity Concentrations of Sr-90 and Cs-137 in Seawater and Sediment in the Gulf of Tonkin, Vietnam | **Nguyen Trong Ngo*, Tran Quang Thien, Nguyen Van Phuc, Lo Nhu Siou, Phan Son Hai, Lo Xuon Thang, Vuong Thi Thu Hang, Nguyen Van Phu, Nguyen Dinh Tung, Tran Donh Khoa, Nguyen Minh Dao, Phan Quang Trung, Vu Thi Mong Tham** | **Journal of Chemistry** ISSN/eISSN: 2090-9063/2090-9071 |
| 40 | Effective biocontrol of nematodes using lipid nanoemulsions co-encapsulating chili oil, cinnamon oil and neem oil. | **Nguyen Minh Hiep*, Vu Ngoc Bich Dao*, Thi-Huynh-Nga Nguyen, Tran Thi Ngoc Mai, Hoang-Sinh Le, Tran Thi Tom, Lo Xuon Cuong, Lo Van Toàn, Nguyen Ngoc Thuy Trang** | **International Journal of Pest Management** ISSN/eISSN: 0967-0874/1366-5863 |
| 41 | Conceptual Design of a 10MW Multipurpose Research Reactor Using VVR-KN Fuel | **Nguyen Nhi Dien, Nguyen Kien Cuong, Huynh Ton Nghiem, Vo Doan Hai Dang, et al.** | **Science and Technology of Nuclear Installations** ISSN/eISSN: 1687-6075/1687-6083 |
| 42 | Estimating partial body ionizing radiation exposure by automated cytogenetic biodosimetry | **Ben C. Shirley, Joan H.M. Knoll, Jayne Moquet, Elizabeth Ainsbury, Pham Ngoc Duy, et al.** | **International Journal of Radiation Biology** |

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| 43 | A confident configuration for an Environmental Radiation Monitoring System | **Dinh Tien Hung*, Pham Dinh Khang, Nguyen Xuan Hai, Nguyen Ngoc Anh, Tran Duc Tan, Dinh Kim Chien, Nguyen Nhi Dien, et al.** | **IEEE Transactions on Nuclear Science** ISSN/eISSN: 0018-9499/1558-1578 |
| 44 | Determination of elements due to atomospheric deposition on barbula indica moss at Dalat, Vietnam using NAA and TXRF techniques | **Nguyen An Son*, Le Hong Khiem, Nguyen Minh Sang, Doan Phan Thao Tien, Ho Huu Thang** | **Sains Malaysiana** ISSN/eISSN: 0126-6039 |
| 45 | Acrylic ibers coated with copper hexacyanoferrate to determine $^{137}Cs$ activity in coastal seawater of Vietnam | **Nguyen Trong Ngo*, Le Xuan Thang, Nguyen Van Phuc, Le Nhu Sieu, Phan Quang Trung, Nguyen Minh Dao, Nguyen Thi Huong Lan, Vo Tho Mong Tham** | **Journal of Radioanalytical and Nuclear Chemistry** ISSN/eISSN: 0236-5731/1588-2780 |
| 46 | Standardization and application of internal monostandard NAA method using the Dalat research reactor | **Tran Tuan Anh*, Ho Manh Dung, Ho Van Doanh, Nguyen Thi Tho, Trinh Van Cuong, Nguyen Duy Quang** | **Radioanalytical and Nuclear Chemistry** ISSN/eISSN: 0236-5731/1588-2780 |
| 47 | Environmental radioactivity and associated radiologycal hazards in surface soil in Ho Chi Minh city, Vietnam | **Tran Hoai Nam*** **Tran Dinh Khoa*, Truong Y, Le Nhu Sieu, Nguyen Van Phu** | **Journal of Radioanalytical and Nuclear Chemistry** ISSN/eISSN: 0236-5731/1588-2780 |
| 48 | Voltammetric Determination of Rhodamine B Using a ZIF-67/Reduced Graphene Oxide Modified Electrode | **Huynh Truong Ngo, Nguyen Thi Minh Triet, Nguyen Thanh Binh, et al.** | **Journal of Nanomaterials** ISSN/eISSN: 1687-4110/1687-4129 |

