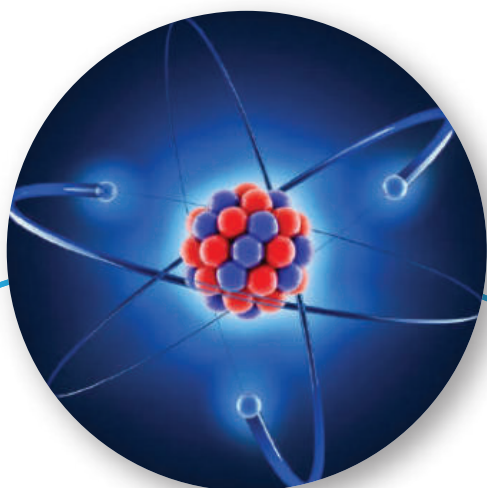




Vietnam Atomic Energy Institute

The **ANNUAL REPORT** for **2021**



Science and Technics Publishing House

VIETNAM ATOMIC ENERGY INSTITUTE

The

ANNUAL REPORT

for 2021

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SCIENCE AND TECHNICS
PUBLISHING HOUSE

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The VINATOM Annual Report for 2021 has been prepared as an account of works carried out at VINATOM for the period 2021. 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 2021

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Following the new format of the Annual Report 2020, the Annual Report 2021 of Vietnam Atomic Energy Institute is modified, completed, and issued. Despite the ongoing COVID-19 pandemic, this report aims to summarize the significant activities of the VINATOM during the period 1 January to 31 December 2021.

The first main part of this publication seeks to provide the status of the VINATOM and illustrative descriptions of the VINATOM's activities within the context of unprecedented difficulties in enduring and coping with 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. Nuclear Physics, Reactor Physics
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 VINATOM's 2021 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

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ABBREVIATIONS AND ACRONYMS

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

1- VINATOM 2021



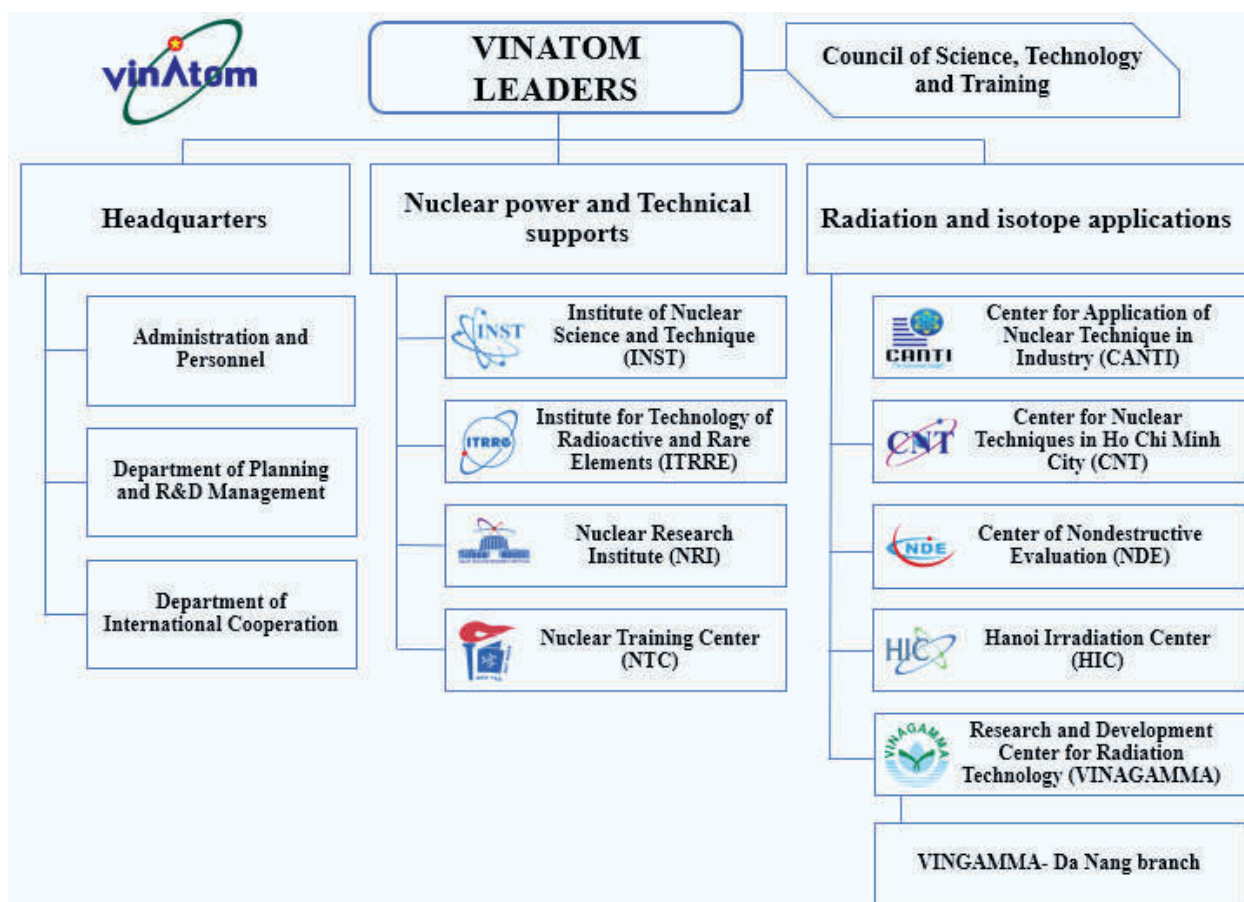
The photo of Nuclear Research Reactor in Dalat Vietnam was taken when the spring came. (source: dalattrip.com)

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 (2020-2021):

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



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

By the end of 2021, VINATOM has 768 officials and contract staff members (228 of whom are women, which accounts for 29.7%). According to Decision No. 680/QD-BKHCH dated March 29, 2021, VINATOM has been assigned 687 working people and labor contracts of 68 (the number of people working is 632, the number of contracts according to Decree 68/ 2000/ ND-CP is 55).

In terms of professional qualifications, there are 67 doctorates (including 02 professors and 08 associate professors), 196 masters, 372 people with bachelor’s degrees and 133 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 125 support staff. In terms of age, there are 153 people under the age of 30 (corresponding to 19.9%), 350 people in the 30-40 age group (45.6%), 147 people in the 40-50 age group (19.1%), There are 87 people in the age group from 50-60 years old (11.3%) and 31 people over 55 years old (female) and over 60 years old (male) whose working time is extended. This is shown in Figure 2.

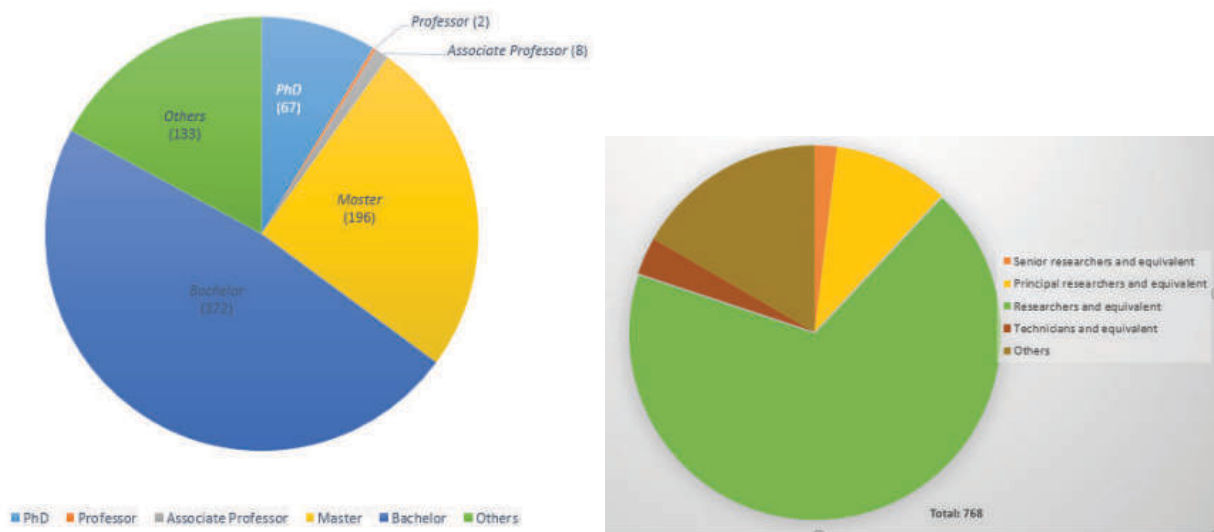


Figure 1 & 2. Academic levels of VINATOM's staff

1.2. INVESTMENT RESOURCES

In 2021, the budget VINATOM was funded by Ministry of Science and Technology was more than 174 billion VND (excluding expenses of development investment and state-level science and technology projects) to carry out research activities.



The President Tran Chi Thanh delivered the speech at the Meeting of Summarizing the work in 2021 and Orientation of the key tasks in 2022

1.3. VINATOM AND THE COVID-19 PANDEMIC

In 2021, the Covid-19 epidemic situation had many complicated and unpredictable developments that seriously affected many aspects of social life and the activities of agencies and organizations across the country. Accompanying the whole country, VINATOM as well as other units under the Ministry of Science and Technology remained active to quickly adapt to the challenging circumstances and continued carrying out its functions. While ensuring the prevention and control of epidemics, the Institute regularly promoted the propaganda, and directed its members to strictly implement the relevant documents of ministries and localities. During the time of social distancing, human resources were proactively arranged to work at the headquarters of the units to not only complete the assigned tasks but also obey the health and safety measures. The plan of “both isolation and on-site production” was implemented by VINATOM’s members in Ho Chi Minh City and Da Nang to provide the irradiation services and logistics in accordance with “3 on-site” model, flexibly and safely adapt to the new situation under the direction of local authorities. The internal security and protection as well as the security of nuclear facilities were strictly implemented in accordance with the relevant regulations.

Throughout the year, the Institute strived to successfully complete the tasks of scientific research and technology deployment as planned. We implemented the assigned tasks in the Action Program promulgated by Ministry of Science and Technology together with the Decision No. 28/QĐ-BKHCHN dated January 8, 2021 of the Minister of Science and Technology on implementation. Resolution No. 01/NQ-CP dated January 1, 2021 on key solutions for socio-economic development and state budget estimate in 2021 and Resolution No. 02/NQ-CP dated January 1/ 2021 about continuing to implement key solutions to improve the business environment and enhance national competitiveness in 2021. Nuclear science and technology were developed in association with practice, application, and focus on the quality of scientific and technological products.

In the national-wide difficult situation, the Institute closely followed the assigned functions and tasks, coordinated with relevant agencies in managing, directing and operating its members, overcame the difficulties and achieved some good results in safe operation and efficient exploitation of Da Lat nuclear reactor; and in the implementation of nuclear and related technical applications for socio-economic development such as production and supply of radioisotopes, sample analysis services, personal dosimetry services and equipment calibration, environmental impact monitoring and assessment, production and supply of agricultural products, product certification, VietGAP, etc. VINATOM’s scientific research results were also been shown by the scientific publications in 2021 in prestigious international and domestic journals. The research projects in the national key program achieved good results and were highly appreciated by the Scientific Council; some projects were evaluated well.

1.4. RESULTS OF RESEARCH, DEVELOPMENT AND APPLICATIONS

1.4.1. Highlight of research activities and service implementation

With the goal of improving the national capacity of nuclear science and technology, approaching the advanced research orientations in the field of atomic energy application in the world, supporting the project implementation of Research Center for Nuclear Science and Technology (CNST), promoting the application and development of radiation technology and radioisotopes in economic and technical branches, VINATOM's members actively strengthened the application and implementation in production and achieved the outstanding results as follows:

- Accomplishing the Request for Proposals for the mission of Development Of Feasibility Study Report and Dossier for Site Approval of CNST project; delivering the documents to the Russian partner on the occasion of the official visit to Russian Federation of President Nguyen Xuan Phuc on November 29 - December 3, 2021;
- Successfully studying and putting the number 1 horizontal channel of Da Lat nuclear reactor into use for nuclear physics research, neutron scattering measurement and staff training.
- Conducting high quality scientific research and publishing 68 international publications, 61 of which were published in the international scientific indexing (ISI) of major international journals and proceedings, regardless of many obstacles due to the Covid-19 pandemic affecting international scientific cooperation which made it almost impossible for domestic experimental groups to collect field samples and participate in the experiments abroad.
- Safely and efficiently operating the Da Lat nuclear reactor for 4,400 hours, preparing 1,002 Ci radioactive isotopes of all kinds and 2114 vials of marker kit, and supplying them to domestic hospitals with a frequency of once a week in order to accompanying and sharing with the difficulties of the country in general and the patients in particular, and exporting 7.4 Ci of radiopharmaceuticals to Cambodia;
- Successfully designing and manufacturing FMI robot to investigate the flooding at drilling rig base by gamma transmission method. Before then, foreign experts had been hired to carry out this technique.
- Successfully doing research, designing, and manufacturing automated field monitoring system for two radioactive isotopes ^{134}Cs and ^{137}Cs in seawater environment, high selective absorption efficiency (99.9%), detection limit 4.4 Bq/m³, ensuring to be operable in harsh conditions of the sea.
- Successfully applying FLEXPART software in research and simulation of radioactive material dispersion in the air when an incident at a nuclear facility was assumed to happen.
- Successfully organizing the 14th National Conference on Nuclear Science and Technology (VINANST-14) with the participation of more than 40 domestic and foreign

organizations and about 300 participants who are researchers from science and technology organizations, education and training organizations, managers of relevant ministries, branches, agencies and localities nationwide, PhD. candidates and university students. This is the first time VINANST has been held as both virtual and in-person event. 181 reports were selected after thorough review process, 111 of which were presented orally at the Technical Sessions and 70 reports were glued as Posters.

- Being certified by Ministry of Health to produce radiopharmaceuticals meeting GMP standards on the Da Lat nuclear reactor and the KOTRON-13 accelerator of Hanoi Irradiation Center. Successfully doing research, designing, and manufacturing the system and software to control the dose divider on the KOTRON-13 accelerator.
- Marking 10 years of establishing the national network of environmental radiation monitoring and warning. After 10 years of implementation, although it did not reach the scale as planned, a monitoring network was initially formed with a control center in Hanoi (located at the Institute of Science and Technology) and regional stations in the North, the Central, Central Highlands, the South regions and some other local stations;

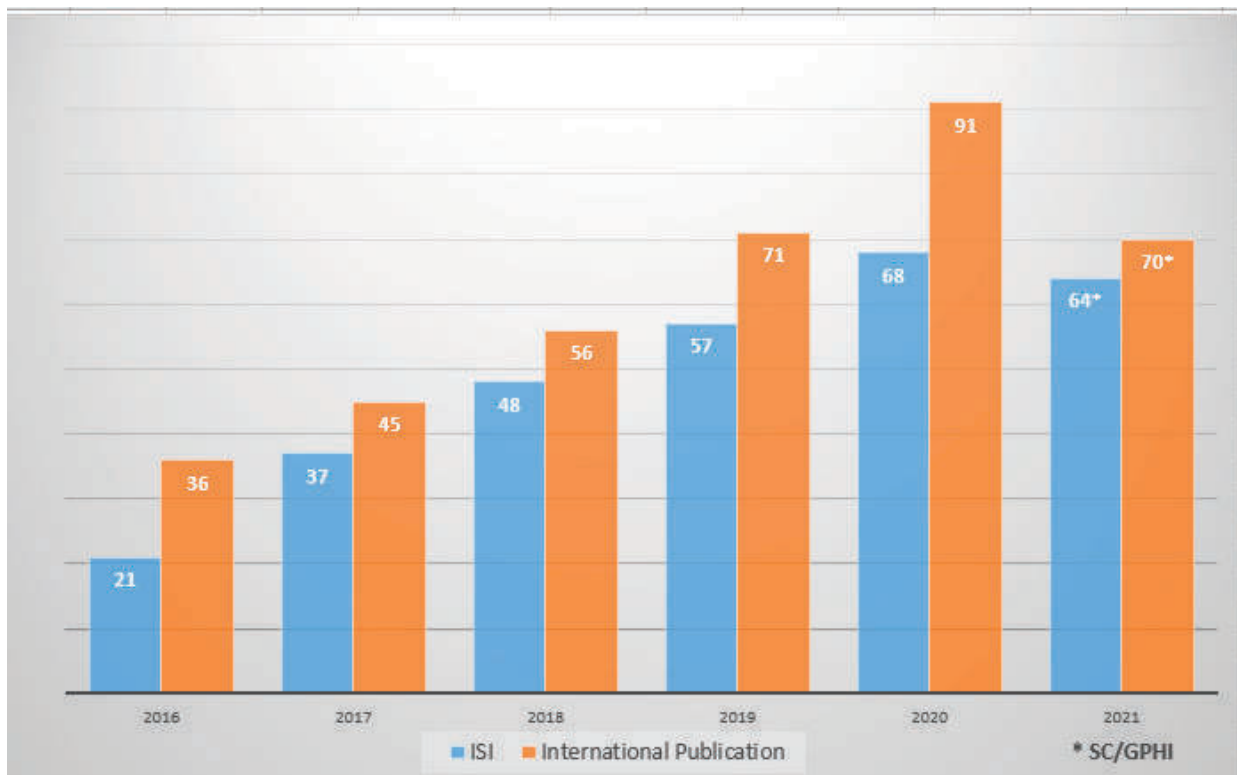
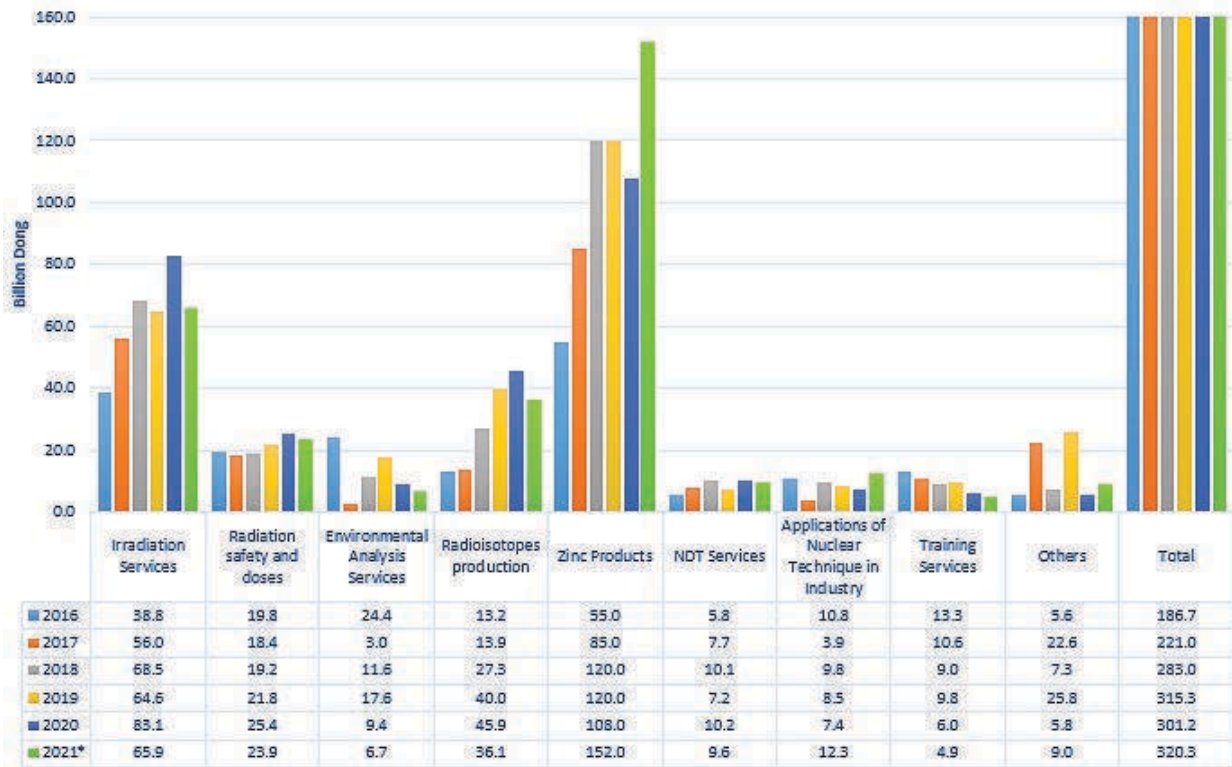


Figure 3: Summary of international publications and patents/ useful solutions in recent years

- Supporting the Board of Directors of the National Key Science and Technology Program KC.05/16-20 to successfully organize a review of 5 years of implementation with the role of the Institute as the permanent body of the Board of Directors and the President of VINATOM as the Program Director;

- Producing zinc products and achieving a revenue of VND 152 billion, exceeding 152% of the plan set out in 2021, nearly 139% higher than that of 2020;



* Estimated revenue in December 2021

Figure 4: Revenue from production and services in recent years

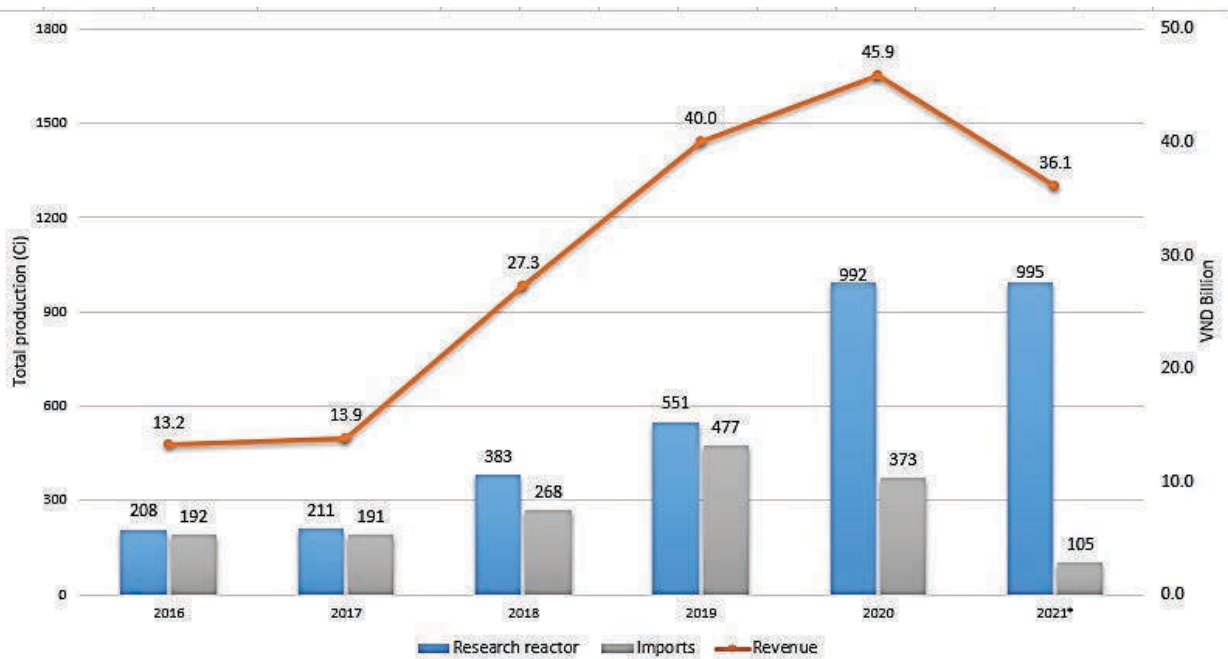


Figure 5: Revenue from Radioisotopes production

1.4.2. Scientific research

In 2021, 51 scientific research and technological development projects at the ministerial and state levels were implemented by VINATOM. 4 state-level projects belonged to the KC.05/16-20 Program; 23 ministerial projects continued to be carried out and 24 new ministerial projects were approved to be conducted. Also, the project assessment and acceptance were implemented. 4 state-level projects were assessed and accepted by Ministry of Science and Technology (01 excellent project and 3 successful ones); 19 ministerial-level projects were assessed and accepted by VINATOM in coordination with functional units of the Ministry. In addition, 100% of other institutional and ministerial-level projects were implemented and completed by VINATOM according to the planned goals and contents. Specifically:

1.4.2.1. Basic research

Nuclear Physics Research

This research orientation was implemented by the research team on Nuclear Physics at the Center for Nuclear Physics (Institute of Nuclear Science and Technology) and focused on the study of nuclear structure and nuclear interaction through microscopic description of nuclear reactions, expanding the research model for the process of low-energy nuclear reactions which is close to nuclear astrophysics, study on the physics of nuclei far from the stability line; study on nuclear reactions and nuclear data on accelerators. To do the above-mentioned studies, the research team was funded by 01 state-level project, 02 ministerial-level projects and 01 institutional-level project. The projects included: study on nuclear structure and nuclear reactions on large devices of advanced nuclear research centers in the world; study on nucleon capture (p,) reactions at low energies in the form of nuclear mean field theory; study of the structure of the neutron-rich nuclei near ^{49}Ar and ^{78}Ni through direct nuclear reaction experiments in the intermediate energy region; applying machine learning method in detecting particle according to pulse shape. The research team also had 10 ISI publications, 06 domestic articles and 05 reports at domestic scientific conferences.

The research team at Nuclear Research Institute implemented 01 state-level research project and 01 basic research project (Nafosted), with the following objectives: (i) Installing and using the horizontal channel No.1 of Da Lat reactor for nuclear physics research, neutron scattering measurement and staff training (ii) Measurement of nuclear data and level structure of some unstable heavy nuclei (^{153}Sm , ^{162}Dy and ^{172}Yb). The research team had 08 ISI publications, 05 domestic articles and 05 reports at domestic scientific conferences.

Research on Reactor Physics, Technology and Safety

Apart from maintaining the research on power reactors, the research teams of VINATOM strengthened the studies on physics and technology of research reactors, small modular reactors, floating nuclear power stations (Center for Energy - Institute of Nuclear Science and Technology). In 2021, 02 projects were carried out: Research on the problem of turning the control rod out of the reactor core of UO₂ and MOX/UO₂ fuel-loaded PWR reactors; research

and design of small nuclear reactors using the fuel bundle of the AP1000 reactor funded by National Foundation for Science and Technology Development (Nafosted) and 01 Institutional project on “Preliminary study of hydrothermal system for small modular pressurized water reactor based on ACPR50S reactor technology”. These research teams had 09 international articles in the ISI, 07 articles published in domestic journals and 11 reports at national and international scientific conferences.

The research team of NRI implemented 01 ministerial-level project on updating the preliminary plan for decontamination and dismantling of Da Lat power plant after completion of operation. They had 3 international articles on the list of journals in ISI, 01 article domestically published and 6 reports at domestic conferences.

In addition, CNT was conducting the research and development of a research reactor core simulation program based on reactor physics and fluid dynamics.

1.4.2.2. Handling and processing of radioactive ores, nuclear fuel and materials, and radioactive waste

The research and development of rare earth ore processing technology and research into application of rare earth elements continued to be strengthened at ITRRE. Some scientific and technological projects were being carried out, including: Study on the technology of making Nd metal from Nd₂O₃ oxide by electrolysis in fluoride salt; Study on the manufacture of sintered (Nd, Dy)-Fe-B magnets with high magnetic resistance at pilot plant scale, applying in motors and generators; and study on samples of Ben Den rare earth technology.

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 2021, CANTI initially paid attention to the methods of manufacturing and applying titanium powder and proposed a fabrication scheme by TiF₄ electrolysis method. VINATOM also actively built cooperation with Hung Thinh Company and Ukraine Titanium Institute in researching technology to produce titanium from Ilmenite.

Additionally, ITRRE kept maintaining the research directions on the nuclear fuel cycle including radioactive ore processing technology and nuclear fuel by the implementation of ministerial and Institutional-level projects.

1.4.2.3. Technical support capacity of safety, security, and environmental protection

VINATOM continued developing the national network of environmental radiation monitoring and warning according to Decision 1636/QĐ-TTg dated August 31, 2010 of the Prime Minister. The objective of building the National Environmental Radiation Monitoring Network is to promptly detect any unusual radiation developments throughout the territory of Vietnam, to support the proactive response to radiation and nuclear incidents and provide the database of national environmental radiation to serve the state management of atomic energy and nuclear safety. By 2021, the network initially formed 01 operation center located in Hanoi and regional

and local stations in the North, Central and South thanks to the equipment enhancement projects, science and technology projects at all levels, environmental projects, and aids from international organizations.

Simultaneously, VINATOM focused on building powerful research teams who are capable of conducting the calculations, simulations, and assess the possibility of radioactive release from possible transboundary nuclear incidents in the future, forecast incident scenarios, serve incident response in many different cases (if any). An automatic device for environmental radiation monitoring was manufactured to meet the needs of marine environmental radiation monitoring stations in the National Environmental Monitoring Network. Two national-level projects was implemented in Program KC05/16-20 on “Research and assessment of the possibility of radiation emission and impacts from China’s Fangcheng and Xuong Giang Port nuclear power plants on Vietnam”, and “Assessment of the current status of radioactive background in Vietnam’s marine environment, research on the possibility of radioactive dispersion and impacts from nuclear power plants operating near Vietnamese territory”. 6 ISI articles and many relevant articles were published in domestic journals of science and technology.

To standardize the monitoring data from the Network with a variety of monitoring equipment systems, the database of environmental radiation was integrated and built in a unified format by INST. In addition, the research team of INST carried out the project of monitoring and warning of environmental radiation from 2020 to 2022, synchronously monitoring environmental radiation status in most environmental objects. The project of monitoring and analyzing environmental radiation and stable isotopes at certain locations in Hanoi, Lang Son, Quang Ninh, Lao Cai, upstream waters of the Red River, Nam Thi River, and Ky Cung River and dust pollution in Nghia Do, Hanoi was also implemented. INST kept doing the investigation, assessment, and development of environmental radiation background data sets in the areas which were likely to be affected early by nuclear incidents outside the northern border to prepare the incident response phase 2.

Besides, NTC and CNT conducted the research on water and environment, groundwater kinetics by isotope hydrological techniques for water resource management in the Southern Delta region and implemented the project under the Technical Cooperation Program 2020-2021 (TC VIE7006).

1.4.2.4. Application of nuclear and radiation technology

The research on the application of nuclear and radiation technology in the production of isotopes and radiopharmaceuticals continued to be promoted and expanded.

NRI conducted the research on radioisotope by implementing scientific research projects, including 2 state-level projects (one of which was led by NRI and the other was coordinated between NRI and 108 Military Central), 1 ministerial-level project and 1 Institutional-level project related to the preparation of radiopharmaceuticals. The research team successfully

prepared the radioactive microsphere ^{90}Y , ^{32}P -chromic phosphate and successfully fabricated the $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$ generator and built the method to label bevacizumab monoclonal antibodies with $^{99\text{m}}\text{Tc}$. The team also published 1 international paper on the ISI list, 6 domestic articles, 1 international conference report and 4 domestic conference reports.

HIC focused on research and development of radiopharmaceuticals which are capable of being applied in diagnosis and treatment and developed the techniques for testing, analyzing, and evaluating radiopharmaceuticals' quality. The Center was also in the process of completing the procedures to be allowed to produce and supply ^{18}F -FDG to hospitals soon.

INST built and developed the capacity to research and apply physical methods, nuclear techniques and applied isotope techniques in a number of fields such as water resource assessment, hydrogeology, irrigation, environmental pollution, quality authentication and traceability of food and foodstuffs by implementing 1 ministerial-level project, 1 international cooperation project named IAEA RAS5081. The research team also applied isotope techniques to study the hydraulic relationship between the Red River flow and aquifers from Son Tay to Hung Yen and evaluated the chemical composition of water and surface water in the study area. The research team had 1 international publication on the ISI list, 1 domestic paper and 2 domestic scientific conference reports. In addition, the research, design, and manufacture of cosmic-ray neutron detectors using polycrystalline scintillators for soil moisture measurement.

NDE Center conducted the research and manufacturing gamma irradiation equipment used radioactive sources for research on plant mutation breeding in agriculture. A quality system for training NDT technicians in accordance with international standards was also studied and built.

CANTI continued carrying out the projects on applying stable isotope technology Deuterium and Oxy-18 to survey the characteristics of groundwater recharge in some areas of Long Khanh city. Moreover, this Center conducted 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; the study on the method, design and manufacture of equipment for testing leakages in gas-lifted wells by tracking techniques; the study on the tracking characteristics of some Perfluorocarbon compounds (PFC) applied to investigation of gas injection in oil fields.

HIC focused on research and application of gamma radiation technology induced mutagenesis of *Trichoderma* to quickly decompose rice straw in the field and irradiation technology for producing resistant maltodextrin from starch used as dietary fiber by implementing 1 state-level project and 4 ministerial-level projects with the aim of promoting the application of irradiation treatment: i) mutagenizing the potential microbial strain in biology and agriculture; ii) making the biologically active substances, functional materials; and iii) production of preparations and products applied in sustainable agricultural production. This research team also had 2 international publications, 2 domestic articles and 5 conference reports.

With the aim of mastering the maintenance and safe operation of the cyclotron accelerator KONTRON-13, designing and manufacturing a number of function blocks, measurement systems, and control software, the research team on application of nuclear electronics and accelerator technology of HIC focused on researching and building a new software controlling irradiation device and being compatible with the Windows 10 operating system, replacing the former software which was suitable only for Windows XP by implementing ministerial-level projects. The research team also had 4 reports at the 14th National Conference on Nuclear Science and Technology.

VINAGAMMA conducted research and development of 3D dose distribution software for research and treatment of liver cancer using microspheres attached to the radioactive isotope ^{90}Y ; research on decomposing the azo dyes from dyehouse wastewater by e-beam irradiation combined with biological; study on irradiation as a quarantine treatment of longan, mango and dragon fruit using e-beam from the UELR-10-15S2 accelerator.

CNT continued to conduct research on determining the age, origin and level of aquifers in the Southwest region; building a laboratory for low-level radioactivity analysis at CNT in accordance with ISO/IEC 17025:2017; research on establishing the X and gamma radiation standard fields in safe level of ISO 4037 standard at CNT; research on disease resistance and growth effects of rare earth organic fertilizers on catfish; research on enhancing the activity of ZSM-5 zeolites was performed by e-beam irradiation technique in cracking. In terms of nuclear electronics, reactor measurement and control, NRI carried out 1 ministerial-level project with the aim of designing and manufacturing a number of functional blocks (reactivity measurement, capacity maintenance control, control of technology parameters) of Da Lat reactor control system by DSP technique using FPGA technology. The research team had 2 national journal publications and 2 domestic conference reports.

Regarding applying nuclear and isotope techniques, NRI carried out 2 ministerial-level projects and 1 basic research project (Nafosted) with the following objectives: (i) 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; (ii) Using the trace and rare earth elements to characterize archeological materials at Cat Tien and Oc Eo - Ba The relic sites; Assessing the k_0 , Q_0 and Er nuclear data of the elements in the k_0 -NAA method. The research team had 2 ISI publications, 4 national journal publications and 4 domestic conference reports.

In regards to radiation technology and biotechnology, NRI implemented 1 ministerial-level project, 1 institutional-level project and 1 research contract with the IAEA, with the following objectives: (i) Making preparations nanoliposomes containing a radiation protectant of natural origin that support cancer radiation therapy; (ii) Developing an analytical procedure for γ -H2AX to evaluate double-stranded DNA damage caused by ionizing radiation. The research team had 4 publications on ISI list, 2 Scopus publications, 1 international publication on the list of open-access journals without ranking, 8 national publications, 1 international conference and 5 domestic conferences.

1.4.2.5. Scientific publications

In 2021, the total number of publications by VINATOM (including publications in domestic and international journals and conferences, patents/utility solution) was 325. Among 68 papers published in international journals (23 less than 2020), 62 articles were published in ISI journals and 2 patents for invention/patents for utility solution). In order to encourage scientific research, VINATOM annually establishes a Council to review and award the international publications' authors who deserve. In 2021, the Council considered and awarded A prize to 15 publications, B prize to 21 publications and C prize to 20 publications.

Table 1. Summary of scientific publications in the Institute

Units	International journals (ISI)	National journals	International conferences	National conferences	Patents /utility solution	Total
Institute for Nuclear Science & Technology	22 (22)	16	11	25	-	74
Nuclear Research Institute	19 (15)	34	2	42	-	97
Institute for Technology of Radioactive Waste and Rare Elements	6 (5)	17	-	13	1	37
Center for Nuclear Technique, Ho Chi Minh City	4 (4)	3	2	14	-	23
Research and Development Center for Radiation Technology	9 (8)	5	10	8	-	32
Center for Application of Nuclear Techniques in Industry	-	7	-	10	-	17
Hanoi Irradiation Center	3 (3)	4	-	10	-	17
Center for Nondestructive Evaluation	-	2	-	5	-	7
Nuclear Training Center	4 (4)	1	8	1	1	15
Head Quarters	1 (1)	-	4	1	-	6
Total	68 (62)	89	37	129	2	325

1.4.3. Results of applications and services

In 2021, VINATOM's members made great efforts to overcome difficulties caused by the Covid-19 pandemic and continued the application and service activities to serve the socio-economic development of the country. In general, all areas of the Institute made significant contributions to the overall results. Some outstanding results of the members are detailed as follows:

Nuclear Research Institute



By November 30, 2021, the total revenue was VND 46.07 billion and was estimated at VND 50 billion for the whole year (around 60 billion VND in 2020). The revenue of each service is specified below.

- Preparing and supplying radiopharmaceuticals and marker kits to domestic hospitals with a frequency of once a week: By December 6, 2021, a total of about 1,002 Ci radioisotopes of all kinds and 2114 kit vials were supplied. The total for the whole year was estimated at 1,100 Ci, 90% of which was produced on the Da Lat nuclear reactor. The revenue reached about 36.1 billion VND (45.9 billion VND in 2020).
- The service of direct analysis for exporting agricultural products and ensuring domestic food hygiene and safety, VietGAP assessment and certification: The revenue reached VND 3.2 billion (3.94 billion VND in 2020).
- Personal dosimetry, calibration and testing of equipment for radiation facilities: The total revenue reached about VND 4.34 billion (VND 4.95 billion in 2020).

- Environmental radiation monitoring, radioactive testing in food, exported food, environmental impact assessment of investment projects, etc.: The revenue was VND 1.44 billion (1.62 billion VND in 2020).
- Regarding radiation technology and biotechnology, a lot of efforts was made in reaching customers and promoting products. Some products are currently used by customers, such as OLICIDE to stimulate growth, orchids using tissue culture methods, chromosomal aberrations for teaching and learning. The total revenue reached VND 0.34 billion (0.98 billion VND in 2020).
- Training and fostering knowledge of radiation safety for radiation staff: 13 training courses were organized with revenue of VND 0.309 billion (0.85 billion VND in 2020).

Institute for Nuclear Science & Technology



The Institute's research results have been applied in many different fields such as measurement standards of ionizing radiation; radiation safety; consulting of radiation therapy and nuclear medicine; survey, analysis and assessment of radioactive environment, water resources; sample analysis; training services, maintenance and repair of nuclear equipment... The total revenue from application and technical services of the Institute by the end of November 2021 reached VND 14,140 billion, which shows an increase of 5.8% over the same period in 2020 (VND 13,367 billion). The total revenue includes:

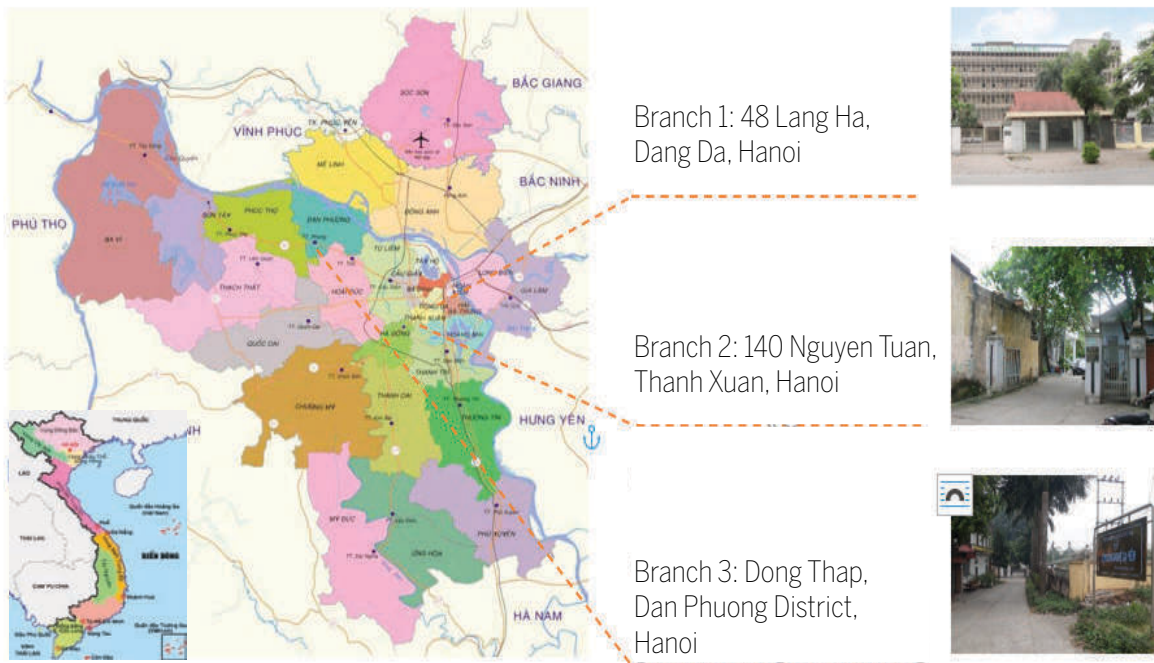
- + Radiation safety service: VND 11,276 billion
- + Analysis services: VND 1,809 billion
- + Training services: VND 1,056 billion

Institute for Technology of Radioactive Waste and Rare Elements

Like 2020, 2021 was challenging for the application, service and production activities of ITRRE due to the Covid-19 pandemic. The price of raw materials increased while trade and export activities with foreign countries were affected. In 2020, 450 catalytic aluminum mesh sheets were produced but not exported; in 2021, this production was suspended; therefore, there was no revenue during these two years. The manufacture of PVC heat stabilizers remained active at modest levels. With the efforts of the leaders and staff of ITRRE to overcome difficulties, its traditional production and service activities were kept moderate throughout the

year. Particularly, the production of the Technology Deployment Center exceeded 152% of the plan set for 2021, and exceeded nearly 139% compared to that of 2020. Despite disease conditions, the cooperation with VREC Company on consulting and technical support for ZOC factory from Vietnam sea placer brought the certain revenue to ITRRE. A number of new services were implemented during the year, including radiation measurement and research on samples of rare earth technology. The total revenue from production and service of ITRRE reached VND 157,356 billion (about VND 113,136 billion in 2020). The revenue of each service is specified below.

- + Production of zinc products: VND 152.00 billion
- + ZOC factory waste treatment service: VND 4,376 billion
- + Analysis service: VND 0.167 billion
- + Production of heat stabilizers: VND 0.250 billion
- + Other activities: VND 0.563 billion



Research and Development Center for Radiation Technology

The 4th outbreak of the Covid-19 pandemic in Vietnam caused extremely serious challenges and difficulties to the social life of the country in general and provinces in the Southern region. VINAGAMMA tried to overcome difficulties to maintain the center's main irradiation activities and achieved proud results, successfully completed the assigned tasks. The total revenue by the end of October/ 2021 reached VND 55,313 billion (VND 70.8 billion in 2020). The revenue of each service is specified below.

- + Irradiation and sterilization of food for export and sterilization of medical instruments: VND 51,539 billion
- + Manufacturing silver nano preparations, chitosan preparations, antibacterial fabrics, super water absorbents: VND 0.294 billion
- + Other activities: 3,480 billion VND



Hanoi Irradiation Center

The total irradiated goods reached about 6,819 m³, equivalent to a volume of irradiated goods of 1,705 tons with an irradiation time of about 7,100 hours. Irradiation and quarantine of fresh fruits for export reached over 110 tons, including 104 tons of lychee and 1.4 tons of mango, and 5.6 tons of longan, which shows an increase of 43.8% compared to that of 2020. The Center also well implemented other services of deploying atomic energy applications, including radiation safety training, radiation testing and incident response. At the reported time, the total revenue from these activities was expected to reach VND 12,930 billion (VND 14.822 billion in 2020). The revenue of each service is specified below.

- + Irradiation of traditional medicines and fruit quarantine: VND 10,092 billion
- + Support for implementation of radiation safety and incident response: VND 1,978 billion
- + Irradiation for research, medicine, and other activities: VND 0.860 billion



Center for Application of Nuclear Techniques in Industry

2021 was considered a fruitful year for the Center in both scientific research and service implementation. In terms of scientific research, the Center had the largest number of implemented projects by the reported time. Moreover, the research topics were new and highly applicable, and the research quality was guaranteed; Service deployment was maintained and improved, especially in the field of oil exploitation, which was re-applied after many years without any contract. In addition, the development and localization of technology, the new application field “investigation of the rig base” brought in nearly VND 1 billion, which marked a great success of the Center in the field of drilling in the domestic market, which has long been manipulated by foreign companies. The revenue from service implementation in 2021 reached over 14 billion VND (an increase of over 60% compared to that of 2020).



Center for Nuclear Technique, Ho Chi Minh City

Most of the contracts and services of the Center could not be implemented due to the lockdown/ social distancing/isolation. The revenue by the end of November 2021 reached VND 3,860 billion (a ~ 30% drop compared to the same period in 2020). The revenue of each service is specified below.

- + Radiation safety and dosimetry: VND 2,956 billion
- + NDT service: VND 0.377 billion
- + Other activities: VND 0.527 billion.



NDE Center, Ha Noi



The total revenue from service deployment by the end of November 2021 reached about VND 14.6 billion. The revenue of each service is specified below.

- + Radiation safety service: VND 1.5 billion
- + NDT service: VND 9.2 billion
- + Training services: VND 3.2 billion
- + Other activities: VND 0.7 billion

Table 3. Types of services and corresponding revenues in 2020 and 2021

No	Services	Revenue (billion VND)	
		Year 2020	Year 2021
1	Irradiation	83,111	65,884
2	Radiation safety, dosimetry	25,412	23,854
3	Analysis services, environment	9,381	6,730
4	Radioisotope production	45,900	36,100
5	Producing zinc products	108,000	152,000
6	NDT	10,237	9,577
7	Application of nuclear techniques in industry	7,372	12,333
8	Training	5,983	4,867
9	Others	5,803	8,998
	Total	301,199	320,343

1.4.4. Training and development of human resources

1.4.4.1. Doctoral Training

In 2021, VINATOM delivered 4 Doctor of Philosophy (PhD) programs including: Atomic and nuclear physics; Theoretical and computational physics; Analytical chemistry; Inorganic chemistry. The total number of lecturers participating in teaching is 51, including 48 permanent lecturers (02 professors and 8 associate professors) and 03 visiting lecturers (01 associate professor and 01 professor).

The total number of PhD candidates at NTC by 2021 was 35, 23 of whom followed Atomic and Nuclear Physics, 5 of whom followed Theoretical and computational physics, 2 of whom followed Analytical chemistry and the rest followed Inorganic chemistry.



A group photo at the doctoral defense ceremony hosted by Nuclear Training Center

1.4.4.2. Human Resources Development

Within the framework of the cooperation program on training and development of nuclear human resources between the VINATOM and the Japan Atomic Energy Agency (JAEA), 02 training courses were successfully organized: (1) Environmental radiation monitoring; (2) Radiation measurement. Due to the Covid-19 epidemic, it was impossible for Japanese lecturers to arrive in Vietnam and deliver in-person lectures; instead, they were online. Additionally, the practice on Japanese-aided equipment was directly guided by Vietnamese lecturers.

Besides, VINATOM organized the courses to improve skills, foster knowledge for the officials inside and outside the Institute, coordinated and supported the internship programs, research

skills to improve the personnel quality. The courses are specified below:

- + 02 training courses on radiation safety for 37 from Departments of Science and Technology, hospitals, and universities.
- + 01 thematic internship for 28 students from Ho Chi Minh City University of Education.
- + 01 training course on application of NO and C-CO isotope techniques in environmental research with 20 participants who are working for VINATOM.
- + 01 advanced training course on ANSYS with 20 participants who are young and working for VINATOM.
- + 02 training courses for staff of Power Construction Consulting Joint Stock Company 2 on (1) Nuclear power technology - IV generation reactors and (2) Legal framework and policy for nuclear power development in Vietnam.
- + Training and granting certificates of radiation safety for 315 students.
- + Online NDT training course for 19 students from the Ministry of Mines and Energy – Cambodia within the framework of cooperation with Cambodia in the field of atomic energy.