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| 49 | Gamma spectrum stabilization for environmental radiation monitoring stations using NaI(Tl) detector | **Dinh Tien Hung, Nguyen Xuan Hai, Nguyen Ngoc Anh, et al.** | **Radiation Protection Dosimetry** ISSN/eISSN: 0144-8420/1742-3406 |
| 50 | Modeling and optimization of biosorption of lead (II) ions from aqueous solution onto pine leaves (Pinus kesiya) using response surface methodology | **Phuong Thao Huynh, Nguyen Ngoc Tuan and et al.** | **Desalination and Water Treatment** ISSN/eISSN: 1944-3994/1944-3986 |
| 51 | Facile Synthesis of $Fe_3O_4$ Nanoparticles Loaded on Activated Carbon Developed from Lotus Seed Pods for Removal of Ni(II) Ions | **Tran Thi Kieu Ngan, Pham Thanh Minh and et al.** | **Journal of Nano Research** ISSN/eISSN: 1662-5250/1661-9897 |
| 52 | Simulation Design of Thermal Neutron Collimators for Neutron Capture Studies at The Dalat Research Reactor | **Pham Dang Quyet, Pham Ngoc Son, Nguyen Nhi Dien, Trinh Tu Anh, Cao Dong Vu** | **Asian journal of scientific research** |
| 53 | Study on Preparation of Y-90 Microspheres in Da Lat Nuclear Reactor for Application in Treatment of Primary and Secondary Liver Cancers | **Pham Thanh Minh, Duong Van Đong, Le Van Thuan, Truong Minh Tri, Truong Duc Toan and Cao Đong Vu** | **Oriental Journal of Chemistry** |
| 54 | Study of heavy metal content (Cd, Cu, Pb, Zn) in farmyard of Lam Dong province, Vietnam | **Quang Hieu Tran and Ngoc Tuan Nguyen** | **Rasayan Journal of Chemistry** |

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| 55 | Antioxidant phlorotannin content from brown algae: Impact of irradiation γ Co-60 | **Dang Xuan Cuong*, Nguyen Trong Hoanh Phong, Nguyen Thi My Trang** | **International Medical Journal** |
| 56 | Study of $^{10}$Li low energy spectrum in the $^{2}$H($^{9}$Li,p) reaction | **A.A. Bezbakh, Mai Quynh Anh and et al.** | **Bulletin of the Russian Academy of Sciences: Physics** |
| 57 | Detection of the low energy recoil $^{3}$He in the reaction $^{2}$H($^{8}$He,$^{3}$He)$^{7}$H | **Ivan Muzalevskii, Mai Quynh Anh and et al.** | **Bulletin of the Russian Academy of Sciences: Physics** |
| 58 | Межатомный потенциал для моделирования радиационных повреждений в сплавах | **Trung N.T.H, H.C.M. Phuong, Popov V.A** | **Fundamental problems in modern material science** |
| 59 | Межатомный потенциал для моделирования радиационных повреждений в тройных сплавах | **Trung N.T.H, H.C.M. Phuong, Popov V.A, Starostenkov M.D** | Fundamental problems in modern material science |
| 60 | Deep learning interatomic potential for simulation of radiation damage in vanadium-rich V-Cr-Ti ternary alloys | **H.C.M. Phuong, Trung N.T.H, Starostenkov M.D.** | **XVI International School-Seminar "Evolution of Defective Structures in Condensed Matter"** |
| 61 | Inter-diffusion and phase transformation in Ni-Al bi-layer at different temperature | **Zokirov F.Z., H.C.M. Phuong, Starostenkov M.D.** | **XVI International School-Seminar "Evolution of Defective Structures in Condensed Matter"** |
| 62 | Recent researches on chitosan applications at Vietnam Atomic Energy Institute | **Nguyen Minh Hiep,**<br>**Nguyen Ngoc Thuy Trang, Vu Ngoc Bich Dao, and et al.** | **30th Annual Meeting & International Symposium of the topic of "Recent** |

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| | | | **Advancement of Chitin and Chitosan Applications"** |
| 63 | Preparation of Chitooligosaccharide by Hydrogen Peroxide Degradation of Chitosan and Its Effect on Soybean Seed Germination | **Nguyen Thi Thanh Hai, Le Hoai Thu, Nguyen Thi Thanh Nga, Tran Thai Hoa, Le Nghiem Anh Tuan, Dang Van Phu, Nguyen Quoc Hien.** | **Journal of Polymers and the Environment** Electronic ISSN: 1572-8919 Print ISSN: 1566-2543 |
| 64 | Preparation and Antifungal Activity Investigation of Oligochitosan-$Zn^{2+}$ on Colletotrichum truncatum | **Dang Van Phu, Bui Duy Du, Le Nghiem Anh Tuan, Le Thanh Hung, Hoang Dac Hiet, and Nguyen Quoc Hien** | **International Journal of Polymer Science** ISSN: 1687-9422 (Print) ISSN: 1687-9430 (Online) |
| 65 | Nanocomposite of silver nanoparticles/diatomite against pathogenous bacteria for catfish | **Hanh Thi Truong*, Thu Diem Nguyen, Hien Quoc Nguyen** | **Aquaculture Reports** ISSN: 2352-5134 |
| 66 | Visible-light-induced photo-Fenton degradation of rhodamine B over $Fe_2O_3$-diatomite materials | **Pham Van Viet*, Duong Van Chuyen, Nguyen Quoc Hien, Nguyen Ngoc Duy*, Cao Minh Thi*.** | **Journal of Science: Advanced Materials and Devices** ISSN: 2468-2179 |
| 67 | Treatment of real textile wastewater using electron beam irradiation | **Nguyen Ngoc Duy, Dang Van Phu, Nguyen Thi Kim Lan, Nguyen Thanh Duoc, Nguyen Quoc Hien, Bui Nghia Hiep, Bui Ngoc Han, Bui Manh Ha** | **Acta Chemica Iasi** ISSN: 2067-2446 |
| 68 | Theoretical calculation by Talys code in combination with Geant4 simulation for consideration of (γ, n) reactions of Eu isotopes in the giant dipole resonance region | **P. V. Cuong, T. D. Thiep, L.T. Anh, T. T. An, B. M. Hue, K. T. Thanh, N. H. Tan, N. T. Vinh and T. T. Anh** | **Nuclear Instr. and Methods in Physics Research B** ISSN : 0168-583X |

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| 69 | The isomeric ratios in (n, γ) neutron capture reactions on $^{108}$Pd and $^{110}$Pd | **Hue Minh Bui, Thiep Duc Tran, An Thi Truong, Cuong Phan Viet, S. M. Lukyanov, A. G. Belov15, S. Mitrofanov** | **Journal of Radioanalytical and Nuclear Chemistry** ISSN : 1588-2780, 0236-5731 |
| 70 | Analysis of trace elements in the fingernails of breast cancer patients using instrumental neutron activation analysis | **Phuong Truc Huynh, Trinh Pham Ngoc Tran, Binh Thanh Dinh, Linh Thi Truc Nguyen, Loan Thi Hong Truong, Anh Tuan Tran, Dung Manh Ho, Dong Van Nguyen** | **Radioanalytical and Nuclear Chemistry** ISSN: 0236-5731 (print); 1588-2780 (web) |
| 71 | A hybrid model for estimation of pore size from ortho-positronium lifetimes in porous materials | **L. Anh Tuyen, T. Dong Xuan, H. A. Tuan Kiet, L. Chi Cuong, P.Trong Phuc, T. Duy Tap, Dinh-Van Phuc, L. Ly Nguyen, N. T. NgocHue, P. Thi Hue, L. Thai Son, D. Van Hoang, N. Hoang Long, N.Quang Hung** | **Radiation Physics and Chemistry** ISSN: 0969-806X |
| 72 | Design of a unique holder for structural modification of ZSM-5 zeolite using a 10 MeV electron beam generated from an industrial UERL-10-15S2 linear accelerator | **P.Trong Phuc, C. V. Chung, H. A. Tuan Kiet, L. Thai Son, Van-Phuc Dinh, T. Dong Xuan, T. Duy Tap, L. Chi Cuong, N. T. Ngoc Hue, P.Thi Hue, L. Ly Nguyen, D. V. Hoang, N. Hoang Long, H. Huu Thang, N. Van Tiep, N. Quang Hung, L. Anh Tuyen** | **Radiation Physics and Chemistry** ISSN: 0969-806X |
| 73 | Multi-scale defects in ZnO thermoelectric ceramic materials co-doped with In and Ga | **Anh Tuan Thanh Pham, Tuyen Anh Luu, Ngoc Kim Pham, et al.** | **Ceramics International** ISSN: 0272-8842 |