In addition, VINATOM also actively participated in postgraduate training at other training institutions such as Institute of Physics, Hanoi University of Science, Da Lat University, and University of Natural Sciences in Ho Chi Minh City, Hanoi University of Science and Technology... Currently, a number of the Institute's staff are following the postgraduate studies at these training institutions.



The training course on application of NO and C-CO isotope techniques in environmental research

1.4.5. International cooperation

Despite many difficulties due to complicated developments of the Covid-19 pandemic, VINATOM made efforts in maintaining specialized cooperation and integration activities with foreign partners under bilateral and multilateral mechanisms as the focal point of the government.

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, RCA program management, 11 of which have been implemented by VINATOM.

As the president of RCA in 2022, Vietnam is responsible for drafting and developing the Conference program and the documents of the Ministerial Conference to consult RCA member countries and prepare for the RCA Ministerial Meeting on the occasion of 66th General Conference of the IAEA on September 2022. Following the rule of rotating roles and duties, the 44th RCA National Coordinator Conference will be hosted by Vietnam in April 2022 in Hanoi.

As the national focal point of FNCA, VINATOM was supervising 7 FNCA projects, 4 of which were implemented by VINATOM. They focused on radiation technology application, research reactor applications, radiation safety, radioactive waste management and climate change. Due to the impact of the Covid-19 epidemic, the FNCA Symposium 2021 on “Nuclear Isotopes and Climate Change” was held online from March 3-4, 2021. At the Conference, the representative of Vietnam gave a presentation on “Application of radiation technology in Agriculture to adapt and minimize the impacts of climate change” in the Discussion session on the topic of Agriculture and Food. The participants of the Conference updated the status of climate change and the applications of nuclear techniques to mitigate the impacts of climate change in FNCA member countries such as the use of nuclear technology in monitoring environmental radiation, using stable isotopes to study global water cycles and origins, and forecasting climate models by water movement and history.

As one of two Vietnamese members of the National Steering Committee of Asian Nuclear Safety Network (ANSN), VINATOM participated in 11 thematic groups of ANSN. In 2021, the Institute updated the list of members of specialized groups at the request of ANSN. The Institute also hosted a regional webinar on strategies to attract and retain high-quality human resources in regulatory agencies within the framework of the Asian Nuclear Safety Network from October 11-15, 2021.

Regarding the cooperation with the IAEA, VINATOM kept implementing the Project VIE1010 “Promoting the program of reactor safety development” to strengthen the national capacity for safety analysis and risk assessment, and to support Vietnam in the project implementation of Research Center of Nuclear Science and Technology in Vietnam (CNST); Additionally, the VIE7006 project “Using isotopes as a tool for general assessment of flow conditions and biogeochemistry of the downstream area of the Red River system of Vietnam” was implemented. However, due to the impact of the Covid-19 pandemic, most of the training activities/scientific

visits and visiting experts of these two projects were replaced by the procurement of research equipment. Moreover, VINATOM carried out the tasks within the cooperation framework of IAEA Collaborating Centre for Water and Environment such as summarizing, assessing, and proposing the center's work plan for the period of 2021-2026 which was submitted to the IAEA for approval.

What's more, the cooperation with India was promoted in the fields of nuclear medicine, developing technology for processing monazite ore, developing relevant legal documents, and providing training courses based on Vietnam's needs. VINATOM is the focal point for implementing the Vietnam-India Intergovernmental Agreement on the use of nuclear energy for peaceful purposes signed on December 9, 2016. On March 18, 2021, VINATOM coordinated with the Indian side to co-organize the 2nd meeting of the Vietnam - India Joint Committee on atomic energy. In the meeting, the participants reviewed the implementation of cooperation in the peaceful use of atomic energy for more than two years after the first meeting was held in Mumbai-India in December 2018 and proposed new cooperation measures and directions for the upcoming period, to remark the 50th anniversary of the establishment of diplomatic relations between the two countries in January 2022.

VINATOM remains the focal point in Vietnam in cooperation with Japanese atomic energy organizations, most notably with the Japan Atomic Energy Agency. (JAEA). In accordance with the schedule and announcement of JAEA, VINATOM nominated many officials to participate in the courses organized by JAEA such as ITC, AITC, MEXT and the training courses on nuclear technology. Due to the epidemic situation, these courses were held online.

In terms of the CNST project implemented together with the partner State Atomic Energy Corporation of the Russian Federation (ROSATOM), online working sessions between VINATOM and ROSATOM were organized in 2021, which brought out positive results. The Terms of Reference for the project's feasibility study report (FS) bidding package and the contract draft were developed. Request for proposals for consulting service contract of bidding package "Development of feasibility study report and dossier for site approval" was prepared and finalized.

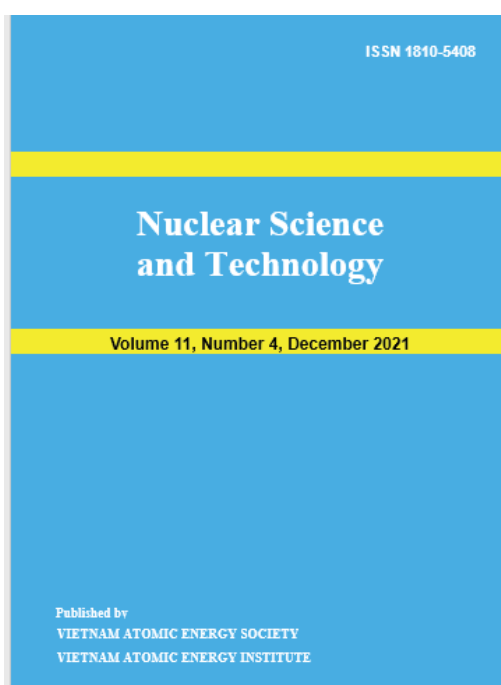
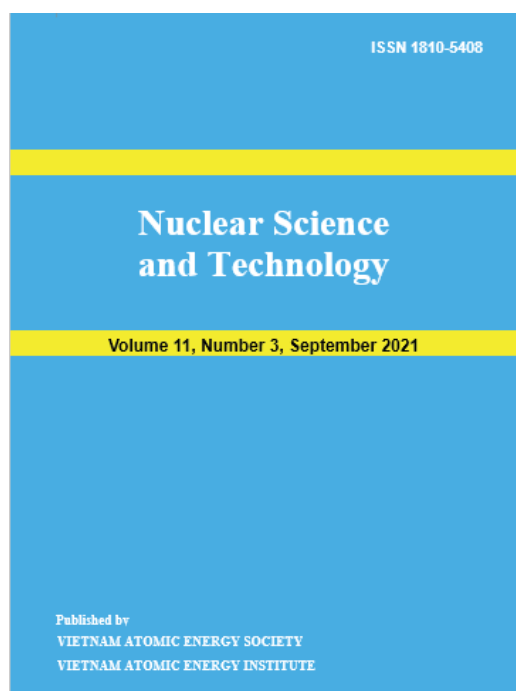
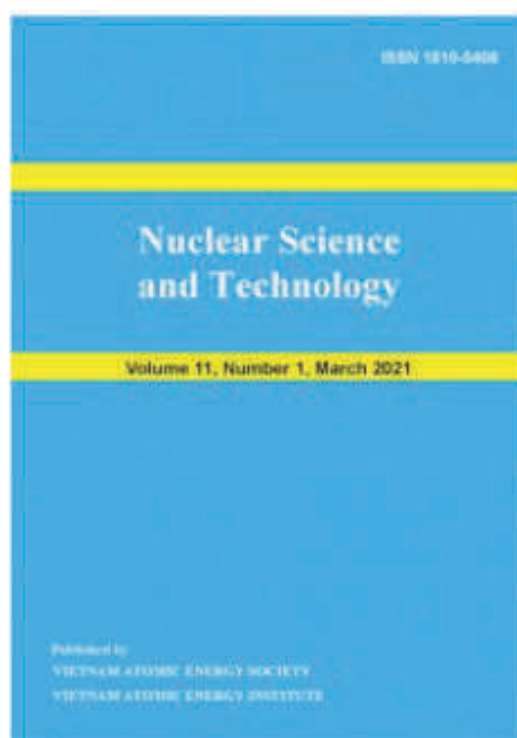


Ambassador of the Russian Federation on his arrival at VINATOM

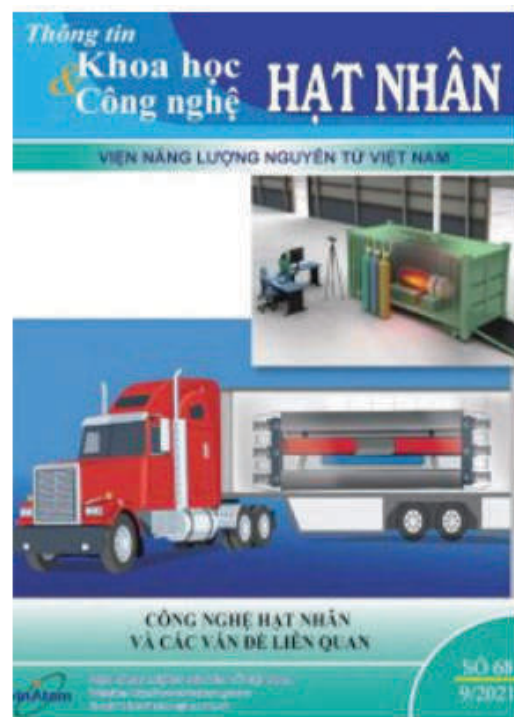
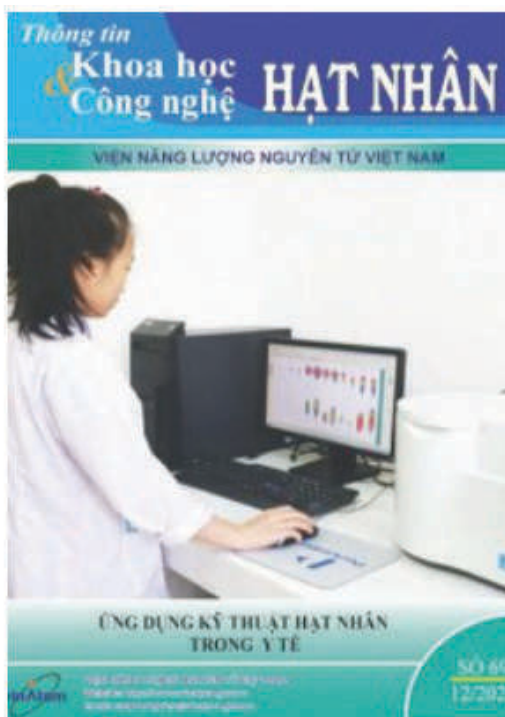
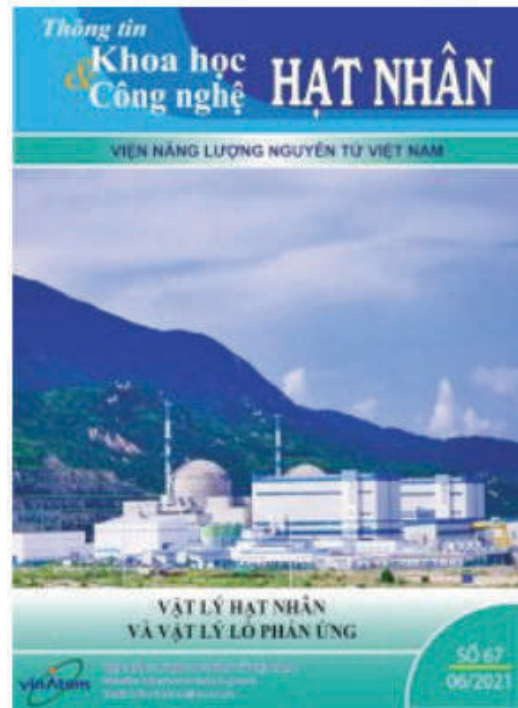
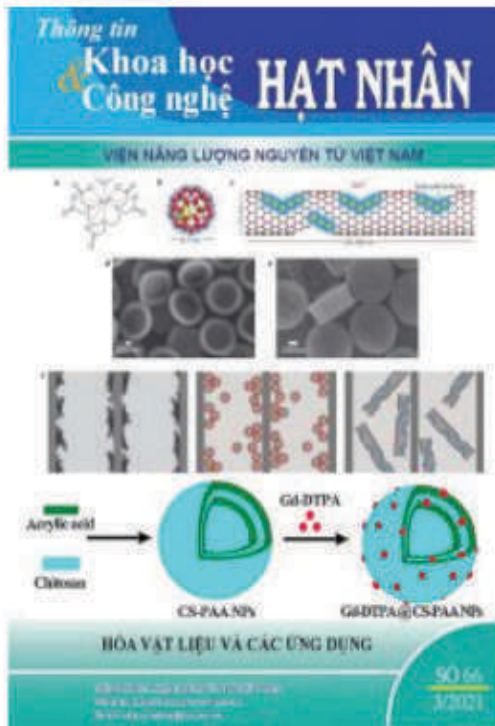
1.4.6. Information & communication, scientific conferences

The following publications were completed by VINATOM in 2021:

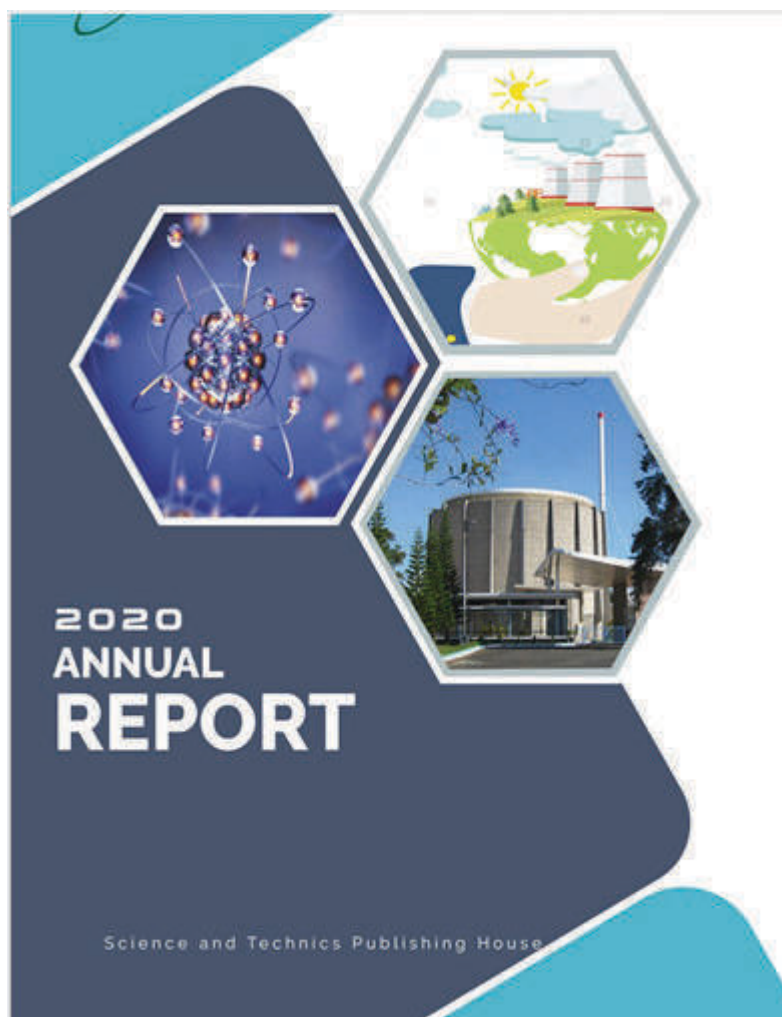
- + 4 issues of Journal of Nuclear Science and Technology (printed and online versions. Available from <https://vinatom.gov.vn/an-pham-tai-lieu/>). The Journal's website (<http://jnst.vn/index.php/nst>) has been put into trial operation, which strongly support the online submission and review of articles and is expected to officially come into operation in early 2022.



- + 4 issues of Nuclear Science and Technology Information (online versions. Available from <https://vinatom.gov.vn/an-pham-tai-lieu>)



- + Annual reports for 2020 (newly printed version providing an insight in VINATOM's activities and scientific research projects in 2020)



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 14th Vietnam Nuclear Science and Technology Conference – VINANST14 was successfully organized on December 9 and 10, 2021 in Da Lat.

1.4.7. Serving state management in the field of atomic energy

1.4.7.1. Making the Plan for development and application of atomic energy in the period of 2021-2030, with a vision to 2050

VINATOM closely coordinated with Vietnam Atomic Energy Agency (VAEA) in developing the plan for the development and application of atomic energy for the period 2021-2030, with a vision to 2050, which was approved by the leaders of Ministry of Science and Technology and then was submitted to the Prime Minister for approval. In addition, the Institute has drafted the content of formulating the planning component of the development of nuclear science and technology potential, human resource development, and ensuring safety and security, which is one of the 6 planning components of the Master Plan on development and application of atomic energy for the period of 2021 - 2030, with a vision to 2050. Also, the Institute participated in the developing the draft of technical and economic quota, making appraisal of the Master plan's component, and sending it to VAEA for synthesis and submission to MOST's leaders. On the other hand, VINATOM supported Ministry of Industry and Trade in proposing the contents and developing the budget estimates in the component of planning for development and application of radiation and radioisotopes in industry.

1.4.7.2. Technical support for radiation and nuclear safety

VINATOM paid close attention to supervising the activity of ensuring radiation and nuclear safety at its units using radioactive sources, radiation, and nuclear equipment. At VINATOM's members, particularly INST and NRI, the plans to collect radioactive sources posing a risk to the safety and security were developed. In general, the affiliated units made efforts in complying with the law on radiation and nuclear safety, nuclear security, radioactive source security and nuclear inspection. In particular, the storage, transportation and use of radioactive sources and radiation equipment was frequently reported; radiation work permits were renewed; the training on radiation safety knowledge and medical examinations for radiation workers were provided; occupational radiation dose was monitored; radiation measuring devices and radiation equipment were calibrated and verified; radioactive sources were examined and counted. The results of occupational radiation dose monitoring showed that no radiation worker was overexposed. Moreover, there was no loss of radioactive sources or radiation equipment. However, the radiation safety inspection at the units showed that there were still shortcomings and limitations that required them to overcome and continuously improve the radiation and nuclear safety according to regulations.

Also, VINATOM cooperated with VARANS and relevant units in doing research and developing drafts/regulatory documents on radiation safety and nuclear safety for the new research reactor.

1.5. INVESTMENT PROJECTS, EQUIPMENT ENHANCEMENT PROJECTS, MINOR CONSTRUCTION AND MAJOR REPAIR PROJECTS IN 2021

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

1.5.1. Research center of nuclear science and technology

The project's investment policy was approved by the Prime Minister in Decision No. 75/QĐ-TTg dated November 19, 2018. Here is the summary of the work performed:

- Establishment of the Project Management Unit (PMU) was carried out after the operating regulations of the PMU was approved and promulgated by Ministry of Science and Technology.
- Key members of the PMU who are VINATOM's staff actively coordinated with consulting contractors, domestic and foreign experts to prepare, verify, and submit for approval the Outline of tasks and cost estimates of Surveying, Making Feasibility Study Report and Site Approval Dossier, Outline of tasks and cost estimate of the bidding package, consulting for the Request for Proposals.
- Based on the content of the Decision approving the list of Confided documents of MOST, the regulations and lists of Confidential documents continued being developed by the PMU according to the guidance of Ministry of Public Security.
- The list of foreign standards to be applied in the process of making feasibility study report and basic design was updated and included in the package's outline and Request for Proposals.
- On December 1, 2021, during the official visit of President Nguyen Xuan Phuc to Russia, the Minister of MOST handed over the Request for Proposals to the partner - the GSPI State Specialized Design Institute under the Russian State Nuclear Energy Corporation (ROSATOM). It is expected that the FS Contract and the Site Approval Dossier will be signed in March 2022. In the period of 2022-2023, the FS will be implemented, and the Site Approval Dossier will be formulated.
- According to the schedule, the implementation of the EPC Contract, construction and operation of the new research reactor will be from 2024-2030. In the next phase, despite arising difficulties, CNST Project is recognized as an important project for the development of the atomic energy industry in 50-60 years. Therefore, MOST and VINATOM make great efforts to implement and meet the approved schedule of the Project.

1.5.2. National measurement standards in the field of ionizing radiation dosimetry measurement for the period 2015-2020

In 2021, the project moved ahead with the coordination between VINATOM and 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 installed, tested, and put into use at the Institute's Division of measurement standards Level II since September 2021. Other tasks of the project were carried out according to the approved schedule and finished in 2021.

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

The project's investor is Institute of Nuclear Science and Technology. The work items of the project were basically completed according to the schedule; however, due to the impact of the COVID 19 pandemic, the project was behind schedule. The actual work volume on site was mostly done. Meanwhile, there were still some unfinished items. Additionally, a lot of time was needed for inspection, evaluation, acceptance, completion of documents, ...related to the completed items, leading to the delay in disbursement. The project could not be wrapped up in 2021; thus, the request for an extension of deadline for Project to 2022 was prepared.

1.5.4. EQUIPMENT ENHANCEMENT PROJECTS

The total budget for 2020-2021 from the State budget for the projects at NRI was 129,889 billion VND for 03 projects, including: (1) Enhancing the equipment for research and production radiopharmaceuticals (20.4 billion VND); (2) Strengthening the environmental radiation monitoring and warning capacity of Radioactive Station 3 (49,264 billion VND); and (3) Enhancing the equipment for environmental research and climate change (60,225 billion VND from the State budget and 250 million VND from Development Fund).

In terms of the project of "Adding Cobalt-60 source for research and application of radiation technology in 2020-2021 of HIC", the total approved investment capital was 29,800,000,000 VND (10% of which was from Development Fund of HIC). The scale of the project is to load 200kCi of Cobalt 60 source for scientific research. At the reported time, the source of Co-60 was on its way to Vietnam. It is expected that the loading will be completed in early 2022.

Regarding the project "Strengthening the capacity of the laboratory for research and application of nuclear technology in medicine" at INST, the total investment capital was 19,730,000,000 VND. The allocated budget in 2020 was 8,730,000,000 VND. In 2021, the Institute submitted the contractor selection plan for approval to re-bid the equipment package. However, due to the impact of the Covid-19 epidemic and the implementation of cost savings, the project was cut by 1.1 billion VND, leading to difficulties in project implementation. There was not enough time for bidding in 2021; thus, it was planned to be carried out in 2022.

2- RESEARCH REPORTS 2021



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Source: <https://1boss.vn/>

2.1. NUCLEAR PHYSICS, REACTOR PHYSICS

PRELIMINARY STUDY OF THERMAL HYDRAULICS SYSTEM FOR PRESSURIZED WATER REACTOR TYPE SMALL MODULAR REACTOR BASED ON ACPR50S REACTOR TECHNOLOGY

Cao Dinh Hung, Pham Tuan Nam, Hoang Tan Hung, Nguyen Van Hien
Institute for Nuclear Science and Technology, 179 Hoang Quoc Viet, Cau Giay, Ha Noi.

Project information:

- Project name: Preliminary study of thermal hydraulics system for pressurized water reactor type small modular reactor based on ACPR50S reactor technology
- Code: CS/21/04-01
- Managerial Level: Institute
- Implementation time: 12 months (Jan 2021- Dec 2021)
- Contact email: caohung191@gmail.com
- Published papers related to the project:
 1. Cao Dinh Hung, Pham Tuan Nam, Hoang Tan Hung, Nguyen Van Hien. Preliminary study of thermal hydraulics system for small modular reactor type pressurized water reactor used for floating nuclear power plant. 14th Vietnam Conference on Nuclear Science and Technology (VINANST-14).