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|---|---|---|---|
| 74 | Chitosan-$MnO_2$ nanocomposite for effective removal of Cr (VI) from aqueous solution | **Van-Phuc Dinh, Anh Tuyen Luu, Tran Duy Tap, Thien-Hoang Ho, Trong Phuc Phan, Trinh Duy Nguyen, et al.** | **Chemosphere** ISSN: 0045-6535 |
| 75 | Deep red fluoride dots-in-nanoparticles for high color quality micro white light-emitting diodes | **Doan Thi Tuyet, Luu Anh Tuyen, Nguyen Quang Hung, et al.** | **Optics Express** ISSN: 1094-4087 |
| 76 | Abnormal Volatile and Normal Stable Bipolar Resistive Switching Characteristics of Hybrid Nanocomposites: Morphology-Defects-Property Relationship | **Tu Uyen Doan Thi, Sungkyun Park, Anh Tuyen Luu, Quang Hung Nguyen, Thai Son Lo, Ngoc Kim Pham, et al.** | **Alloys and Compounds** ISSN: 0925-8388 |
| 77 | Internal and interfacial structure analysis of graft-type fluorinated polymer electrolyte membranes by small-angle X-ray scattering in the high-q range | **Tran D. Tap, La L. Nguyen, Shin Hasegawa, Shin-ichi Sawada, Le Q. Luan, Yasunari Maekawa** | **Applied Polymer Science** ISSN: 1097-4628 |
| 78 | Calculation of the neutron flux distribution in the accelerator driven subcritical reactor with (Th-$^{233}U)O_2$ and (Th-$^{235}U)O_2$mix fuel | **Tran Minh Tien, Tran Quoc Dung** | **Journal of Physics: Conference Series** ISSN: 1742-6588, 1742-6596. |
| 79 | Swelling of alpha-quartz induced by MeV ions irradiation: Critical dose and swelling mechanism | **Nhut Luu Vu, Kenta Murakami, Hamza Samouh, Ippei Maruyama, et al.** | **Journal of Nuclear Materials** ISSN: 0022-3115 |

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|---|---|---|---|
| 80 | Applicability of ultrasonic-wave based method for integrity assessment of concrete severely damaged by heat | **Vu Nhut LUU, Kenta MURAKAMI, Thi Mai Dung DO, Masahide SUZUKI, et al.** | **E-Journal of Advanced Maintenance** ISSN:1883-9894 |
| 81 | Ion irradiation-induced the radiation hardening in Fe and Fe-0.3Si alloys | **Phongsakorn Prak Tom, Kenta Murakami1 and Luu Vu Nhut** | **IOP Conf. Series: Materials Science and Engineering** |
| 82 | Changes in properties of alpha-quartz and feldspars under 3 MeV Si-ion irradiation | **Vu Nhut Luu, Kenta Murakami, Hamza Samouh, et al.** | **Journal of Nuclear Materials** ISSN: 0022-3115 |
| 83 | An analysis of In-Vessel Melt Retention strategy for VVER-1000 considering the effect of torospherical lower head vessel | **Manh Long Doan, Van Thai Nguyen, Chi Thanh Tran** | **Nuclear Engineering and Design** ISSN/eISSN: 0029-5493/1872-759X |
| 84 | Stable isotopes as an effective tool for N nutrient source identification in a heavily urbanized and agriculturally intensive tropical lowland basin | **Thi Nguyet Minh Luu, Thu Nga Do, Ioannis Matiatos, Virginia Natalie Panizzo and Anh Duc Trinh** | **Biogeochemistry** ISSN/eISSN: 0168-2563/1573-515X |
| 85 | Using stable isotopes to estimate young water fractions in a heavily regulated, topical lowland river basin | **Anh Duc Trinh, Thu Nga Do, Virginia N. Panizzo, Suzanne McGowan, Melanie J. Leng** | **Hydrological processes** ISSN/eISSN: 0885-6087/1099-1085 |
| 86 | Investigations of chemical and atomic composition of native oxide layers covering SI GaAs implanted with Xe ions | **P.L.Tuan, M.KulikbcJ.Nowicka-Scheibe, et al.** | **Surface and Coatings Technology** ISSN: 0257-8972 |