According to International Atomic Energy Agency (IAEA) statistics up to 2020, there are more than 70 small modular reactor (SMR) designs around the world. There are many applications of SMR, especially is installed in floating nuclear power plants (FNPP) to provide electrical and thermal energy for remote areas and offshore islands. This application is interested in many countries and some countries have suitable small modular reactor designs for floating nuclear power plants such as the KLT-40S design of the Russian Federation, the ACPR50S design of China, and the BANDI- 60 design of Korea.

ACPR50S is the small modular reactor design that China plans to install on the first floating nuclear power plant. The fact that China can deploy FNPPs in the East Sea will cause concerns for adjacent countries to the East Sea, including Vietnam. The analysis and safety assessment for ACPR50S installed on FNPP needs to calculate the physics and thermal-hydraulics parameters of the reactor core. However, the parameters of the ACPR50S's thermal hydraulic system have collected very little, so it is necessary to design an equivalent preliminary thermal hydraulic system based on the ACPR50S reactor technology. In addition to the reference parameters from the ACPR50S reactor, the missing parameters are assumed basing on theoretical calculations or the power ratio of the pressurized water reactor with full parameters.

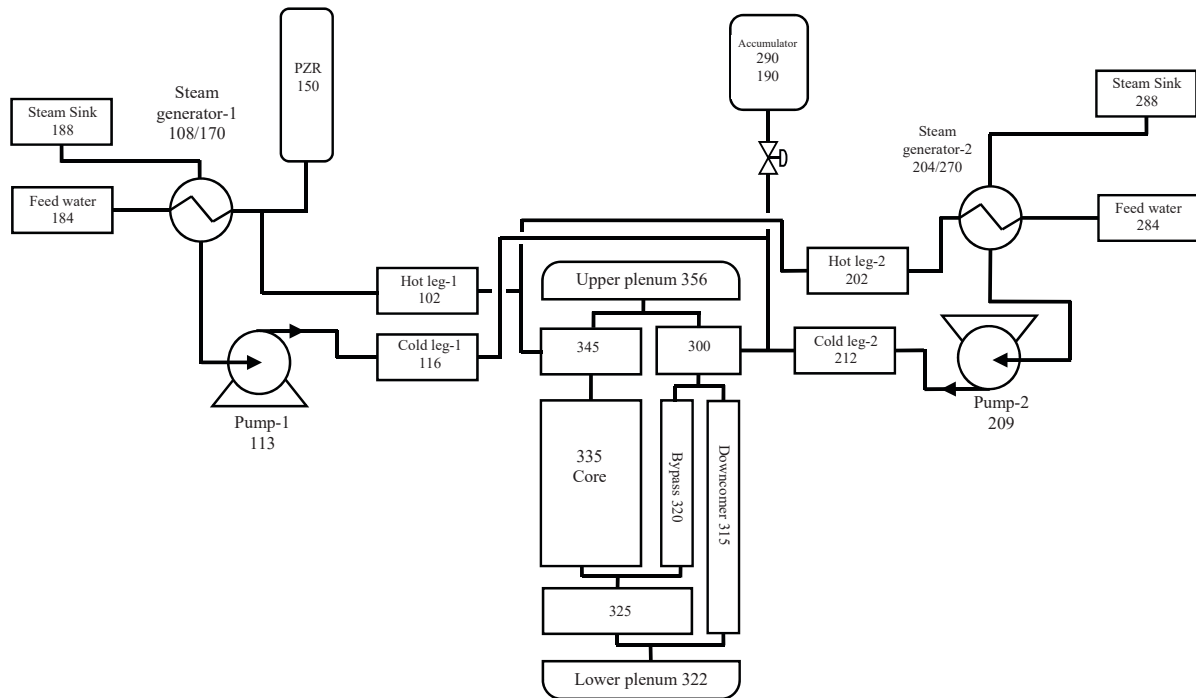


Figure 1. Nodalization of PWR thermal-hydraulic system based on ACPR50S in RELAP5

The simulation of the thermal hydraulics system based on the ACPR50S reactor is performed by the RELAP5 program. Calculations are performed in the steady state of the reactor. Figure 1 shows the nodalization diagram of the thermal hydraulics system of an equivalent pressurized water reactor (PWR) based on the ACPR50S reactor.

Important parameters such as mass flow rate of coolant, inlet, and outlet temperature of the core are consistent with the design parameters of the ACPR50S, and Minimum Departure from Nucleate Boiling Ratio (MDNBR), the temperature of fuel pellet center, outer cladding surface are compared with IAEA safety criteria.

Table 1. The parameter comparisons between simulation results and ACPR50S design, safety criteria.

Parameters	Units	Simulation values	Target values	Different
Mass flow rate through reactor core	kg/s	1325.47	1383.1259	4.17%
Inlet temperature of reactor core	K	575.20	572.30	0.51%
Outlet temperature of the reactor core	K	600.54	594.80	0.97%
Parameters	Units	Simulation values	Safety criteria	
Minimum departure from nucleate boiling ratio (MDNBR) of hottest channel		4.49	≥ 1.3	
Temperature of fuel pellet center	K	1178.45	< 2273 K	
Temperature of outer cladding surface	K	623.98	< 1755 K for PWR < 1473 K for VVER	

Table 1 shows the results of some parameters, the difference in important parameters is not large, except for the mass flow rate through the reactor core (4.17%). In addition, the temperature parameters of the fuel rod and MDNBR both meet safety criteria.

The project provides knowledge about ACPR50S reactor as well as safety criteria related to China's ACPR50S reactor. The project simulated the steady state of PWR's thermal hydraulics system based on the ACPR50S reactor. In future work, this study will be improved by reducing the error of calculation results and extending the simulation of a small modular reactor installed on floating nuclear power plants in the transient state and analysis safety of FNPP in accident cases.

2.2. INSTRUMENTATION, NUCLEAR ELECTRONIC

RESEARCH AND EVALUATION OF RADIOACTIVE CHARACTERISTICS IN MAJOR STRUCTURES AND UPDATE OF THE PRELIMINARY PLAN ON DECONTAMINATION AND DISMANTLING FOR THE DALAT NUCLEAR RESEARCH REACTOR AFTER THE END OF ITS OPERATION TIME

Tran Quoc Duong, Nguyen Kien Cuong, Huynh Ton Nghiem, Nguyen Minh Tuan, Pham Quang Huy, Vo Doan Hai Dang, Trang Cao Su, Nguyen Tien Vu, Ho Nguyen Thanh Vinh, Pham Hoai Phuong

Nuclear Research Institute, 01 Nguyen Tu Luc Street, Dalat

Project information:

- Project name: "Research and evaluation of radioactive characteristics in major structures and update of the preliminary plan on decontamination and dismantling for the Dalat Nuclear Research Reactor after the end of its operation time"
- Code: ĐTCB.05/20/VNCHN
- Managerial Level: Ministry
- Implementation time: 24 months (Jan 2020 – Dec 2021)
- Contact email: tqd79@yahoo.com
- Published papers related to the project:

Bui Phuong Nam, Tran Quoc Duong, Luong Ba Vien, Nguyen Nhi Dien, Huynh Ton Nghiem, Pham Quang Huy, Nguyen Minh Tuan, "Calculation of activity inventory in the graphite reflector of Dalat Nuclear Research Reactor using MCNPX and ORIGEN2.1 code", the 14th National Conference on Nuclear Science and Technology, Dalat, December 2021.

Tran Quoc Duong, Nguyen Nhi Dien, Nguyen Kien Cuong, Huynh Ton Nghiem, Luong Ba Vien, Nguyen Minh Tuan, Pham Quang Huy, Vo Doan Hai Dang, Do Minh Phong, Ho Nguyen Thanh Vinh, "Evaluation of neutron flux distribution in structural components and activation products in aluminum alloy at 13-2 channel of the DNRR". Nuclear Science and Technology.

Quoc-Duong Tran, Kien-Cuong Nguyen, Ba-Vien Luong, Ton-Nghiem Huynh, Quang-Huy Pham, Doan-Hai-Dang Vo, Nhi-Dien Nguyen, "Calculation of Activity Inventory in Structural Components of the DNRR for Decommissioning Planning", Science and Technology of Nuclear Installations. Reviewing.

Kien-Cuong Nguyen, Vinh-Vinh Le, Ton-Nghiem Huynh, Ba-Vien Luong, Nhi-Dien Nguyen and Hoai-Nam Tran, "Interim Storage of the Dalat Nuclear Research Reactor: Radiation Safety Analysis", Science and Technology of Nuclear Installations-Hindawi, Volume 2020, Article ID 7327045, 10 pages. DOI: <https://doi.org/10.1155/2020/7327045>.

The Dalat Nuclear Research Reactor (DNRR) was constructed in 1963 (250-kW power), and then reconstructed and upgraded to 500 kW in 1984. From the first start-up after construction, the reactor has been operating for nearly 60 years. The DNRR is an unique research reactor in Vietnam at present. The main applications of the reactor are radioisotopes production

(such as I-131, P-32, Te-99m, ...), neutron activation analysis, and manpower training for the development program of nuclear energy for peace in Vietnam. According to the strategy of using and exploiting the DNRR, the reactor is expected to be operated for about 10 years more until a new research reactor with thermal power of 10 MW is constructed and put into operation.

When the new reactor is put into operation, the DNRR should be changed its applications (only for training and education, and neutron activation analysis) or decontaminated and dismantled depending on actual conditions and decisions of top management agencies. In any case, according to the recommendations of the International Atomic Energy Agency (IAEA) and the nuclear regulatory agency in Vietnam, the Nuclear Research Institute (NRI) needs to prepare a plan in advance for decontamination and dismantling of the DNRR at the end of its operating period. This plan should be regularly updated and re-evaluated every five years.

Following the recommendations of the IAEA and regulatory agency in Vietnam, the NRI has developed a preliminary plan on decontamination and decommissioning for the DNRR as a result of a national project of “Research and evaluation of radiological characteristics in main structures and development of a preliminary plan on decontamination and decommissioning for DNRR ” during the period 2009 - 2011.

However, after 10 years of performing the above-mentioned project, some issues were identified, for example, the number and types of activated structural material samples needed to be analyzed are limited, the radiation dose of the important structural materials of the reactor has not been experimentally investigated, the computational models have been still simple, the nuclear data library has not been updated, and especially the costs for decontamination and dismantling have not been estimated following the IAEA standards. Those issues can affect the input data and information, the calculation models, the capability to verify the accuracy and reliability of the calculation and forecasting results. The major structures of the DNRR, including core, reflectors, beam channels, reactor tank, concrete biological shields, thermal column, etc. have complicated geometry, very high radiation dose, and are extremely difficult to approach, therefore it is necessary to set up an experiment on the thermal column to be able to verify the accuracy and reliability of the calculation results and models.

A national research project to assess in detail radioactive characteristics in main structures and update the preliminary plan on decontamination and dismantling for the DNRR after the end of its operation period has been proposed and implemented in the 2020 – 2021 years (it can be considered as the second phase of the national project of 2009 – 2011 years before). The proposed project is aimed to resolve the findings of the previous project and update the preliminary plan on decontamination and dismantling for the DNRR. Some of the research activities and results are summarized below.

In the DNRR, concrete and aluminum alloy 6061 (USA) and SAV-1 (Russia) are the two major structural materials and have well-known material components. The other structural materials such as beryllium, graphite, steel, and stainless steel have been sampled and analyzed by neutron activation technique to determine the contents of impurities, especially the major contributors on radiation dose rate. The precise determination of the content of these

elements is very important and is input data for calculating the activity and radiation dose rate when performing decontamination and dismantling works.

The investigation of radioactivity characteristics in the thermal column, where experimental measurements can be approached and performed, is also one of contents of the project. This investigation included the measurement of radiation dose rates at several locations inside and outside the thermal column and the measurement of gamma spectrum to identify radionuclides and radiation dose rates on some removable graphite blocks. The obtained experimental data is to verify the accuracy, reliability of the models and the calculated results of dose rate using computer codes. In addition, there are four graphite rods, which were removed from the thermal column to measure the surface gamma dose rate and sampled for analysis of gamma-emitting radioisotopes by gamma spectrometer. The results of the gamma spectrum of graphite samples showed that two main gamma-emitting isotopes contributing to the radiation dose rate are Eu-152 and Sc-46. In addition, there are many other isotopes such as Cr-51, Mn-54, Fe-55, and Gd-153. However, the concentrations of these isotopes in the samples are very low thus their contribution to the dose rate can be ignored. In which, Sc-46 has a short half-life (about 83 days), compared with the time of carrying out decontamination and dismantling works (several years), it can be considered that Eu-152 (with a half-life of longer than 13 years) is the main contributor.

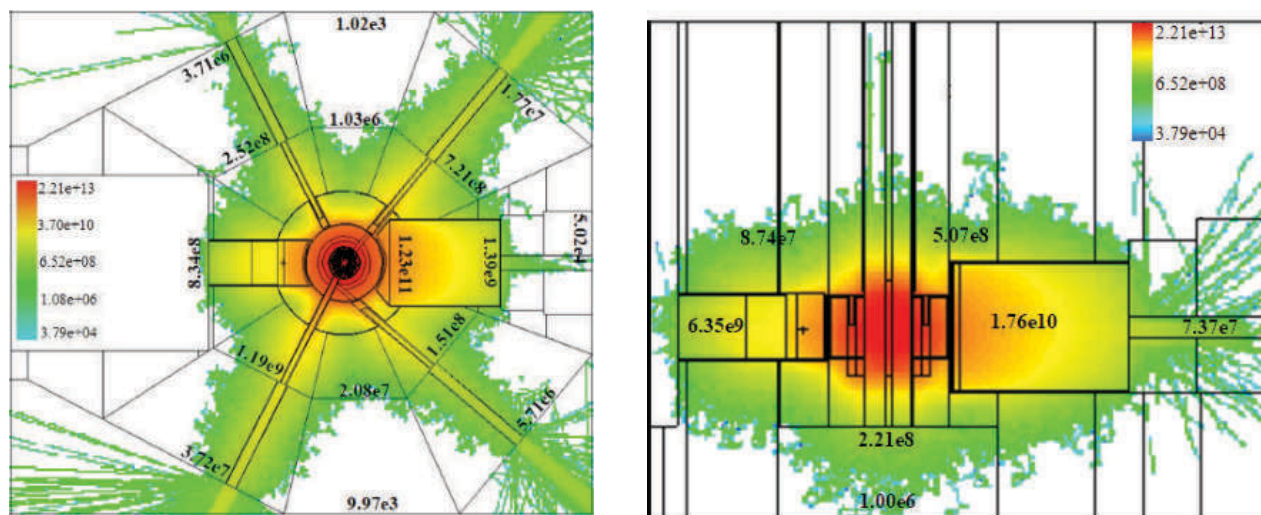


Figure 1. The calculated thermal neutron flux distribution ($n/cm^2.s$).

The detailed calculation of the neutron flux and spectrum is an important content of the project. The calculation results will be used to recalculate the interaction cross-sections of some types of nuclear reactions, the activity and radiation dose in the main structures of the DNRR. For calculations, all structures of the reactor, including core, reflectors, aluminum tank, and shielding concrete structure, were modeled with exact geometry and simulated neutron transport using MCNP5 code (Monte-Carlo N-Particle Transport Code, mode n), nuclear data library ENDF/B-VII.1, and continuous neutron energy from 10^{-11} to 20 MeV. Regarding the history of the reactor operation (1984 - 2021), there are two typical core configurations that

have been selected for the calculation, namely the configurations of 89 HEU fuel assemblies (36% enrichment of U-235) and 92 LEU fuel assemblies (19.7% enrichment of U-235). The simulated calculation by MCNP5 was performed with 10^6 particles, 305 cycles, and the “weight windows” technique was applied to reduce error, and the standard deviation reached 0.00005. As an illustration, the calculated results of the thermal neutron flux distribution are presented in Figure 1.

The calculation of radioactivity distribution in the structures of the DNRR as a follow-up calculation was performed. In this, the neutron spectrum is used to recalculate the cross-sections of nuclear reactions such as (n, γ) , $(n, 2n)$, (n, α) , (n, p) for all isotopes presented in concrete, graphite, and aluminum of the reactor. From the cross-sections of the above-mentioned reactions and flux distributions combined with the irradiation history, the cumulative radioactivity distribution in all the major structures of the reactor was determined using ORIGEN2.1 code, of particular interest is the activity of long-lived isotopes. These data are the basis for determining the volume of radioactive wastes generated from the dismantling of the DNRR. The calculation of the radioactivity distribution in the structures of the reactor was performed for the period of times: right after shutting down the reactor, then 1 year, 3 years, 5 years, and 10 years of decay. As an illustration, the calculated results of radioactivity distribution in the structures of the reactor right after its shutdown is shown in Figure 2.

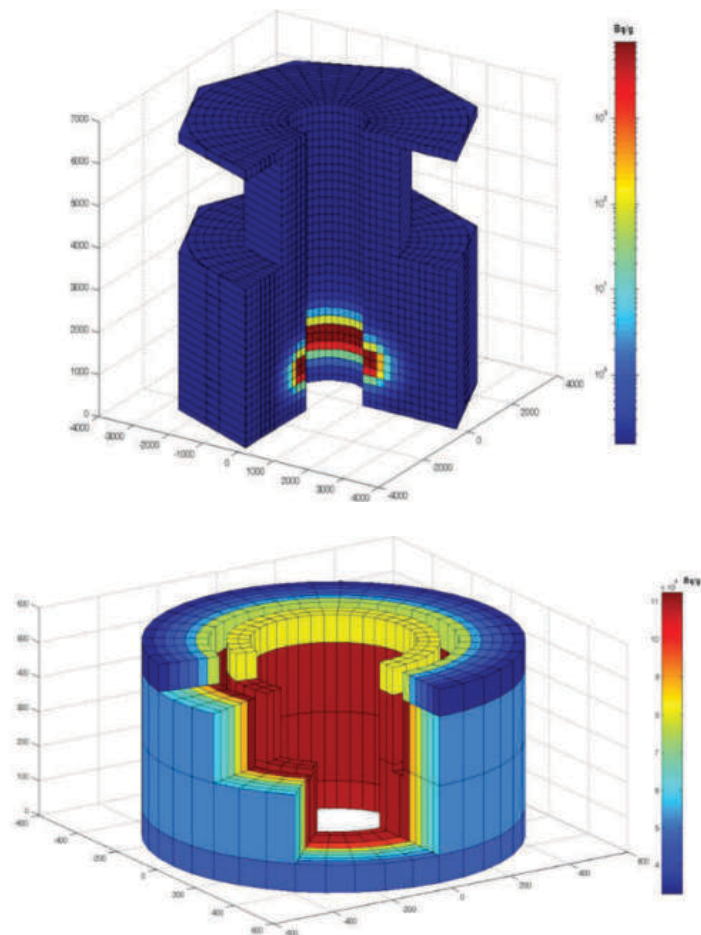


Figure 2. The calculated results of radioactivity distribution in the structures of the DNRR right after its shutdown.

The next step is to perform gamma dose rate calculations in the structures of the DNRR. The codes of WIMS-ANL, ORIGEN2.1, and MCNP5 were used to calculate the source term, photon spectrum, and radiation dose rate, respectively. The WIMS-ANL code is used to calculate the cross-sections of nuclear reactions of (n, γ) , $(n, \text{fission})$, (n, α) , $(n, 2n)$ for heavy nuclear isotopes such as U-235, U-238, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Np-237. This data is updated in the nuclear library of ORIGEN2.1 when combined with the history of the reactor operation and neutron flux, the source term, and the photon spectrum are determined using the ORIGEN2.1 code. The calculated results of the source terms and photon spectrum, especially for heavy nuclei and fission products from the ORIGEN2.1 code using 18 energy groups were continued to be used for the radiation dose rate calculation of the DNRR structures using photon transport calculation by MCNP5 code. The MCNP5 model was used to calculate the radiation dose rate includes the core area, shielding concrete structure, reactor building, and control room. Due to the complicated configuration of the DNRR and the shielding concrete structure, the non-analog computational model used with the weight-window technique was chosen. The flux-to-dose conversion factor ANSI/ANL-6.1.1-1977 is used to convert photon flux to dose. The calculation results of dose rate give a statistical error of less than 1% at all positions of interest. As an illustration, the calculation results of gamma dose rate ($\mu\text{Sv/h}$) compared with the measurement results and the calculated value of gamma dose rate depends on the cooling time since shutting down the reactor is presented in Table 1.

Table 1. The calculation results of gamma dose rate ($\mu\text{Sv/h}$) compared with the measurement results.

Positions of interest	Dose rate ($\mu\text{Sv/h}$)							
	500 kW		Calculation results of gamma dose rate depend on the cooling time					
	Calculation	Measurement	1 h	2 h	3 h	5 h	10 h	24 h
Reactor steal cover	28.66	26.50	9.76	7.64	6.62	5.53	4.28	2.87
Intermediate Floor	6.19	5.20	2.11	1.65	1.43	1.19	0.92	0.62
Reactor building	6.45	6.07	2.21	1.73	1.50	1.25	0.97	0.66
Control room	1.69	1.50	0.57	0.45	0.39	0.33	0.25	0.17

The calculation results of the distribution of radioactivity and gamma dose rate in the structures of the DNRR are the basis for establishing a suitable decontamination and dismantling strategy and plan.

Preliminary cost estimation for decontamination and decommissioning project of the DNRR is carried out based on CERREX software developed by the IAEA and applying the “Bottom-up” technique and the “Work Breakdown Structure – WBS” method. This approach has been developed in the collaboration of the European Community (EC), the International Atomic

Energy Agency (IAEA), and the OECD/Nuclear Energy Agency (NEA). When analyzing and estimating cost for the decontamination and decommissioning projects of the DNRR, the costs for decontamination and decommissioning of other nuclear facilities of some countries have been used for reference. Particularly, the preliminary cost estimation has been compared with the cost for decontamination and dismantling of the TRIGA Mark II research reactor at the University of Illinois, Champaign-Urbana, USA, which has similar characteristics to the DNRR. The preliminary cost estimation mentioned here is based on the assumption that the chosen strategy for the DNRR is immediate dismantling. In addition, the cost of storage and transport of nuclear material has not been taken into account because it is possible that the spent fuel is either stored for a long term in the NRI or will be returned to Russia.

All the above-mentioned research results have been described and updated to the decontamination and decommissioning plan following the IAEA format, including 15 chapters

2.3. INDUSTRIAL APPLICATIONS

RESEARCH AND MANUFACTURE GAMMA DETECTOR USING SCINTILLATION CRYSTAL Nal(Tl) AND SILICON PHOTOMULTIPLIER (SiPM) APPLIED IN NUCLEAR IMAGING TECHNIQUE (COMPUTED TOMOGRAPHY)

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Nguyen Ngoc Nhat Anh, Tran Minh Tien

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01 DT 723, ward 12, Dalat city, Lamdong province*

Project information:

- Project name: "Research and manufacture gamma detector using scintillation crystal Nal(Tl) and silicon photomultiplier (SiPM) applied in nuclear imaging technique (computed tomography)"

- Managerial Level: Institute

- Code: CS/20/06-02

- Implementation time: 12 months

- Contact email: hailv@canti.vn

- Published papers related to the project:

1. Building single channel gamma measurement system using silicon photomultiplier (SiPM) technology, Lai Viet Hai, Dang Quoc Trieu, Vuong Duc Phung, Journal of Thu Dau Mot University, No. 1(56) (2022).

2. Application of Nal(Tl) - Silicon Photomultiplier (SiPM) gamma detector in computed tomography setup with single - source and single-detector, Lai Viet Hai, Dang Nguyen The Duy, Dang Quoc Trieu, Journal of Thu Dau Mot University (accepted in 3/2022).

Nuclear imaging is a non-destructive or non-invasive method that uses the radiation beams emitted by radioactive isotopes to create images of the inside of industrial structures, biological bodies, or objects that cannot use invasive methods. In Vietnam, the research and application of nuclear imaging techniques in the industry have made remarkable achievements. For example, the Centre for Applications of Nuclear Technique in Industry - CANTI has successfully researched and manufactured gamma-ray tomography devices. However, these devices use Nal(Tl) scintillation detector combined with a photomultiplier tube - PMT, with high performance but sensitive to the magnetic field, poor mechanical strength, and relatively high cost. Today, with the development of science and technology, many types of photodetectors have emerged that have many advantages and overcome the limitations of PMT, the most prominent of which is the semiconductor photomultiplier - SiPM. Therefore, in order to enhance the applicability of gamma-ray tomography as well as other transmitted gamma techniques, CANTI has implemented the project "Research and manufacture of gamma detector using scintillation crystal Nal(Tl) and silicon photomultiplier (SiPM) applied in nuclear imaging technique (computed tomography)".

The objective of the project is to successfully fabricate a gamma detector using NaI(Tl) scintillation crystal combined with silicon photomultiplier - SiPM and a single-channel measurement system for this type of detector. In this project, we used a 0.5-inch x 1-inch NaI(Tl) crystal combined with semiconductor photomultiplier (SiPM) - MICROFC-60035-SMT-TR1 (ONSEMI) with optical glue Meltmount to build a gamma detector and made electronic circuit units such as bias source, amplifier, pulse amplitude discrimination, low voltage source, then combined these blocks with each other and with the module Arduino MEGA 2560 PRO to form a complete single-channel gamma measurement system. To control the measurement system, the project team programmed software to control, store and display data. To investigate the operability and applicability of the detector in computed tomography, experiments such as resolution-performance survey, time-stability survey, and application of detector in computed tomography imaging, were carried out. As a result, the resolution at the energy peaks of 511 KeV and 662 KeV is 20.61% and 18.75%, respectively, compared with the Ludlums M44-62 detector having a same crystal, which is 2.37 (8.68%) and 2.19 (8.56%) times smaller. The full-energy peak efficiency at 662 KeV is 2.60×10^{-4} , which is 1.27 times that of the Ludlums M44-62 detector (2.04×10^{-4}). In the survey of stability over time, the deviation of the ^{137}Cs spectral peak fluctuates in the range of 20mV and the average energy resolution fluctuates around 0.64% with a duration time of 20 hours and the measuring step is 10s/spectrum. The results of tomography with three different specimens were able to determine the structure of the specimens.



Figure 1. NaI(Tl)+SiPM detector and single-channel measuring system for this type of probe

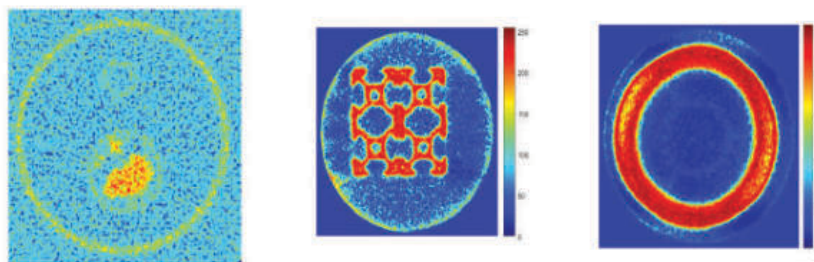


Figure 2. Reconstructed images of the specimens using tomography method

From the obtained results, it can be concluded that the project has achieved the expected objectives, proving the applicability of SiPM in the field of gamma-ray tomography as well as use of NaI(Tl)/SiPM detectors in other transmitted gamma techniques such as column scanning, and flooded member detection, and so on.

RESEARCH, DESIGN AND MANUFACTURE OF THE BRIDGMAN FURNACE APPLICATED IN SCINTILLATION CRYSTALS GROWTH USE IN RADIATION MEASUREMENT

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Huynh The Phi¹, Phan Viet Cuong¹

¹Radiation Technology Research and Development Center - Da Nang Campus

²Institute of Nuclear Science and Technology

Project information:

- Project name: "Research, design and manufacture of the Bridgman furnace applied in scintillation crystals growth use in radiation measurement"
- Code: Cs/21/07-02
- Managerial Level: Institute
- Implementation time: 18 months (Jan 2021- Jun 2022)
- Contact email: votaidai1994@gmail.com
- Published papers related to the project:

1. Lam Tan Truc et al., Research on properties of self-made Bridgman furnace grown scintillation crystals, Proceedings of the 14th Vietnam Conference on Nuclear Science and Technology (VINANST 14), Da Lat, Vietnam, 2021.

In line with the general trend of the world, the application of nuclear technology for daily life has been developing strongly in Vietnam in recent years. Accompanying this development is the use of a large number of detector systems containing scintillation crystals. It can be said that the crystal culture technology in the world is still a potential field, although it has made great strides and far. The current main direction in crystal culture is to find new substances, new blends that bring better measurement performance, resolution, durability, cost,... This is a promising research direction and is completely suitable for the difficult equipment conditions in Vietnam.

The Bridgman method was developed by Percy Williams Bridgman in the 1920s and perfected by Donald C. Stockbarger. This is the method commonly applied to grow semiconductor monocrystals, alkali metal halide monocrystals, because of its simplicity, ease of access and implementation, as well as reasonable investment costs. The ideal temperature diagram of a Bridgman-type crystal furnace is depicted in Figure 1.

The objective of the project is to successfully fabricate a Bridgman-type crystal furnace capable of growing NaI crystals and some other types of crystals. In addition, one of the objectives of the

project is to create learning and research conditions for young staff at the Center for Research and Development of Radiation Technology - Da Nang Campus. The process of implementing the topic according to 3 contents. Content 1: Studying the working principle and mechanism of crystal formation of the Bridgman method, thereby designing a detailed kiln diagram. Content 2: Fabrication of kilns with physical parameters programmed for automatic control. Content 3: Check the properties of cultured crystals, process data, summarize and evaluate the topic.

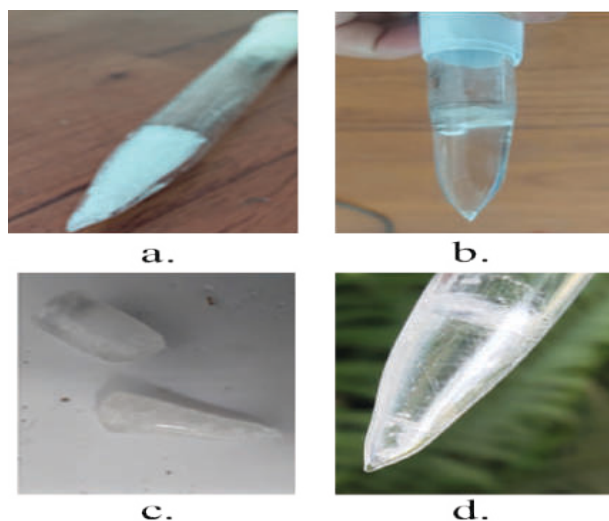


Figure 1. Bridgman type crystal furnace



Figure 2. Crystals raised from home-made Bridgman furnace

Figure 1. Bridgman crystal furnace after fabrication. The furnace after fabrication has the following parameters: Working voltage 220V-AC, maximum power consumption 1000W, actual power consumption about 770W, furnace core inner diameter 50mm, fine travel length body 420mm, maximum working temperature 800°C, temperature error within 2°C, number of temperature sensors 6, stepper motor operating in differential divider is 1/2, 1/4, 1/8, 1/16, 1/32, automatic operation method with parameter monitoring via HMI screen and Website interface

After successfully designing and manufacturing the kiln, the crystal growing process was carried out with crystals: KDP crystals (KH_2PO_4), NaI crystals and CsI crystals. KDP crystals are used as electro-optical modulators, optical switches (Q-Switches) and laser frequency modulators through quadratic and third-order nonlinear effects. NaI crystals are widely used in nuclear medicine, logging, environmental monitoring, high-energy physics, and in many other applications. CsI crystals are useful in applications as diverse as: Specialized applications in high-energy, nuclear, space and medical physics. The results are shown in figure 3.

Figure 2a shows that KDP crystals were grown at 258 with 24 hours of incubation, resulting in crystallization not completely dissolved because the culture temperature and incubation time were set lower than the required parameters. Figure 2b shows that KDP crystals were grown at 262 with a culture time of 48 hours and the diameter of the crystals was twice as much as that of sample 1, the results after increasing the temperature and time were clear crystals, KDP

salts completely dissolved, no air bubbles appear and no cracking. Figure 2c shows NaI crystals grown at 690 for 36 hours, the results obtained are cloudy crystals - this is a sign of the lack of time to grow the crystals, the amount of salt has not been dissolved. Figure 2d shows that CsI crystals were grown at 650°C for 288 hours, the results obtained were completely dissolved CsI crystals, no air bubbles and no cracks. From the above results, it can be seen that the initial crystal culture was successful with KDP crystals, CsI crystals. With NaI crystals, although the process of growing NaI crystals has not been successful, important experiences have been gained in culture. And with these experiences will be a stepping stone for future successes.

Although the design and manufacture of the kiln has been completed and successfully raised some crystal samples, the study still has some limitations that need to be completed. In the coming time, the kiln will be improved to improve operating parameters such as: Increase the maximum working temperature, reduce temperature error, reduce power consumption, perfecting the monitoring and remote control system through the website. At the same time, the new flashing crystals will be studied about the parameters of physical properties, and suitable cultivation procedures will be developed from the results learned.

2.4. APPLICATIONS IN ECOLOGY, ENVIRONMENT AND GEOLOGY

BUILDING UP A QUALIFICATION SYSTEM FOR TRAINING NDT TECHNICIANS ACCORDING TO THE INTERNATIONAL STANDARDS

Dang Thi Thu Hong et al

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

Project information:

Project name: “Building up a qualification system for training NDT technicians according to the international standards”

Code:

Managerial Level: Ministry

Implementation time: 30 months (Jan 2020- Jun 2022)

Contact email: dangthuhong76@gmail.com

Published papers related to the project:

1. Dang Thi Thu Hong, “Researching for building up training qualification system according to international standards”, Vietnam Journal of Science, Technology and Engineering, The Ministry of Science and Technology, Vietnam, Sep 21st, 2020.
2. Dang Thi Thu Hong et al, Presentation “Researching for building up training qualification system according to international standards”. Vietnam Conference on Nuclear Science and Technology – VINANST XIV (Dec 2021).

As a particular field, Non-destructive testing (NDT) is continuously developed; New and more advanced methods and techniques have emerged, utilized, and even capable of replacing the conventional or out-of-date ones. Simultaneously, the relevant training documents, standards, and regulations used not only during operations but also in the NDT personnel training and evaluation have been added and updated. On the other hand, appropriately applying diverse international standards for the NDT working procedures is necessary to meet the requirements of the market and industry. For instance, the process of building training programs, NDT personnel evaluation and certification should comply with not only ASNT SNT - TC - 1A but also ISO 9712/TCVN 5868 as well, which is an indispensable orientation for the Center to meet the increasing needs of the society and to be ready for approaching the world’s developed science and technology in the coming period of the “global integration”.

The Project aims to build a qualification system of training according to the ISO 9001:2015. This training program shall be studied and developed to adapt the demand of training and evaluation activities of the Center with providing qualified personnel proactively without other international organizations (high cost and not proactive about time). In addition, the project is expected to expand the staff of highly qualified personnel whose capabilities satisfy the requirements of daily activities of the Center and make them suitable to joint international

projects in Vietnam and abroad. Another objective of the project is capacity building with facilities by using government's donation and operating expenses. The facilities include the equipment, test samples for training and evaluation purposes.

The methods of this study are listed below.

Firstly, study relevant documents, build and standardize essential requirement of a NDT training center (Figure 1)

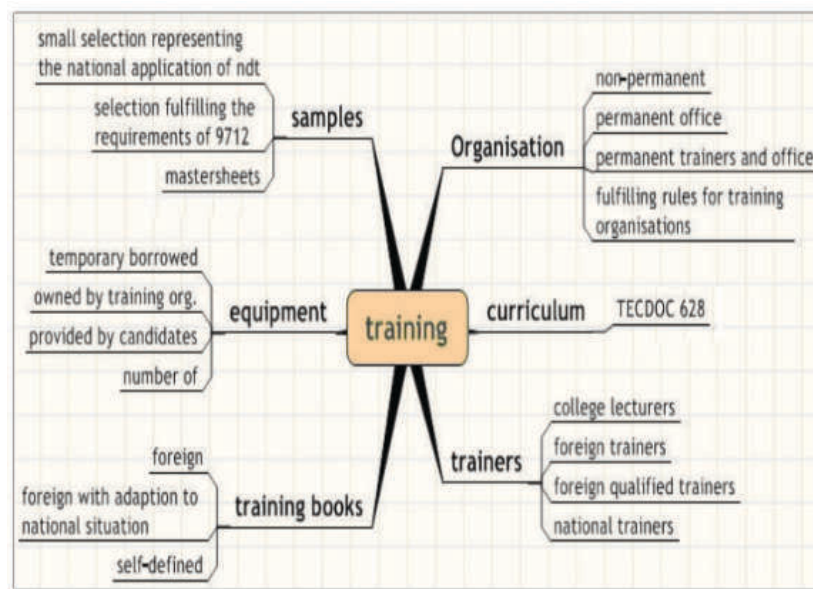


Figure 1: Essential requirements for an NDT training Center

Secondly, study popular NDT training programs worldwide, build NDT programs with characteristic features which are suitable for industrial development of Vietnam.

Thirdly, set up technical seminars and collect feedback from experts. Conduct training courses to introduce and initially evaluate the training programs according to ISO 25107, also apply ISO 9001:2015 in implementation and management of training programs.

Finally, invite certified agencies in Vietnam as advisor, evaluator, and certifier to certify the NDE Center's built programs which fit and meet requirement in ISO 9001:2015.

The main products of the Project consist of the followings:

- (1) A handbook of training quality
- (2) A series of training programs for the 6 methods of NDT in accordance with ISO/TR 25107
- (3) A set of criteria in evaluating a system of NDT training facilities based on ISO 25108:2018
- (4) Procedures for training and managing the training quality
- (5) A dossier set for Internal Quality Assessment
- (6) Certification of Quality system according to ISO 9001:2015 from Viet Nam Certification Centre QUACERT (FIG 2)



Figure 2: ISO 9001:2015 CERTIFICATE for Quality Management System

In general, the products of the Project were completed on schedule; however, more testing and modification are necessary to be done in the future prior to putting them into practice. During the implementation of the Project a lot of valuable advice from experts and partners in the field of NDT were received. It is expected that the established program will be effectively applied to the training activities at the NDE Center and it could be widely applicable to the potential NDT markets such as Laos and Cambodia.

It can be seen that the quality system for training NDT technicians built within this Project is a great step towards the promotion of the internationalization process, it contributes to the goal of building the NDT certifications system according to the ISO 9712, it improves the quality of the NDT training inside Vietnam with the purpose of approaching the achievements of the developed countries in the world. The successful implementation and application of this Project will be a driving force to strengthen NDE's leading position in personnel training, develop the highly qualified personnel who can perform a variety of professional tasks at key industrial projects of Vietnam.

2.5. APPLICATIONS IN BIOLOGY, AGRICULTURE AND MEDICINE

APPLICATION OF STABLE ISOTOPIC TECHNIQUES USING DEUTERIUM AND OXYGEN-18 TO SURVEY THE GROUNDWATER RECHARGE CHARACTERISTICS IN LONG KHANH CITY

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Nguyen Huu Quang, Duong Thi Bich Chi, Le Van Son

Center for Applications of Nuclear Technique in Industry, 01 DT723, 12 Ward, Da Lat

Project information:

- Project name: Application of stable isotopic techniques using deuterium and oxygen-18 to survey the groundwater recharge characteristics in some areas of Long Khanh city
- Code: ĐTCB.18/19/TTUDKTHN
- Managerial Level: Ministry
- Implementation time: 24 months (Nov 2019- Oct 2021)
- Contact email: Email: tribq@canti.vn
- Published papers related to the project:

1. Bui Quang Tri, Huynh Thi Thu Huong¹, Pham Uyen Thi¹, Duong Thi Bich Chi¹, Phan Thi Luan¹, Le Thi Thanh Tam¹, Tran Trí Hai¹, Le Van Son¹, Nguyen Van Muoi², Dang Duc Nhan³. Study on the isotopic composition of rainwater in Long Khanh city, Southeast of the Mekong Delta region. Vietnam Journal of Science and Technology, Vol 63(8), 2021, p.14-18 (in Vietnamese).

2. Pham Uyen Thi, Bui Quang Tri, Huynh Thi Thu Huong, Duong Thi Bich Chi, Le Van Son. Use of oxygen-18, hydrogen-2 in hydrological studies and groundwater recharge in Long Khanh area. Proceedings of the 14th Vietnam Conference on Nuclear Science and Technology (VINANST 14), Da Lat, Vietnam, 2021.

Stable isotopes of deuterium and oxygen-18 (^2H and ^{18}O) in water molecules are useful indicators in studying the genesis of groundwater, the hydraulic interaction between surface and groundwater, in estimating the evaporation rate of water from lakes as well as in the climate change investigation. The genesis of groundwater and the hydraulic interaction between surface and groundwater were discussed based on the local meteoric water line and the water line of surface water. These are the relationships between isotopic composition of deuterium and oxygen 18 ($\delta^2\text{H}$ and $\delta^{18}\text{O}$) in both types of water. Additionally, the isotopic compositions of local precipitation, of water in lakes, rivers or springs are the data used in the estimation of the contribution of surface water to groundwater as well as in the estimation of evaporation rate of water from lakes in comparison to the input flow (E / I) which is an important parameter that quantifies the loss of lake water under the local climatic conditions.

This study consists the following activities: collecting local precipitation and surface water from Suoi Tre lake bimonthly, sampling groundwater around Long Khanh city during the dry and rainy seasons

followed by analyses for the isotopic compositions ($\delta^2\text{H}$ and $\delta^{18}\text{O}$) in the collected water samples. Based on the isotopic compositions in local precipitation and in those from the lake the local meteoric water line for the Long Khanh city (LKLLMWL) and evaporative line (LEL) for the Suoi Tre lake were built. The data of $\delta^{18}\text{O}$ in the water samples were used for the assessment of the surface water recharge to groundwater in the uppermost aquifer (β_{qp_2}) and used for calculation of evaporation rate of Suoi Tre Lake.

During the research period from April 2020 to February 2021, 19 rainwater samples were collected at Long Khanh Meteorological Station. Sixty-one groundwater, of which 31 samples were collected in the dry season and 30 samples in the rainy season. Ten water samples from small springs around the study region were collected, of which 4 samples were in the dry season and 6 samples in the rainy season. Twenty-nine water samples from Suoi Tre Lake were collected at the time of precipitation collection. All the samples were stored in 500ml plastic bottles with two tight-fitting lids to avoid evaporation and transferred to the laboratory in Da Lat for analysis of the isotopic compositions of deuterium and oxygen 18 ($\delta^2\text{H}$ and $\delta^{18}\text{O}$).

The isotopic compositions ($\delta^2\text{H}$ and $\delta^{18}\text{O}$) of the water samples were quantified using an IWA-35EP laser spectrometer (Los Gatos Research - LGR) at the Laboratory of Isotope Hydrology and Environment of the Center for Applications of Nuclear Technique in Industry. A quality control program for the analyses was performed by conducting an inter-laboratory comparison analysis with the participation of Isotopes Hydrology Laboratories of the Center for Nuclear Techniques in HCM city and of the Institute for Nuclear Sciences and Technology in Ha Noi. Results of the exercise showed that the deviation of the $\delta^2\text{H}$ and $\delta^{18}\text{O}$ from the mean values derived from the three Laboratories was within $\pm 3\%$.

Figure 1 depicts the local meteoric water line, this is a relationship between $\delta^2\text{H}$ and $\delta^{18}\text{O}$ in rainwater over the Long Khanh city (LK LMWL) along with the Global Meteorological Water Line (GMWL). Figure 2 presents a relationship between $\delta^2\text{H}$ and $\delta^{18}\text{O}$ of water samples from Suoi Tre Lake along with the LK LMWL. The relationships between the $\delta^2\text{H}$ and $\delta^{18}\text{O}$ of the groundwater samples in relation to the LK LMWL in the dry and rainy seasons are presented in Figures 3 and Figure 4, respectively.

As seen from Figure 1, the $\delta^{18}\text{O}$ values of rainwater range from -10.91‰ to -1.59‰ with an average of -7.28‰ ; the $\delta^2\text{H}$ values ranges from -73.64‰ to 0.36‰ with an average of -47.12‰ ($n = 19$). The local meteoric water line LK LMWL follows the model $\delta^2\text{H} = (7.89 \pm 0.38) \times \delta^{18}\text{O} + (10.31 \pm 2.93)$; ($R^2=0.96$). Experimental results show that the value of d-excess calculated based on the equation $d\text{-ex} = \delta^2\text{H} - 8 \times \delta^{18}\text{O}$, varies from time to time of sampling and ranges from 4.76 to 18.23‰. The slope and d-excess of the LK LMWL reflect a fact that the moisture causing rain over the Long Khanh area originates mainly from the ocean.

The isotopic compositions in water samples from Suoi Tre Lake distributed along the right side and positioned lower the LK LMWL characterizing for a local evaporation line (LEL) with a slope of 5.92 (Fig. 2). This indicates that water in the lake is enriched in the heavy isotopes due to the evaporation effect. As seen from Fig. 2, during the rainy season isotopic compositions of lake water positioned right on the local meteoric water line indicating lake water is rainwater (Fig.2). The d-excess of the LEL is -6.3‰ lower than that of the LMWL (10.31‰) confirming the enrichment in the water heavy isotopic compositions in lake water due to evaporation.

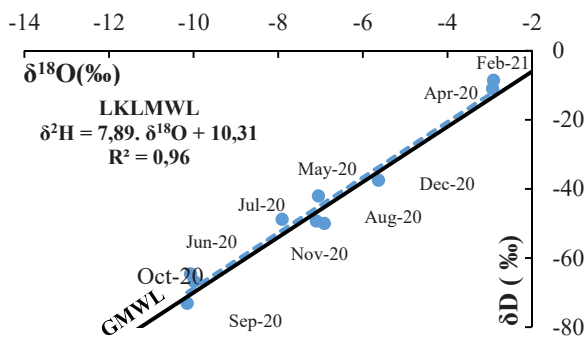


Figure 1. Long Khanh local meteoric water line (LK LMWL) depicted along with the global meteoric water line ($2H=8 \times 18O+10$)

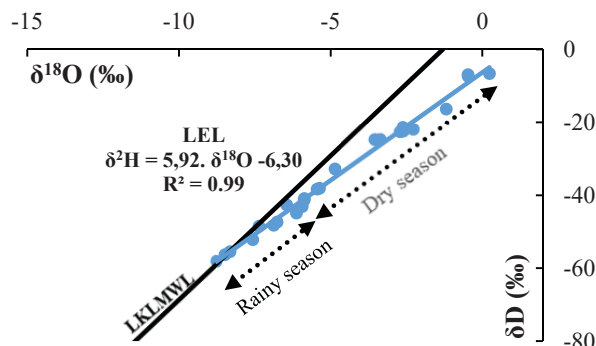


Figure 2. Isotopic compositions ($\delta 18O$ and $\delta 2H$) in Suoi Tre Lake water (LEL) depicted along with the local meteoric water line (LK LMWL)

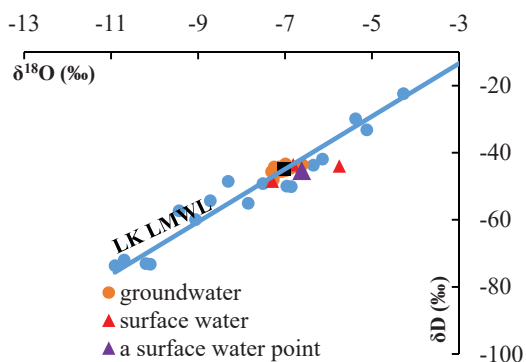


Figure 3. Isotopic compositions ($\delta 2H$ and $\delta 18O$) of groundwater and surface water in the rainy season along with the local meteoric water line

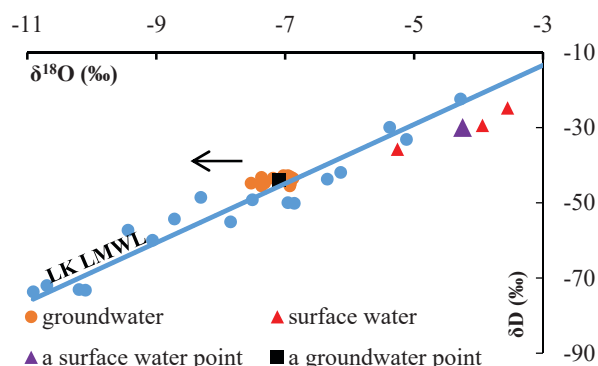


Figure 2. Isotopic compositions ($\delta 18O$ and $\delta 2H$) in Suoi Tre Lake water (LEL) depicted along with the local meteoric water line (LK LMWL)

The data in Figure 3 show that in the rainy season the isotopic compositions in groundwater from the uppermost aquifer (β_{qp_2}) in the study region located right on the LK LMWL indicating a fact that groundwater is recharged from local precipitation. In the dry season it was revealed that the mean values of isotopic compositions of groundwater were much different from that in water from Suoi Tre lake (Fig. 4) implying that groundwater in the dry season has no hydraulic relation with surface water in the lake. As seen from Fig 4 the isotopic compositions of groundwater from the β_{qp_2} aquifer also positioned close to the LK LMWL, however with some deviation in the direction of oxygen-18 composition depletion as shown by the arrow in Fig.4. This reflects a fact that groundwater in that aquifer is also recharged from the local precipitation but with some delay due to infiltration. During the infiltration oxygen in the infiltrated rainwater participated in isotopic exchange with those in bio-carbonic acid released from plant roots making $\delta^{18}O$ in water to deplete. It concludes that groundwater in the uppermost aquifer in Long Khanh city has the local precipitation genesis in both seasons.