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| 87 | Effects of Foliar Fertilization of Micronutrients and Low Molecular Weight Chitosan on the Growth, Yield and Quality of Tomato | **Tran Minh Quynh, NguyenVan Binh and Duong Kim Thoa** | **International Journal of Agricultural Research** ISSN: 1816-4897 |
| 88 | Radiation degradation of xanthan gum for use as bioadhensive to improve the efeiciencey of foliar fertilizer. Modern Environmental Science and Engineering | **Nguyen Van Binh, Hoang Dang Sang, Tran Van An, Nguyen Thi Thom, Tran Bang Diep, Tran Minh Quynh** | **Modern Environmental Science and Engineering** ISSN: 2333-2581 |
| 89 | Investigations of elemental depth distribution and chemical compositions in the $TiO_2/SiO_2/Si$ structures after ion irradiation | **T.V.Phuc, L.H.Khiem, P.L.Tuan, et al.** | **Surface and Coatings Technology** ISSN: 0257-8972 |
| 90 | Challenges and limitations of the $^{210}Pb$ sediment dating method: Resultsfrom an IAEA modelling interlaboratory comparison exercise | **M.Barsanti, A. Laissaoui, H.Q.Nguyen, et al.** | **Quaternary Geochronology** ISSN/eISSN: 1871-1014/1878-0350 |
| 91 | From radiometry to chronology of a marine sediment core: A $^{210}Pb$ dating interlaboratory comparison exercise organised by the IAEA | **R. Garcia-Tenorioa, M. Rozmaricb, A. Harmsb,c, J.M. De Oliveira Godoyd, A. Schironee, A.C. Ruiz-Fernándezf, M. Erikssong,h, V. Hatjei, A. Laissaouij, H.Q. Nguyen, E. Okukul, et al.** | **Marine Pollution Bulletin** ISSN/eISSN: 0025-326X/1879-3363 |

## 4.2. LISTS OF INTERNATIONAL PROJECTS 2020

### 4.2.1 - LIST OF VIE PROJECTS 2020
(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 | 2021 | 210,000.00 | **Tran Chi Thanh** | VINATOM |
| VIE7006 | Assessing Flow Regimes and River Biogeochemistry of Lower Red River in an Integrated Manner Using Isotope Techniques | 2020 | 2021 | 150,885.00 | **Trinh Anh Duc** | NTC |

### 4.2.2 - LIST OF INT AND NON-RCA PROJECT 2020
(Implemented by VINATOM)

| Code | Project Title | Start Year | Finish year | Budget (Euro) | Field code | Project Counterpart |
|---|---|---|---|---|---|---|
| INT2019 | Deploying Technology and Management of Sustainable Uranium Extraction Projects | 2016 | 2020 | 1,362,599.91 | **Hoang Nhuan** | ITRRE |
| INT9186 | Sustaining Cradle-to-Grave Control of Radioactive Sources - Phase II | 2020 | 2024 | 1,653,718.75 | **Hoang Nhuan** | ITRRE |
| RAS2018 | Supporting Decision Making for Nuclear Power Planning and Development - Phase III | 2016 | 2020 | 833,564.95 | **Tran Chi Thanh** | VINATOM |

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|---|---|---|---|---|---|---|
| RAS2019 | Conducting the Comprehensive Management and Recovery of Radioactive and Associated Mineral Resources | 2016 | 2020 | 419,999.96 | **Hoang Nhuan** | 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 | **Tran The Dinh** | ITRRE |
| RAS1021 | Harnessing Nuclear Science and Technology for the Preservation and Conservation of Cultural Heritage | 2018 | 2022 | 278,474.99 | **Cao Dong Vu** | NRI |
| RAS1026 | Strengthening Nuclear Instrumentation Capacity in the Areas of Nuclear Sciences and Applications | 2020 | 2022 | 465,331.50 | **Nguyen Duc Tuan** | INST |