The results of this study are limited in terms of sample number; therefore, it needs to be further expanded to the whole Southeast Nam Bo region and Dong Nai river basin.

APPLICATION OF ISOTOPE TECHNIQUE FOR DETERMINATION OF FRACTION OF YOUNG WATER AT THE LONG BIEN METEO-HYDROLOGICAL STATION

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Project information:

- Project name: Application of isotope technique for determination of fraction of young water at the Long Bien meteo-hydrological station

- Code: CS/21/10-01

Managerial Level: Institute

Implementation time: 12 months (Jan 2017- Dec 2017)

- Contact email: dtthuypt@gmail.com

- Published papers related to the project:

1. Nho Lan Nguyen, Thu Nga Do, Trinh Anh Duc Trinh, Application of Water Stable Isotopes for Hydrological Characterization of the Red River (Asia), *Water*, 2021, 13 (15), 2051.

2. Nguyen Nho Lan, Dam Thi Thanh Thuy, Nguyen Kim Dung, Trinh Anh Duc, Trinh Hong Quan; Application of stable isotopes for hydrological assessment of the Red River system concerning the impact of the upstream reservoirs; The 14th Regional Conference on Nuclear Science and Technology, Da Lat, December 2021.

In tropical-coastal catchments like Red River (Vietnam), water has extensively been exploited and used for socioeconomic development. A comprehensive understanding of catchment hydrology (e.g. transit time, drainage network) helps attain sustainability of water resource exploitation. Isotope hydrology is a research specialty well suited for the determination of transit rate, transit time, flow paths of different water sources in the catchments and therefore extensively applied in water resources, water management, environment, and meteo-hydrology assessment. In Vietnam, hydrological assessment at the catchment scale is based on direct measurement and numerical simulation/calculation (rarely derived from isotope hydrology). Few hydrological researchers use water stable isotopes for assessment of hydrodynamics, transit time, or flow rate of streamflow in the surface. Water isotopes have been applied to study groundwater or rainwater rather than to surface flow/overflow.

This project uses water isotopes for estimating Fyw in the Red River (the Hanoi station), the basin that has been undergone intensive human alterations, especially hydropower production.

The approach is considered simple, efficient, and particularly useful for inter-boundary river systems where comprehensive hydrological assessment is not always practicable. The broader aim is that the use of isotopic data for the calculation of principal hydrological characteristics will help inform regional stakeholders and policymakers in better water resource management practices. The time taken for water to travel from precipitation, through a catchment, and to its outlet, is an important descriptor of the catchment functioning with broad implications for runoff generation, contaminant transport, and biogeochemical cycling.

FORMULATION FOR CALCULATION OF FRACTION OF YOUNG WATER (F_{yw})

F_{yw} was calculated by fitting a sine wave to both the seasonal-varying precipitation and streamflow ¹⁸O isotope signals. These are calculated, respectively, as:

$$C_p(t) = A_p \sin(2\pi ft - \phi_p) + k_p \quad (1)$$

$$C_s(t) = A_s \sin(2\pi ft - \phi_s) + k_s \quad (2)$$

where $C_p(t)$ is simulated precipitation and $C_s(t)$ is streamflow, $\delta^{18}\text{O}$ isotope values of time t (decimal years), A is the amplitude (‰), ϕ is the phase of the seasonal cycle (in radians, with 2π rad equaling 1 year), f is the frequency (yr^{-1}), and k (‰) is a constant describing the vertical offset of the isotope signal. After fitting these multiple regression equations, the F_{yw} can be calculated as:

$$F_{yw} = \frac{A_s}{A_p} \quad (3)$$

Numerous studies have shown that when the F_{yw} is correlated with forcing factors such as weather (precipitation, temperature), topography (slope), geology, and land use (agriculture, forestry, ...), the strength and pattern of the correlations between F_{yw} and these factors (parameters) are very useful for effective management of water resources in the catchments.

Monitoring results and regression lines of $\delta^{18}\text{O}$ values in rainwater and the Red River water are shown in Figures 1a and 1b.

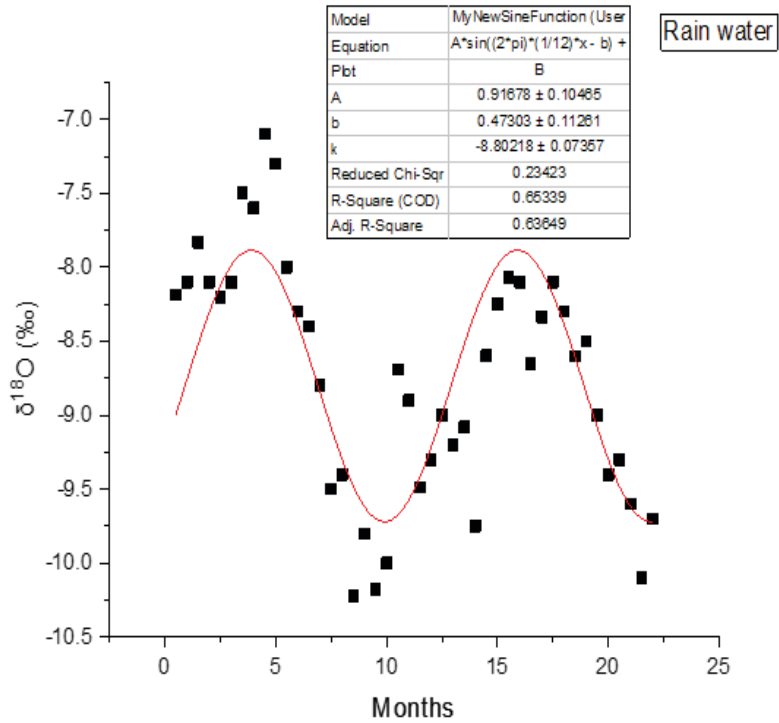


Figure 1a: Experimental results and regression line of $\delta^{18}\text{O}$ values in rainwater at Hanoi Meteo-hydrological station

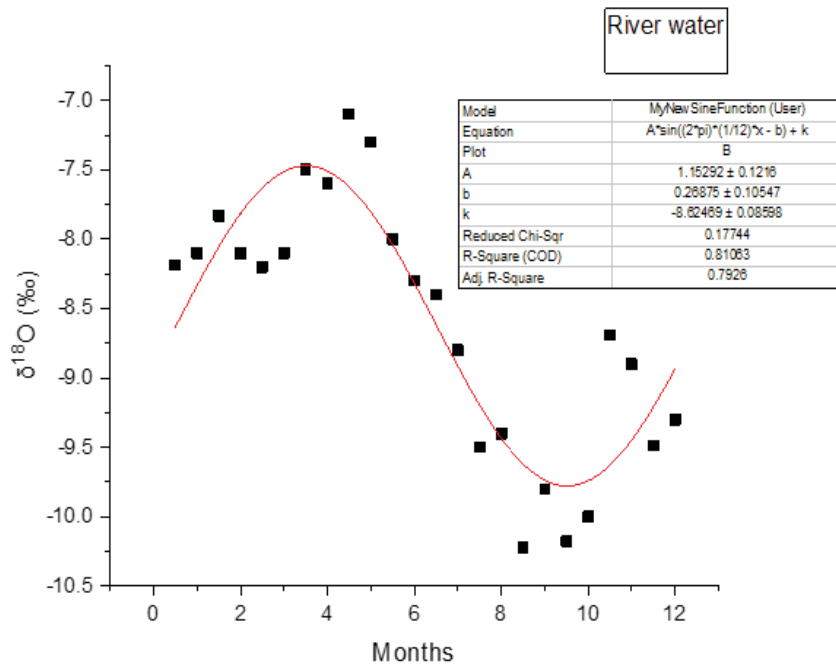


Figure 1b: Experimental results and regression line of $\delta^{18}\text{O}$ values in riverwater at Long Biên Meteo-hydrological station, Hanoi

Fitting data result in the young water fraction of Red River at Long Bien, Hanoi, as 0.19ff10.04. The Fyw calculated for the period 2021 to October 2021 gives a higher value than the period 2015-2019 and is in the same range of the period 2003-2005 that we have recently published (Nguyen et al., 2021). These values are lower than those calculated exclusively for the Day river basin (Trinh et al., 2017).

The calculation formulas and calculation methods are quite simple, although the calculated error has not taken into account measurement error or error due to sampling. Results are somewhat higher than the changing trend calculated in recent times. The reason could be weather changes, changes in river flows, or not enough data for the rest of 2021.

It is recommended to continue sampling and water stable isotope analysis, to collect meteorological and hydrological data, and to use land-use methods to ensure accurate and more realistic calculation results. the law of hydrological change over time. It is necessary to study and set up the process of calculating the uncertainty of the modeling results with the use of Bayesian simulation - MCMC.

Advantages of the method are fast, simple in calculation/modeling, unaffected by complex factors of basin topography, and has just begun to be applied in Vietnam, showing the potential of using water isotope approaches and datasets in the assessment and management at a provincial level in Vietnam.

2.6. RADIATION SAFETY AND RADIOACTIVE WASTE MANAGEMENT

APPLICATION OF GAMMA IRRADIATION INDUCING *TRICHODERMA* MUTANTS FOR PREPARATION OF RICE-STRAW DEGRADATION PRODUCT

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Hanoi Irradiation Centre, Minh Khai- Tu Liem- Hanoi

Project information:

Project name: Application of gamma irradiation inducing *Trichoderma* mutants for preparation of rice-straw degradation product

Code: ĐTCB.01/18/TTCX

Managerial Level: Ministry

Implementation time: 45 months (Jan 2018- Sept 2021)

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- Published papers related to the project:

Diep TB, Thom NT, Sang HD, An TX, Binh NV, Quynh TM. Effect of gamma irradiation on the viability and cellulase production of some filamentous fungi. *Journal of Biotechnology*, 18 (2), 2020, p. 341-348.

Nguyen Thi Thom, Hoang Dang Sang, Tran Xuan An, Nguyen Van Binh, Tran Bang Diep. Study on creation of high producing cellulase mutants of *Trichoderma* by gamma irradiation. *Information of Nuclear Science and Technology*, 65, 2020, p. 34-39 (In Vietnamese).

Nguyen Thi Thom, Hoang Dang Sang, Tran Xuan An, Nguyen Van Binh, Tran Bang Diep. Study on creation of high producing cellulase mutants of *Trichoderma* by gamma irradiation. Report at the 6th Conference on Nuclear Science and Technology for Young Scientists. Hanoi 08-09/10/2020 (In Vietnamese).

Nguyen Thi Thom, Hoang Dang Sang, Tran Xuan An, Nguyen Van Binh, Tran Minh Quynh, Tran Bang Diep. Effects of gamma irradiation on the survival rate, phenotype and cellulase activity in *Trichoderma*. Report at the 13th National Conference on Nuclear Science and Technology. Quang Ninh 07-09/08/2019 (In Vietnamese).

Vietnam is an agricultural country with million tons of rice straw left after harvesting each year. Open burning of rice straw in paddy fields has become a long-standing habit of Southeast Asian farmers including Vietnamese farmers. However, this burning process adversely affects the nutrition composition of the soil. When crop residue is burnt, existing minerals presenting in the soil are destroyed, which adversely hampers the cultivation of the next crop. Moreover, the emission of gases such as methane, nitrogen oxide and ammonia in the straw smoke can cause severe air pollution. These gaseous emissions can pose health risks, aggravating asthma, chronic bronchitis, and decreased lung function... So, the naturally degraded rice

straw in the field is an option for solving this problem and reducing the amount of fertilizer used in agriculture. The supplementation of hyper cellulose degradation microorganisms such as filamentous fungi, actinomycetes, bacteria ...into crop residue or rice straw after harvesting can facilitate the efficient degradation, which promises the long-term effect and no pollution that chemical method cannot get.

Trichoderma koningiopsis VTCC 31435 and *T. reesei* VTCC 31572 are high cellulase-producing filamentous fungus selected from several domestic laboratories. The spore suspensions and PDA plates inoculated these fungi were irradiated at dose ranging 0-2500 Gy under gamma Cobalt-60 source at Hanoi Irradiation Center. In both cases of irradiation treatment, the survival rate of fungus decreased with the increasing gamma ray irradiation dose. The required irradiation dose to kill 90% of the total number of fungal spores (D10) of both strains was found about 400 Gy. The survival number of *T. koningiopsis* spore decreased by about 7 Log units at 2500 Gy compared with control. While, there was not any viability of *T. reesei* spore observed at this irradiation dose.

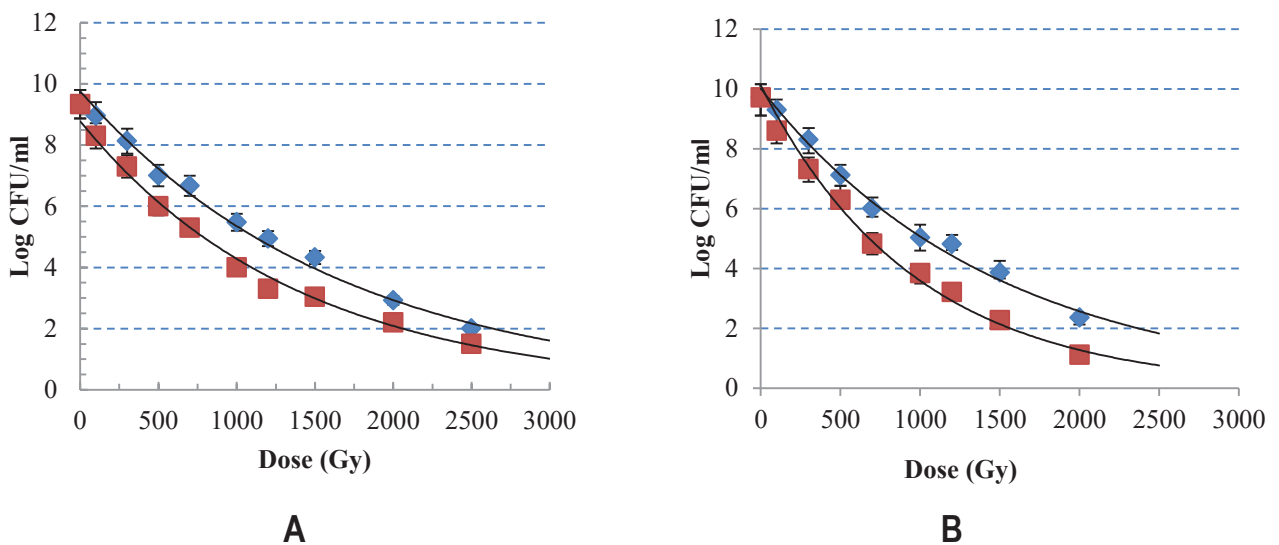


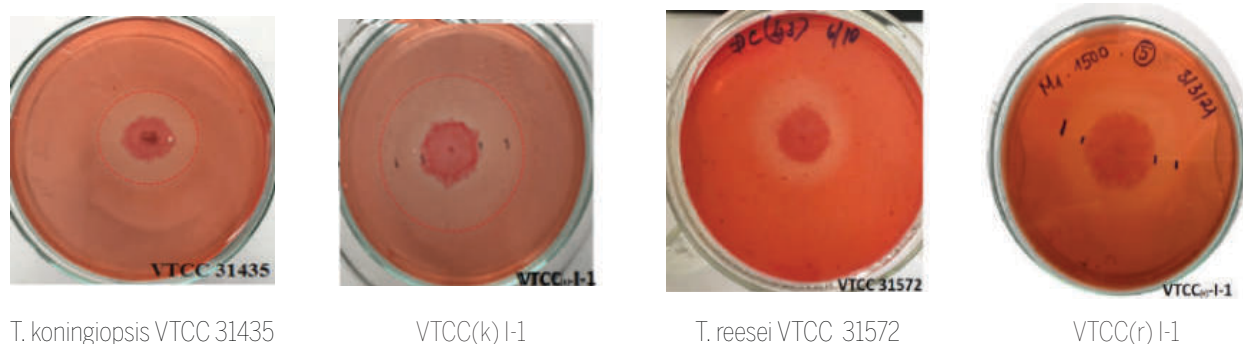
Figure 1. Effects of gamma irradiation on the viability of *T. koningiopsis* VTCC 31435 (A) and *T. reesei* VTCC 31572 (B) (■- Irradiated PDA plates; ◆- Irradiated spore suspensions)

Table 1. The cellulose hydrolysis capacity (HC) of two fungal strains irradiated at different doses

Dose (Gy)	T. koningiopsis VTCC 31435			T. reesei VTCC 31572		
	The cellulose hydrolysis capacity (HC)		The rate of high cellulase-producing colonies (%)	The cellulose hydrolysis capacity (HC)		The rate of high cellulase-producing colonies (%)
	Average HC value	Max HC		Average HC value	Max HC	
Wild-type	-	1,74	-	-	1,87	-
300	1,95 ^a ff10,10	2,22	4,33 ^a ff10,28	2,01 ^a ff10,07	2,34	6,26 ^b ff10,16
500	1,94 ^a ff10,05	2,23	7,67 ^c ff10,28	2,03 ^{ab} ff10,03	2,29	9,74 ^c ff10,08
700	2,05 ^{ab} ff10,03	2,48	12,33 ^d ff10,56	2,22 ^{cd} ff10,05	2,38	12,57 ^d ff10,14
1000	2,21 ^c ff10,11	2,38	14,05 ^e ff10,67	2,27 ^d ff10,10	2,67	15,32 ^e ff10,66
1200	2,17 ^{bc} ff10,09	2,41	14,25 ^e ff10,78	2,33 ^d ff10,03	2,35	15,87 ^f ff10,54
1500	2,06 ^{ab} ff10,06	2,62	13,67 ^e ff10,62	2,34 ^d ff10,02	2,69	14,75 ^e ff10,48
2000	2,01 ^a ff10,07	2,36	7,33 ^c ff10,44	2,07 ^{bc} ff10,02	2,30	4,01 ^a ff10,09
2500	1,95 ^a ff10,02	2,15	5,33 ^b ff10,28	-	-	-

*Statistically significant at 95% of confidence level. Different letters indicate significant differences between the means within column.

The high cellulase-producing colonies in two kinds of *Trichoderma* strains were observed at all irradiation doses and seems to be greater at the dose range of 700-1500 Gy, at which the survival spores of *Trichoderma* decreased by 3-6 log unit. By screening in PDA medium with the addition of CMC (carboxymethyl cellulose) and Congo-Red, 5 potential mutants with superior and stable cellulose-producing capacity from each wild-type strain were selected from hundreds of radiation-resistant colonies (dose range 700-1500 kGy) having higher HC (hydrolysis capacity's value compared to the initial strain. The enzyme production (CMCase and FPase) of the mutants were fairly stable after at least 4 consecutive generations. It is important to notice the 2 potential mutants VTCC(k) I-1 (screened from *T. koningiopsis*) and VTCC(r)-1 (screened from *T. reesei* VTCC) demonstrated the higher activities of CMCase (2.48-2.47 folds) and FPase (1.87-2.29 folds) compared to the original strains. Simultaneously, when investigating of nucleotide mutations in a gene coding for endoglucanase of VTCC (r)-1 we found a nucleotide substitution resulting in the substitution of Alanine 325 to Threonine and an codon inserted to the gene to add Alanine at amino acid residue 413. Thus, these mutations may be the reason for increased CMCase activity in mutant VTCC(r)-1.



T. koningiopsis VTCC 31435

VTCC(k) I-1

T. reesei VTCC 31572

VTCC(r) I-1

Figure 2. The clear zones of CMC resolution of wild type strains and potential mutants incubated at 28°C for 24 hours, followed by a 5-day incubation at 37°C

The solid-state fermentation (SSF) on substrate of rice-by products was performed with VTCC(k) I-1 and VTCC(r) I-1. After fermentation at optimal parameters, the average densities of spores were 1.43×10^{10} CFU/g and 1.79×10^{10} CFU/g for VTCC(k) I-1 and VTCC(r) I-1 strains, respectively. After separated fermentation and collection, the spores of the two mutant strains were mixed in a 1:1 ratio. The results showed that the density of spores was still higher than 10^{10} CFU/g. The created IRT_r preparation is a mixture of Trichoderma's spores and the carrier material containing sterilized starch and xanthan under an irradiation dose of 15 kGy. The IRT_r preparation has specifications satisfying TCVN 6168: 2002, and its quality is maintained for at least 6 months after production. Laboratory-scale and field testing shows the more efficient degradation of rice straw under this preparation, compared to other commercialized products.

Table 2. Optimal parameters for SSF of two Trichoderma mutants VTCC(k) I-1 and VTCC(r) I-1

Specifications	Optimal parameters	
	VTCC(k) I-1	VTCC(r) I-1
pH	6.5	6.5
Temperature (°C)	30	33
Times for incubation (days)	7	7
Substrate	Rice bran/Rice husk/ molasses (The ratio: 6 – 3.5 – 0.5)	Rice bran/Rice husk/ molasses (The ratio: 6 – 3.5 – 0.5)
Spore suspension/substrate (%)	10	10
Moisture content (%)	60	60
The density of spores (CFU/g)	1.43×10^{10}	1.79×10^{10}

STUDY ON LABELLING OF BEVACIZUMAB ANTIBODY WITH RADIOISOTOPE ^{99m}Tc FOR THE RADIOIMMUNOSCINTIGRAPHY OF CANCERS

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Project information:

Project name: Study on labelling of bevacizumab antibody with radioisotope ^{99m}Tc for the radioimmunoscintigraphy of cancers

Code: CS/21/01-02

Managerial Level: Institute

Implementation time: 12 months (Jan 2021- Dec 2021)

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Published papers related to the project:

Giang Nguyen Thi Khanh, Thu Nguyen Thi, Ngoc Nguyen Thi, Cuong Bui Van, Binh Nguyen Thanh, Quang Dang Ho Hong, Nhan Nguyen Thanh. Study on labelling of bevacizumab antibody with ^{99m}Tc for the radioimmunoscintigraphy of cancers. 14th Vietnam Conference on Nuclear Science and Technology (VINANST 14), (2021), (in Vietnamese).

Over the last two decades, the radioactive labeled monoclonal antibodies have been widely used in the diagnosis and clinical therapy. Amongst the bevacizumab is the most clinically tested antibody which has been approved by the FDA for the treatment of various types of cancers. Bevacizumab labeled with ^{99m}Tc , ^{111}In , ^{89}Zr , ^{124}I , and ^{64}Cu for imaging of VEGF expressing tumors has been reported. This paper presents the radiolabeling with ^{99m}Tc protocol of bevacizumab by the direct method. The aim of this study was to prepare and quality control of radiopharmaceutical ^{99m}Tc -bevacizumab for the radioimmunoscintigraphy (RIS) of cancer.

Antibody bevacizumab (Roche, Switzerland) 25 mg/ml. Tc-^{99m} ($\text{Na}^{99m}\text{TcO}_4$) 20 mCi/ml in saline, concentration at calibration time. The quality control of ^{99m}Tc -bevacizumab by Cyclone Plus Phosphor Scanner. The antibody bevacizumab was labeled with the radionuclide ^{99m}Tc by the direct method using stannous chloride as a reductant. Optimization of the labeling bevacizumab with ^{99m}Tc including the varied stannous chloride content, antibody mass, radioactive in the reaction, pH, reaction time, and temperature. The quality control of ^{99m}Tc -bevacizumab was performed on radiochemical purity and radionuclide purity, radiolabeled yields, invitro stability. The products were analyzed by Thin Layer Chromatography method. The results were processed using the software Optiquant 5.0 and Excel, GraphPad Prism 8.4.3.

The results of optimized radiolabeling conditions antibody with radioisotope Tc-99m were shown in Table 1. The radiolabeling was performed in 0.5 M phosphate buffer, pH 7.4, 200 μ g of antibody and 40 μ g of stannous chloride were added, 5 mCi ^{99m}Tc , pH 6,0-7,0. The reaction mixture was lightly mixed, put in 15 minutes at room temperature (24°C).

Table 1. Optimized radiolabeling conditions of bevacizumab with ^{99m}Tc (*Ab: antibody)

SnCl ₂ (mg)	Eff. (%)	pH	Eff. (%)	Time (min.)	Eff. (%)	Ab* (mg)	Eff. (%)	^{99m}Tc (mCi)	Eff. (%)	Temp. (°C)	Eff. (%)
1	67.05	3	99.10	1	94.70	1	97.95	0.2	86.80	4	96.45
10	90.45	4	99.40	5	97.55	10	97.65	1	99.15	24	99.10
20	96.50	5	99.50	10	96.10	100	98.90	5	98.75	37	95.15
30	97.15	6	99.70	15	99.10	400	98.10	10	98.60	-	-
40	99.10	7	99.85	30	98.60	600	97.75	20	98.90	-	-
50	98.75	8	94.55	60	99.50	1000	96.80	40	99.05	-	-

The quality control results show that the radiochemical purity of ^{99m}Tc -bevacizumab is more than 98%. Free ^{99m}Tc was separated to the solvent front while labeled ^{99m}Tc -bevacizumab remained at the origin of the chromatography strip (Figure 1A). The control chromatography strip of ^{99m}Tc ($\text{Na}^{99m}\text{TcO}_4$) was moved to the front of the TLC (Figure 1B). The product could be stable until 24 hours with added ascorbic acid and human serum albumin (Figure 1C).

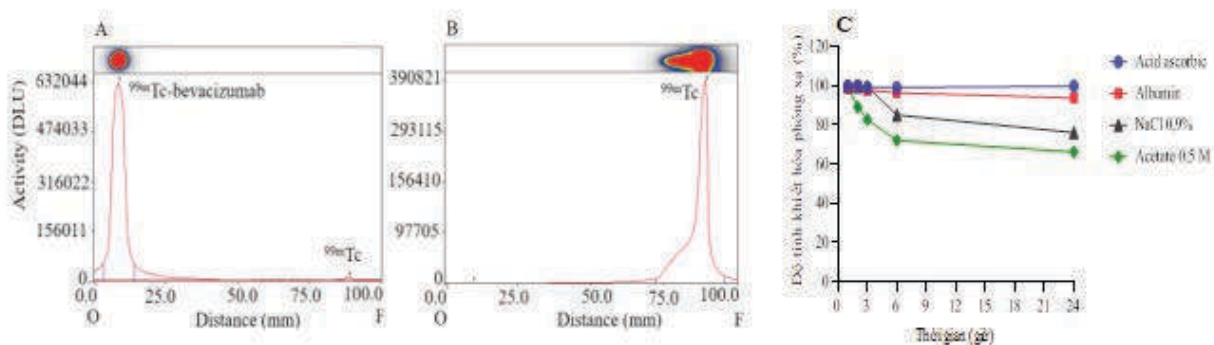


Figure 1. Typical radiochemical purity of ^{99m}Tc -bevacizumab; (A) ^{99m}Tc -bevacizumab, (B) ^{99m}Tc TLC in acetone and radioautography, (C) Stability of ^{99m}Tc -bevacizumab in ascorbic acid, 0.9% NaCl, human serum albumin and 0.5 M sodium acetate.

In conclusion, the monoclonal antibody bevacizumab has been labeled with radioisotope ^{99m}Tc for the preparation of radiopharmaceuticals specific to VEGF express on the vascular endothelial growth areas. The ^{99m}Tc -bevacizumab was obtained with high radiochemical purity, radiolabeling yield, and invitro stability. This radiopharmaceutical is ideal for diagnostic cancer imaging in clinical trials. We should perform the preclinical evaluation including other quality control, immunoreactivity, biodistribution, and cancer imaging testing, which are complying with requirements for radiopharmaceuticals.

ESTABLISHMENT OF γ H2AX ANALYSIS TECHNIQUE TO ASSESS DNA DOUBLE-STRAND BREAK INDUCED BY IONIZING RADIATION

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Han Huynh Dien, Le Thi Bich Thy**

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Project information:

Project name: Establishment of γ H2AX analysis technique to assess DNA double strand break-induced by ionizing radiation

Code: CS/21/01-01

Managerial Level: Institute

Implementation time: 12 months (Jan 2021- Dec 2021)

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Published papers related to the project:

Pham Ngoc Duy, Tran Thanh Mai. Study on the kinetic of γ H2AX foci in human peripheral blood lymphocyte and fibroblast cells exposed to X-Ray irradiation (in Vietnamese) (accepted).

Some types of DNA damage are caused by ionizing radiation, including DNA double-strand break (DSB). The H2AX proteins become apparent earlier than other damage response proteins in the presence of DSBs. Each radiation-induced H2AX foci represents a single DSB in G1 phase cell. Analysis of DNA lesions can be performed by H2AX foci quantification using anti-H2AX antibodies and fluorescently labeled secondary antibodies. This study aims is to establish technical procedures for analyzing H2AX in human peripheral blood lymphocytes and human fibroblasts to assess the extent of DSB damage in cells post-irradiation.

Human lymphocytes and fibroblasts were in vitro irradiated by 2 Gy of X-ray source at the dose rate of 0.5 Gy/min. The cells were fixed by 4% formaldehyde/PBS in 15 minutes at room temperature and treated with 0.5 % TritonX100/PBS. Then, 1 % FBS/PBS was used for blocking for 30 minutes. The cells then were incubated with Anti-phospho-Histone H2A.X (Ser139) JBW301 antibody at 37 °C in 60 minutes. After that, Alexa Flour 488 goat anti-mouse IgG antibody was incubated with them at 37 °C in 30 minutes. These antibodies were examined at 1:500, 1:1000, 1:2000 and 1:3000 dilution. Next, we determined the time point after 2 Gy X-ray irradiation to have the highest H2AX foci rate within 300 minutes post-irradiation. The H2AX foci was analyzed by a Carl Zeiss AXIO Imager Z2 fluorescence microscope system combined with Metafer 4.0 and Metacyte software (Metasystem). DAPI and FITC fluorescence filters were used. Excel software was used for statistical analysis, t-test, ANOVA ($\alpha = 0,05$) and graphs.

According to that, when human lymphocytes were in vitro irradiated by an X-ray source at a dose of 2 Gy and a density of $2 \cdot 10^5$ cells/mL, the optimal concentration of both antibodies was 1:1000 dilution. Besides, with human fibroblasts that had a density of 10^5 cells/mL, antibodies were diluted at 1:2000. With these experiment conditions, the time point within 300 minutes after irradiation that reach the highest γ H2AX foci rate was examined. The results showed that γ H2AX foci of human lymphocytes appeared almost immediately after irradiation with a mean of 3.23 ± 1.16 foci/cell. The mean rate of foci gradually increased and reached the highest at 60 minutes after irradiation with the mean of 8.05 ± 1.33 foci/cell. After that, the foci steadily decreased until the time point 300 minutes and tended to decrease further. And the γ H2AX foci of human fibroblasts were increased with the mean of 5.67 ± 1.55 foci/cell. The rate of γ H2AX foci continued to increase after irradiation at 15 minutes, 30 minutes and reached the highest value at 45 minutes with the mean of 17.54 ± 1.70 foci/cell. After that, the rate gradually decreased from 60 min to 300 min post-irradiation. Figures 1 and 2 show the changing of γ H2AX foci in human lymphocytes and human fibroblasts within 300 minutes after an X-ray irradiation at 2 Gy.

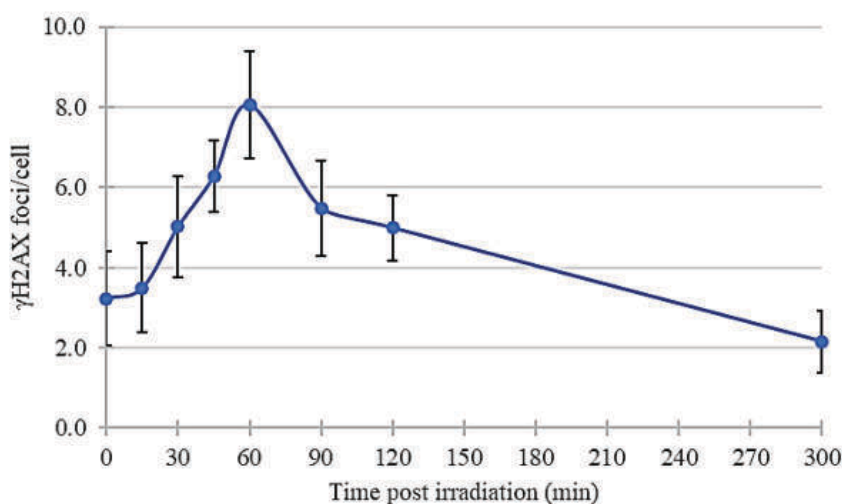


Figure 1:
Kinetics of
 γ H2AX foci
formation
in human
lymphocytes
within 300 min
after 2 Gy X-ray
irradiation

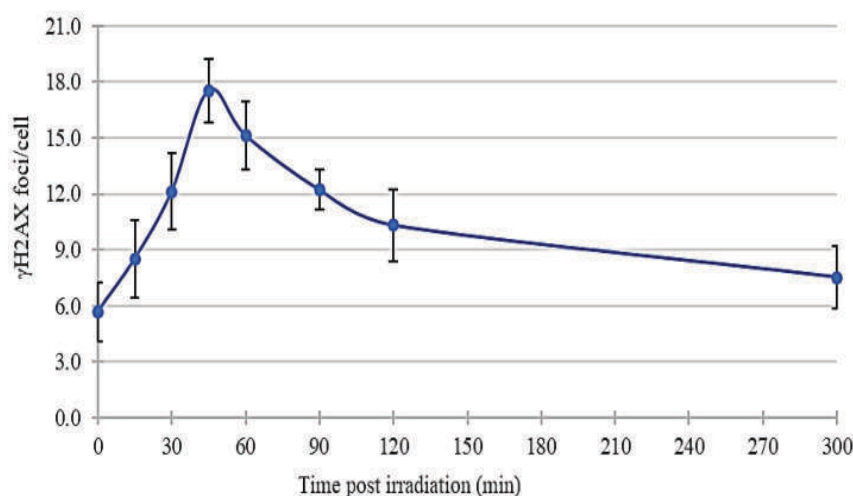


Figure 2:
Kinetics of
 γ H2AX foci
formation
in human
fibroblasts
within 300 min
after 2 Gy X-ray
irradiation

Initially, when DSBs occurred, there was phosphorylation of H2AX proteins, and this process was more intense to implement cellular damage repair pathways and would peak at some time points after irradiation. Then, as the cell gradually completed the DSB repair, the number of H2AX foci also decreased with time. Proteins such as DNA ligase IV, DNA-PK, MRE11-Rad50-NBS1 complex, Artemis, 53BP1 and ATM-related DSB which joined repair pathway were also declined. This was indicated by studies on DSB repair mechanisms and pathways that Rothkamm K et al. (2003) and Kühne M et al (2004) had performed. The fluorescence signal of foci from 0 to 300 min after irradiation showed that the mean ratios of H2AX foci of peripheral blood lymphocytes was lower than that of human fibroblasts. Simultaneously, the ratio of H2AX foci in lymphocytes increased more slowly but decreased more rapidly compared to human fibroblasts at the same time points. This showed that the ability to damage DSBs and to repair DSB damage caused by ionizing radiation are different between these two cell types. Many factors influence the formation and loss of kinetics of foci. Kai Rothkamm and Simon Horn (2009) showed that H2AX protein content varies between cell lines, there might be a chance that a biological variation in the number of phosphorylated H2AX molecules presented at break sites. In addition, Hartmut Mahrhofer et al. (2006) concluded that the phosphorylation of H2AX histone at DSB sites by ionizing radiation was dependent on different cell lines.

In brief, the H2AX analysis techniques in human peripheral blood lymphocytes and human fibroblasts after ionizing radiation were established. They can be used to analyze many different cell types and can be widely applied for in vitro, in vivo, and ex vivo studies in radiobiology.

STUDY ON THE MAILLARD REACTION PRODUCTS OF CHITOSAN AND GLUCOSAMINE INDUCED BY GAMMA IRRADIATION FOR APPLICATION IN PORK FILLET PRESERVATION

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Project information:

Project name: Study on the formation of Maillard reaction products of chitosan and glucosamine induced by gamma irradiation method for application of pork fillet preservation

Code: CS/21/07-01

Managerial Level: Institute

Implementation time: 18 months (Jan 2021 – June 2022)

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Published papers related to the protect:

Le Anh Quoc, Dang Van Phu, Nguyen Quoc Hien, Nguyen Chi Thuan, Chu Nhut Khanh, "Study on the Minimum Bactericidal Concentration (MBC) of Maillard reaction product of chitosan and glucosamine prepared by gamma-irradiation method", an oral presentation at 14th Vietnam Conference on Nuclear Science and technology (VINANST 14), Lam Dong, Vietnam, 2021.

Le Anh Quoc, Dang Van Phu, Nguyen Quoc Hien, Nguyen Chi Thuan, Chu Nhut Khanh, "Study on the Minimum Bactericidal Concentration (MBC) of Maillard reaction product of chitosan and glucosamine prepared by gamma-irradiation method", Nuclear Science and Technology, Vol. 11, No. 3 (2021), pp 44-51.

Nowadays, abusing of chemical preservatives has become a global concern. There are more and more consumer awareness and concern regarding consuming these synthetic chemical additives even below the recommended limits as defined by regulatory agencies, such as the FDA. Therefore, there are numerous efforts to find alternative food preservatives and natural additives are supposed the most potential candidate because of their safety. Therefore, a new strategy in food preservation is the application of natural compounds with bactericidal activity, such as chitosan (CTS). Chitosan is a non-toxic, biocompatible, biodegradable polysaccharide with antibacterial and antioxidant activity. There have been many studies to apply chitosan in food preservation, such as in fruit and vegetable, seafood, meat and meat products. However, the applications of chitosan are limited because of its poor solubility at neutral or basic pH. For this reason, a numerous research has been carried out to improve the solubility and/or increase the biological activities of chitosan upon chemical or enzymatic modifications. Recently, Maillard reaction, which is a reaction that occurs between the carbonyl group in

reducing sugars and the amino group in proteins, has been applied in many studies to enhance the biological activities of chitosan. Among the Maillard reaction products (MRPs) of chitosan with different reducing sugars, the MRPs of chitosan and glucosamine exhibited excellent antibacterial activities even at pH 7. In recent years the Maillard reaction induced by gamma irradiation has been reported as a reaction that can take place rapidly at room temperature without forming any toxic by-products, such as 5-hydroxymethylfurfural. However, up to now, there has been barely any publication on the preparation of chitosan-glucosamine MRPs by irradiation method and their applications for food preservation.

In this study, the factors affecting the irradiation induced Maillard reaction efficiency were investigated. Specifically, a mixture of CTS (1.6 %) and glucosamine (GA) (0.4 %) solution was irradiated at 25 kGy to form CTS-GA MRPs. In addition, the CTS-GA MRPs solution was also studied for its antibacterial activity and evaluated its preservative effect on fresh pork fillet.

The antibacterial activity of the CTS-GA MRPs solution was studied by agar well diffusion method, the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) determination method against both *Escherichia coli* and *Staphylococcus aureus*. The results revealed that CTS-GA MRPs solution exhibited greater antibacterial activity than that of native chitosan and the antibacterial activity depended on not only the bacterial species but also the pH value of the medium, namely CTS-GA MRPs solution exhibited higher antibacterial activity at pH 5 than at pH 7, and *E. coli* expressed more sensitive to CTS-GA MRPs solution than *B. aureus*.

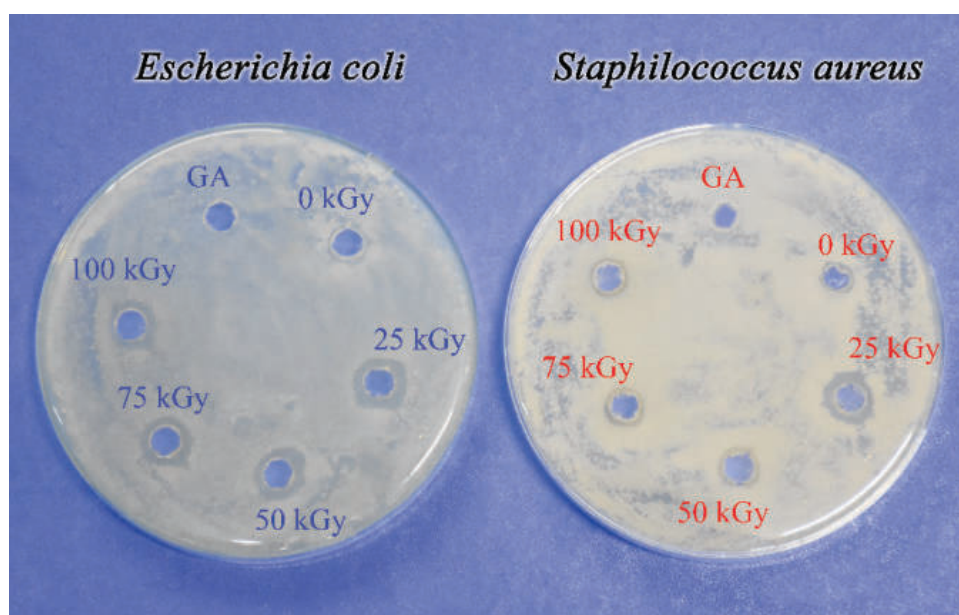


Figure 1. Agar well diffusion result of CTS-GA MPRs solutions prepared at different radiation doses

5-hydroxymethylfurfural (5-HMF) is a by-product of heat-induced Maillard reaction. At high concentrations, it is cytotoxic and irritant to eyes, skin, and mucous membranes. The presence of 5-HMF in the CTS-GA MRPs solutions induced by irradiation and heat was determined by high-performance liquid chromatography technique (HPLC). The heat-induced CTS-GA MRPs

solution possessed an absorption peak at a retention time of 7 minutes, which is characteristic of 5-HMF, while the irradiation-induced CTS-GA MRPs solution did not. This result revealed that the irradiation method does not produce by-products 5-HMF in CTS-GA MRPs solution.

The preservation effect of the CTS-GA MRPs solution prepared at a radiation dose of 25 kGy for pork fillets was investigated at different storage temperatures such as -20°C, 5°C, and 30°C. The monitoring indicators during meat preservation are sensory quality, total protein content, and total aerobic microorganisms. The results showed that the CTS-GA MRPs solution diluted with the ratio 1:25 (v:v) by water could prolong the storage time of pork at 5°C by 8 days in comparison to the control samples.

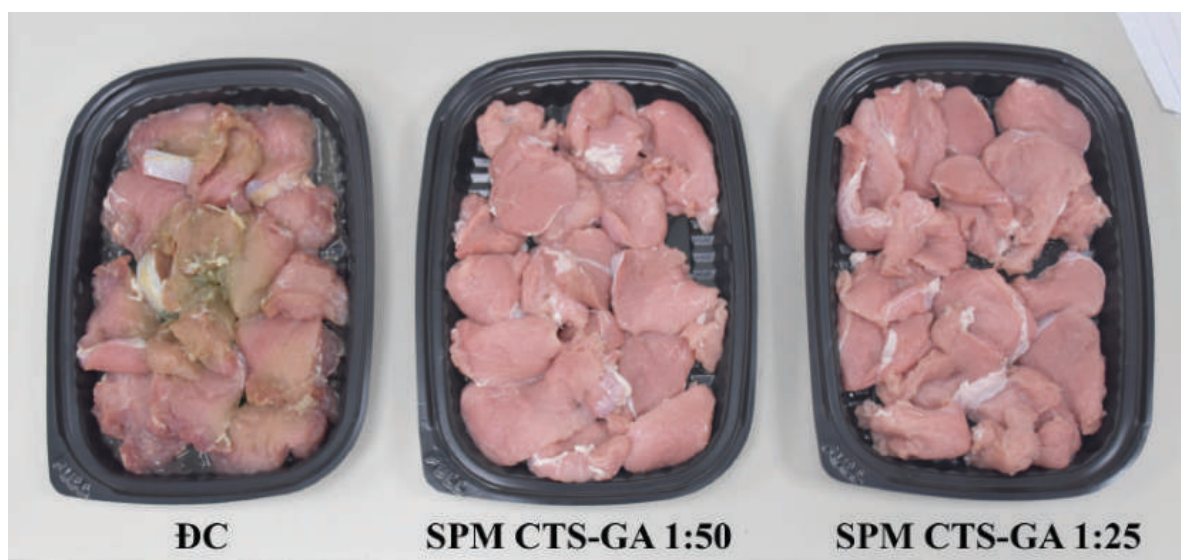


Figure 2. Pork fillet samples were stored at 5°C after 6 days.

In this study, the CTS-GA MRPs solution was effectively prepared by the gamma Co-60 irradiation method. The CTS-GA MRPs solution prepared at a radiation dose of 25 kGy was completely free of 5-HMF and exhibited high antibacterial activity against *E. coli* and *S. aureus* at both pH 5 and pH 7. In addition, the CTS-GA MRPs solution also effectively prolonged the shelf time of pork fillet storage at different temperatures and in particular it could extend the shelf time by 8 days at 5°C. Therefore, the CTS-GA MRPs solution has great potential for application as a natural food preservative and contributes to alternate chemical preservatives that carry many risks to consumers' health.

2.7. RADIOCHEMISTRY AND MATERIALS SCIENCE

STUDY ON THE TREATMENT OF AZO DYE RESIDUES FROM TEXTILE WASTEWATER BY ELECTRON BEAM IRRADIATION COMBINED WITH BIOLOGICAL TREATMENT

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Project information:

Project name: Study on decontamination of azo dye residues from textile wastewater by electron beam irradiation with biological treatment

Code: ĐTCB.03/20/TTNCTK

Managerial Level: Ministry

Allocated Fund: 900,000,000 VND

Implementation time: 30 months (January 2020- June 2022)

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Published papers related to the project:

1. Nguyen Chi Thuan, Nguyen Ngoc Duy, Nguyen Thi Kim Lan, Bui Manh Ha, Nguyen Quoc Hien, "Treatment of textile wastewater using the combination of electron beam irradiation with hydrogen peroxide" The Vietnam conference on Nuclear science and Technology 14th (09-10/12/2021, Da Lat-Lam Dong)
2. Nguyen Thi Kim Lan, Nguyen Ngoc Duy, Chu Nhut Khanh, Nguyen Chi Thuan, Duong Thi Giang Huong, Nguyen Quoc Hien, "Control of textile wastewater by electron beam irradiation in combination with biological treatment", Nuclear Science and Technology, Vol 11 (3), (2021), 27-33.
3. Duy Ngoc Nguyen, Hiep Nghia Bui, Kun-Yi Andrew Lin, Yuan-Shing Perng, Thanh Tran, Lan Thi Kim Nguyen, Hieu Trung Nguyen, Ha Manh Bui, "Efficient removal of reactive red 24 from aqueous solution through electron beam and aeration tank using response surface methodology", Sustainable Energy Technologies and Assessments, SCIE, IF: 5.353, Q1 (Accepted June, 15, 2022).