4.2.3 - LIST OF FNCA PROJECTS 2020
(Participated by VINATOM and other Vietnam organizations)

| Field | Project Title | Project Coordinator |
|---|---|---|
| Research Reactor Utilization Development | Research Reactor Network | **Dr. Duong Van Dong**<br>Director, Center for Research and Production of Radioisotope,<br>Nuclear Research Institute (NRI)<br>Vietnam Atomic Energy Institute (VINATOM) |
| | Neutron Activation Analysis | **Dr. Tran Tuan Anh**<br>Researcher,<br>Center for Nuclear Physics & Electronics |

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|---|---|---|
| | | Nuclear Research Institute (NRI))<br>Vietnam Atomic Energy Institute (VINATOM) |
| Radiation Utilization Development (Agricultural/ Healthcare /Industrial/ Environmental Utilization) | Mutation Breeding | **Dr. Le Duc Thao**<br>Deputy General Director<br>Agricultural Genetics Institute (AGI)<br>Ministry of of Agriculture and Rural Development (MARD) |
| | Radiation Oncology | **Dr. Nguyen Cong Hoang**<br>Head of General Radiation Oncology Department,<br>National Cancer Hospital (K Hospital) |
| | Radiation Processing and Polymer Modification for Agricultural, Environmental and Medical Applications Project | **Dr. Nguyen Ngoc Duy**<br>Head of Research and Development Department, Research and Development Center for Radiation Technology (VINAGAMMA),<br>Vietnam Atomic Energy Institute (VINATOM) |
| | Research on Climate Change using Nuclear and Isotopic Techniques | **Dr. Nguyen Trong Ngo**<br>Nuclear Research Institute (NRI),<br>Vietnam Atomic Energy Institute (VINATOM) |
| Nuclear Safety Strengthening | Radiation Safety and Radioactive Waste Management | **Assoc. Prof. Dr. Le Thi Mai Huong**<br>Deputy Director<br>Nuclear Training Center (NTC)<br>Vietnam Atomic Energy Institute (VINATOM) |
| Nuclear Infrastructure Strengthening | Nuclear Security and Safeguard | **Ms. Bui Thi Thuy Anh**<br>Director, International Cooperation Division<br>Vietnam Agency for Radiation and Nuclear Safety (VARANS) |

4.2.4 - LIST OF RAS PROJECTS 2020
(Participated by VINATOM and other Vietnam organizations)

| Code | Title | Year of approval | Budget (EUR) | Project Type | Project Coordinators |
|---|---|---|---|---|---|
| RAS1022 | Strengthening Regional Capacity in Non-Destructive Testing and Examination Using Nuclear and Related Techniques for Safer, Reliable, More Efficient and Sustainable Industries Including Civil Engineering (RCA) | 2019 | 558.600,00 | RCA | **Tran Dang Manh** Non-Destructive Evaluation Center |
| RAS5077 | Promoting the Application of Mutation Techniques and Related Biotechnologies for the Development of Green Crop Varieties (RCA) | 2017 | 635.000,00 | RCA | **Le Huy Ham** Agricultural Genetics Institute |
| RAS5081 | Enhancing Food Safety and Supporting Regional Authentication of Foodstuffs through Implementation of Nuclear Techniques | 2018 | 646.250,00 | RCA | **Nguyen Thi Hong Thinh** Institute for Nuclear Science & Technology |
| RAS5084 | Assessing and Improving Soil and Water Quality to Minimize Land Degradation and Enhance Crop Productivity Using Nuclear Techniques (RCA) | 2018 | 498.775,00 | RCA | **Nguyen Thi Hương Lan** Nuclear Research Institute |
| RAS5087 | Promoting Food Irradiation by Electron Beam and X Ray Technology to Enhance Food Safety, Security and Trade (RCA) | 2020 | 300.300,00 | RCA | **Tran Minh Quynh** Hanoi Irradiation Center |

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| RAS6086 | Strengthening Cancer Management Programmes in Government Parties through Collaboration with National and Regional Radiation Oncology Societies | 2018 | 702.450,00 | RCA | **Mai Trong Khoa**<br>Nuclear Medicine and Oncology Center<br>Bach Mai Hospital |
| RAS6087 | Enhancing Medical Physics Services to Develop Government Parties through Regional Leadership in Standards and Education and Training Support | 2018 | 531.900,00 | RCA | **Tran Ngoc Toan**<br>Vice President Vietnam Atomic Energy Institute |
| RAS6093 | Strengthening Capacity to Manage Non-Communicable Diseases Using Imaging Modalities in Radiology and Nuclear Medicine (RCA) | 2019 | 490.450,00 | RCA | **Lam Khanh**<br>Central Military Hospital 108 |
| RAS6096 | Empowering Regional Collaboration among Radiotherapy Professionals through Online Clinical Networks (RCA) | 2020 | 201.000,00 | RCA | **Bui Quang Bieu**<br>Central Military Hospital 108 |
| RAS6097 | Enhancing Capacity and Capability for the Production of Cyclotron-Based Radiopharmaceuticals (RCA) | 2020 | 445.200,00 | RCA | **Nguyen Quang Anh**<br>Hanoi Irradiation Center |
| RAS7028 | Enhancing Regional Capabilities for Marine Radioactivity Monitoring and Assessment of the Potential Impact of Radioactive Releases from | 2016 | 790,222.85 | RCA | **Nguyen Van Phuc**<br>Nuclear Research Institute, |

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|---|---|---|---|---|---|
| | Nuclear Facilities in Asia-Pacific Marine Ecosystems (RCA) | | | | VINATOM |
| RAS7031 | Assessing the Vulnerability of Coastal Landscapes and Ecosystems to Sea-Level Rise and Climate Change (RCA) | 2019 | 504.000,00 | RCA | **Le Nhu Sieu** Nuclear Research Institute, VINATOM |
| RAS7035 | Enhancing Regional Capability for the Effective Management of Ground Water Resources Using Isotopic Techniques (RCA) | 2020 | 404.225,00 | RCA | **Nguyen Kien Chinh** Center for Nuclear Techniques, VINATOM |
| RAS7037 | Enhancing Wetland Management and Sustainable Conservation Planning (RCA) | 2020 | 390.075,00 | RCA | **Tran Thi Nhu Trang** Nguyen Tat Thanh University |
| RAS9092 | Strengthening the Capacity to Respond to Radiological Emergencies of Category II and III Facilities (RCA) | 2020 | 390.075,00 | RCA | **Pham Hung Thai** Nuclear Research Institute, VINATOM |

### 4.2.5. LIST OF NATIONAL COORDINATOR AND TOPICAL GROUP MEMBER, ASIAN NUCLEAR SAFETY NETWORK (ANSN) 2020 (Implemented by VINATOM)

| Topic | National Coordinator | Topical Group Member | Institution |
|---|---|---|---|
| Asian Nuclear Safety Network (ANSN) | Tran Ngoc Toan | | Department of International Cooperation, VINATOM |

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|---|---|---|---|
| Regulatory Infrastructure (RITG) | | **Cao Hong Lan** | Department of International Cooperation, VINATOM |
| Education and Training (ETTG) | | **Pham Ngoc Dong** | VINATOM |
| Sitting (STG) | | **Truong Van Khanh Nhat** | Department of International Cooperation, VINATOM |
| Safety Assessment (SATG) | | **Tran Thanh Tram** | Nuclear Education and Training Center, VINATOM |
| Radioactive Waste Management (RWMTG) | | **Bui Dang Hanh** | Department of International Cooperation, VINATOM |
| Emergency Preparedness and Response (EPRTG**)** | | **Vuong Thu Bac** | Institute for Nuclear Science and Technology, VINATOM |
| Safety Management of Research Reactor (SMRRTG**)** | | **Luong Ba Vien** | Dalat Nuclear Research Institute, VINATOM |
| Communication (CTG**)** | | **Hoang Sy Than** | Department of R&D Planning & Management, VINATOM |
| Self-Assessment Coordination Group (SACG) | | **Cao Hong Lan** | Department of International Cooperation, VINATOM |
| RTTG (Radiation Protection)<br>(Transport Safety) | | **Pham Khac Tuyen**<br>**Nguyen Huu Quyet** | Department of International Cooperation, VINATOM<br>Institute of Nuclear Science and Technology, VINATOM |
| ITSG | | **Le Anh Tuan** | Department of International Cooperation, VINATOM |

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