Nowadays, environmental pollution is become a threatening problem globally. Population growth and industrial development have released more and more garbage, include harmful wastes to our nature. Most of these pollutants are relatively stable, very hard to be degrade in nature, easily to be migrated, contribute to global aming, and may cause harmful effects to animal and human [1]. Thus, the textile industry produced large effluents with harmful poluttants threatening our environment and life [2, 3]. In average, 1 kg of fabric need about 70-150 liters of water for, so then a large number of harmful factors including suspended solids, chemicals, colorants, and odorants also release to the environment. The dyes in wastewater can cause several diseases such as hemorrhage, skin ulcers, nausea, etc. [4]. Azo dyes as well as other suspending solids in the wastewater may preventthe

sunlight from the water's , and inhibit photosynthesis of phytoplankton as well as other plants, so that less oxygen was generate for aquatic lifes. Therefore, pollutants and harmful chemicals must be removed from textile effluents before discharging to nature. Up to now, many methods have been studied and applied to remove those substances. The physicochemical processes such as adsorption, flocculation, filtration, oxidation have been used to treat textile wastewater but have produced secondary sludge that needs further treatment [3]. The biological method using activated sludge for textile wastewater treatment can effectively reduce COD but cannot complete de-color and requires large treatment space [2]. Using electron beam irradiation (EB) to handle decomposition of pollutants in wastewater, flue gas and sewage sludge is interested as new trend of research. Main advantage of irradiation treatment is ionization radiation can generate active free radiacals without the use of any toxic chemicals, and not produce secondary sludges at ambient temperature [5]. However, a high radiation dose of over 20 kGy is required to decontaminate textile wastewater, made it to be difficult to compete with the current traditional methods. The efficiency in decontamination of textile effluent by EB irradiation can enhance by combining hydrogen peroxide (H_2O_2) due to the increased concentration of $\cdot OH$ during irradiation in the presence of H_2O_2 [6]. In this study, low dose EB irradiation was combined with biological method to decontaminate textile wastewater.

The samples of textile effluent were taken directly from a harmonic tank of the textile factory's dyeing department. Sampling and pre-processing of wastewater samples were followed TCVN 6663-1:2011. The wastewater was filtered through a sand and gravel filter column to remove suspended solids before further experiments. Wastewater samples were separately put into the plastic boxes with lids, each with 4 liters. Samples were irradiated by the electron beam accelerator UERL-10-15S2 at the Vinagamma with radiation doses of 0.5, 1, 2, 5 kGy and 1 kGy + 5, 10, 15 and 20 mM H_2O_2 , respectively. Then, the irradiated sample was pumped into the aerobic model from the bottom up by a metering pump to ensure a maximum retention time of 9 days for biological treatment. Wastewater determined the color degree, biological oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), total suspended solids (TSS) and pH before and after irradiation, biological treatment.

The effects of irradiation dose and H_2O_2 concentration at 1 kGy on the color of wastewater are presented in figure 1. The results showed that the color degree decreased with increase of radiation dose and H_2O_2 concentration. The presence of H_2O_2 increased the concentration of $\cdot OH$, which facilitated the complete mineralization of a part of pigment molecule to CO_2 and H_2O , reduced the color degree of the wastewater.

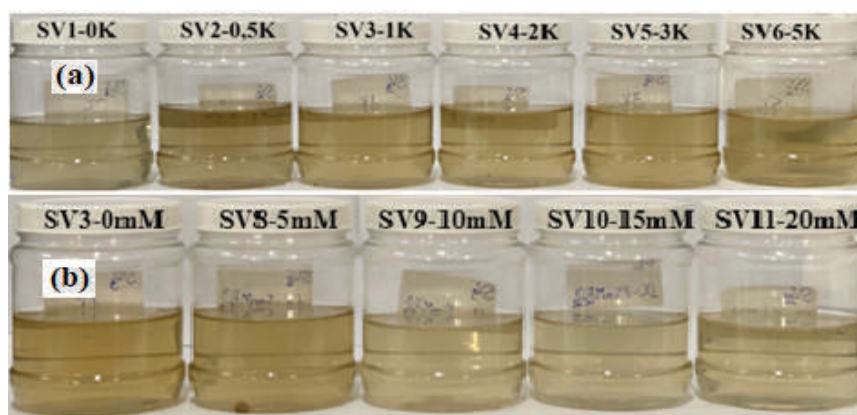


Figure 1. The photo of wastewater according to the irradiation dose (a) and the concentration of H_2O_2 at 1 kGy (b)

To elucidate the effect of EB irradiation on the pH, COD, BOD_5 , TOC, TSS and dye concentration in textile wastewater, the samples were irradiated with the dose ranging from 0,5 to 5 kGy at the same dose rate.

Table 1. The Influence of absorbed dose on the pH, COD, BOD_5 , TOC, TSS and color degree of textile wastewater

Sample	Dose (kGy)	[Dye] (Pt-Co)	COD (mg/l)	BOD_5 (mg/l)	TOC (mg/l)	TSS (mg/l)	pH
SV - 0 kGy	0	480 ffl 24	256 ffl 13	120 ffl 7	142 ffl 4	195 ffl 9	7.8 ffl 0,6
SV - 0,5 kGy	0,5	435 ffl 22	188 ffl 9	122 ffl 4	91 ffl 3	48 ffl 2	7.7 ffl 0,5
SV - 1 kGy	1	385 ffl 19	178 ffl 9	134 ffl 3	87 ffl 2	71 ffl 3	7.7 ffl 0,3
SV - 2 kGy	2	367 ffl 18	174 ffl 8	139 ffl 3	74 ffl 2	78 ffl 3	7.6 ffl 0,4
SV - 3 kGy	3	315 ffl 16	149 ffl 7	89 ffl 2	59 ffl 1	36 ffl 2	7.7 ffl 0,3
SV - 5 kGy	5	295 ffl 15	144 ffl 7	58 ffl 2	58 ffl 1	55 ffl 2	7.8 ffl 0,5

The results in the table I showed that COD, BOD_5 , TOC, TSS and dye concentration decreased with increasing absorbed dose. When the dose increased from 0.5 to 5 kGy, the dye concentration, COD, BOD_5 , TOC and TSS decreased from 480, 256, 120, 142 195 mg/l to 295, 144, 58, 58 and 55 mg/l, respectively. A similar result was also reported by Kim et al. when they applied electron beam radiation to enhance the biodegradability of textile wastewater for an activated sludge process [7].

Previous studies reported that the presence of H_2O_2 in the solution could lead the formation of hydroxyl radical which contributed the removal efficiency of COD, BOD_5 , TOC, TSS and dye concentration in wastewater [3, 5, 6]. To investigate of the effect of different H_2O_2 concentration

from 5 to 20 mM on the characteristics of wastewater was carried out. The results in table II showed that adding small amounts of hydrogen peroxide could improve the radiation capacity for eliminating pollutants in wastewater. The COD, BOD₅, TOC, TSS and dye concentration of textile wastewater decreased fast at 5 mM H₂O₂ concentration and absorbed dose of 1 kGy. The degree of decolorization of sample increased to 84% at H₂O₂ 15 mM. The removal percentage of COD, BOD₅, TOC, TSS also increased to 52%, 50%, 29% and 41%, respectively. These results can be explained that hydrogen peroxide reacts rapidly with hydrated electron formed in the radiolysis of water, leading to the formation of $\cdot\text{OH}$ radical. Therefore, the increase in the degree of decoloration, COD, BOD₅, TOC, TSS removal percentage by the addition of hydrogen peroxide would be mainly attributed to increase the $\cdot\text{OH}$ radical [3, 5].

Table 2: The Influence of H₂O₂ concentration at absorbed dose of 1 kGy on the pH, COD, BOD₅, TOC, TSS, pH and dye concentration of textile wastewater

Sample	Dose (kGy)	[Dye] (Pt-Co)	COD (mg/l)	BOD ₅ (mg/l)	TOC (mg/l)	TSS (mg/l)	pH
SV-0mM	1	385 ffl 19	178 ffl 9	134 ffl 3	87 ffl 3	71 ffl 3	7.7 ffl 0,4
SV-5mM	1	182 ffl 9	170 ffl 8	137 ffl 4	78 ffl 3	74 ffl 4	7.7 ffl 0,5
SV-10mM	1	146 ffl 7	162 ffl 8	111 ffl 3	75 ffl 2	60 ffl 2	7.5 ffl 0,3
SV-15mM	1	60 ffl 3	136 ffl 7	83 ffl 2	72 ffl 2	34 ffl 1	7.6 ffl 0,5
SV-20mM	1	67 ffl 3	117 ffl 6	67 ffl 2	62 ffl 2	42 ffl 1	7.6 ffl 0,6

The results of the combination of EB irradiation and biological treatment method showed in Fig. 2. The results showed that COD, BOD₅, TOC and dye concentration decreased with increasing the time of biological treatment. After 5 days of biological treatment, the color degree was 44 Pt-Co (reduced by 76% compared to the original Control) and the next days the sample continued to decrease slightly. By day 9, the remaining color was 29 Pt-Co (84% reduction compared to control). While the parameters of COD, BOD₅ and TOC decreased by 62, 84 and 71% respectively compared to the sample before irradiation, the parameters all achieved the discharge standards grade A of QCVN 13/2015 for textile wastewater.

Research on textile wastewater treatment using EB irradiation method combined with the biological method has been carried out. Dye in textile wastewater was partially degraded by low irradiation doses of 0.5-1 kGy. Presence of H₂O₂ showed to increase dye degradation efficiency at low irradiation doses of 1 kGy. Electronic beam irradiation of the textile wastewater containing 5 mM H₂O₂ followed by biological treatment significantly reduced the color degree of wastewater by 85% after 9 days of implementation and achieved grade A QCVN 13 2015.

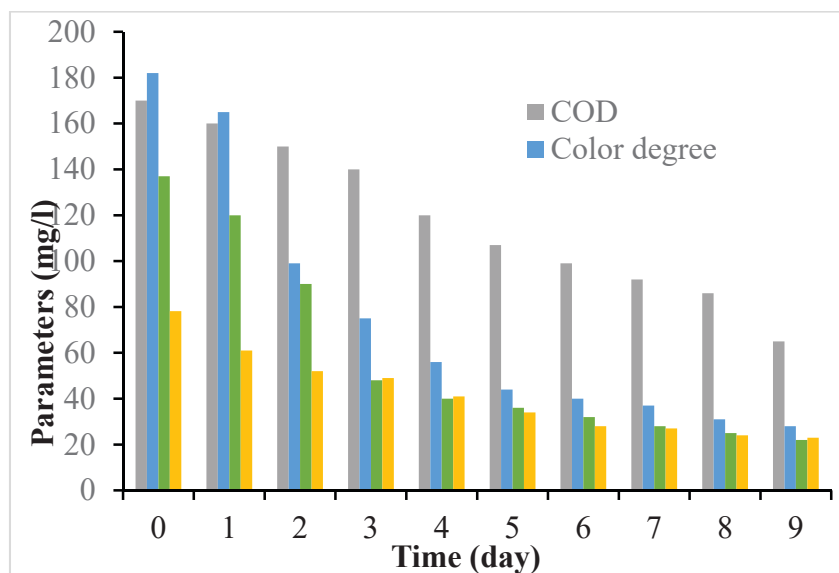


Figure 2. The change of some parameters (COD, BOD₅, TOC, color degree) of textile wastewater on time of biological treatment

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2.8. COMPUTATION AND OTHER RELATED TOPICS

AN OVERVIEW OF FABRICATION METHODS FOR POWDERED TITANIUM AND ITS APPLICATION, THE PROPOSITION OF MANUFACTURING SCHEMATIC USING TiF_4 ELECTROLYSIS METHOD

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Vo Thi Ngoc Cam

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Project information:

- Project name: "An overview of fabrication methods for powdered titanium and its application, the proposition of manufacturing schematic using TiF_4 electrolysis method"
- Code: CS/21/06-02
- Managerial Level: Institute
- Implementation time: 12 months (April 2021 – March 2022)
- Contact Email: vunt@canti.vn
- Published papers related to the project:
 1. Nguyen Trong Vu, Bui Quang Tri, Phan Van Phuc, "Fluoride processing of Ilmenite - The proposition of manufacturing schematic using TiF_4 electrolysis method", The 14th Vietnam Conference on Nuclear Science and Technology Report

Vietnam has abundant titanium mineral resources, with an estimated total reserve of about 658 million tons and ranks sixth among countries with the largest titanium reserves in the world. However, Vietnam is a developing country and the titanium industry is not significant.

Up to now, there are three main types of technology to produce TiO_2 pigment in the world: sulfate technology using concentrated aqueous sulfuric acid to decompose ilmenite ore, halogenation technology using chlorine gas or fluorine: HF/NH_4F to halogenate titanium slag or natural rutile with high TiO_2 content, and alkaline treatment technology ($NaOH$) combined with chlorination. Each technology has its advantages and disadvantages.

The sulfate method is the oldest method used to process titanium-containing minerals. This technology has some advantages such as low investment cost, input ilmenite concentrate needn't have high TiO_2 content and special requirements. The equipment is quite simple and easy to find and manufacture. However, the biggest disadvantage of this technology is that it will release a huge number of contaminants, especially H_2SO_4 . The residual amount of H_2SO_4 is about 1.2÷1.4 tons with a very high concentration (ranging from 25% to 28%) when producing one ton of TiO_2 . Most facilities use $Ca(OH)_2$ to neutralize H_2SO_4 , but a significant amount of $CaSO_4$ is produced. It contains many toxic substances attached, which can cause

environmental pollution. Therefore, at present, almost all facilities have stopped using this method to produce TiO_2 pigment or produce it in moderation.

The chlorination method is the most used method to process titanium-containing minerals and produce TiO_2 and metallic titanium. By 2018, the capacity of producing titanium dioxide by this method had exceeded the capacity of the sulfate method. The outstanding advantages of chlorine technology are less waste, higher product quality, and lower operating costs (only 60÷75% of the sulfate method). However, the equipment used for this technology must be made from special materials, resistant to corrosion in a high-temperature chlorine gas environment, and it requires the operators to be well-trained, knowledgeable, and experienced. One of the difficulties in using this technology in Vietnam is that the large companies using chlorination technology in the world do not transfer the technology to their partners, and we can't own this technology.

Based on the references, we highly recommend using the fluorination method using TiF_4 electrolysis – a new technology to process Ilmenite because of its low emission and environmental friendliness. By using fluorine gas as the fluorinated agent, the process will be shortened, simplified, and closed since the fluorine gas liberated at the anode will return cyclically to decompose the ore.

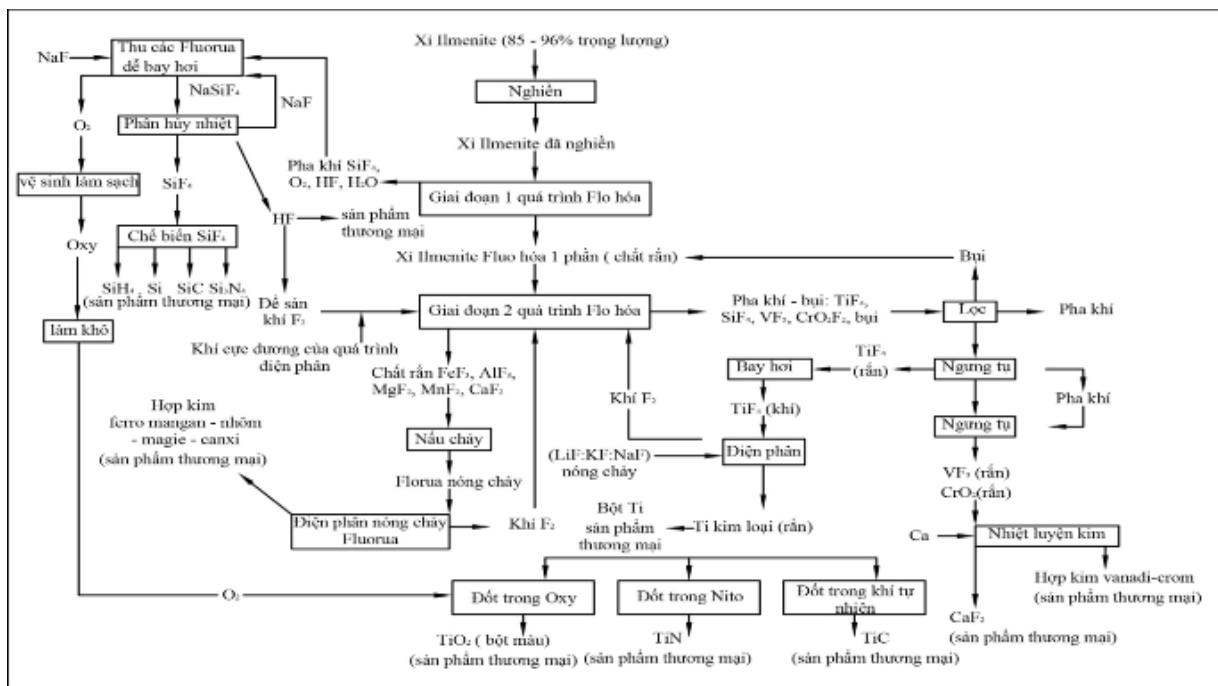


Figure 1: Diagram of TiF_4 electrolysis technology combined with fluorination of ilmenite ore for processing powdered titanium.

Fluorination technology for processing titanium-containing minerals combined with TiF_4 electrolysis technologies is currently considered one of the most potential technology thanks to the following advantages: The technological process that is carried out in the device is completely sealed, it doesn't cause environmental contamination. The equipment is used in several other fields, like uranium ore processing, and has low corrosive effects. The fluorinated

agent is cyclic with an efficiency of about 90%, which helps to save chemicals. During the fluorination process, the exothermic reactions help maintain temperature and save energy; the by-products in of the process have commercial value. So far, electrolysis technology has been widely applied in non-ferrous metal processing. The process is continuous and uninterrupted, and fossil fuels aren't used, which helps to reduce carbon emissions and minimize contaminants. Electrolysis technology uses fluoride salts and low temperature melting crystals to save energy and obtain high pure titanium powder.

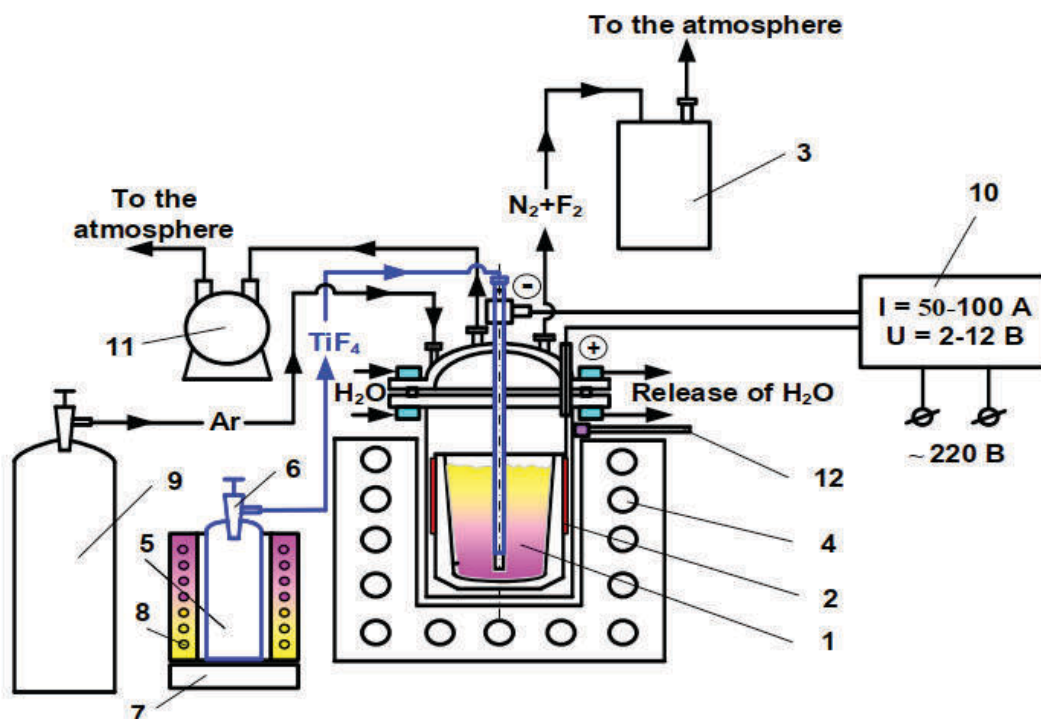


Figure 2: The installation diagram of testing equipment for TiF_4 electrolysis to make powdered titanium: 1 - electrolytic cell; 2 - annealing layer; 3 - sorbents ($Ca(OH)_2$ and $NaOH$); 4 - electric furnace; 5 - TiF_4 tank; 6 regulating valve; 7 - balance; 8 - heater of TiF_4 tank; 9 - cylinder with inert gas (Ar); 10 - check valve; 11 - vacuum pump; 12 - thermocouple

RESEARCH ON ALKALINE DECOMPOSITION BAKING FOR VIETNAMESE MONAZITE CONCENTRATE

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Project information

Project name: “Research on alkaline baking technology for Vietnamese monazite concentrates”

Code: CS/21/03-01

Managerial Level: Institute

Implementation time: 12 months (Jan 2021- Dec 2021)

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Published papers related to the project:

1. Hoang Xuan Thi, Ngo Van Tuyen, Nguyen Thi Men, Hoang Thi Tuyen, Hoang Nhuon, Research on the technological process of alkaline (KOH) decomposition baking for Vietnamese monazite concentrates, Proceedings of the 14th Vietnam Conference on Nuclear Science and Technology (VINANST 14), Da Lat, Vietnam, 2021.
2. Hoang Xuan Thi, Hoang Nhuon, Ngo Van Tuyen, Nguyen Thi Men, Hoang Thi Tuyen, Investigation of alkaline (NaOH, KOH) baking technology for Vietnamese monazite concentrate, Vietnam Journal of Science and Technology – MOST (Series B), 2021.

Processing monazite by alkaline (NaOH) leaching is currently used in the production of total light rare earth oxides (TLREOs) and thorium oxide (ThO₂) in industry. Besides the acknowledged advantages, the technology also has certain disadvantages such as requiring ultrafine grinding of concentrates to -325mesh; and the leaching time in the case of 200mesh can be extended up from 8 to 10 hours for the efficiency to be approximate ~93%...

To overcome that limitation, we have conducted research on alkaline (NaOH, KOH) decomposition baking technology for Vietnamese monazite concentrate. Our goal is to conduct research on decomposing baking efficiency and proposing a laboratory-scale decomposition baking process for production deployment in the field of monazite deep processing in the future.

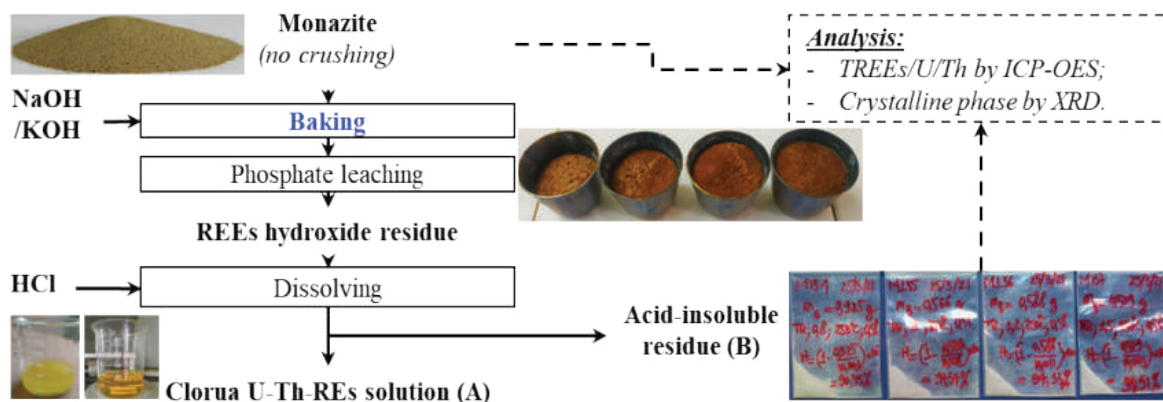


Figure 1: Experiment diagram of alkaline decomposition baking for Vietnamese monazite concentrate.

Figure 1 shows the experiment diagram. Monazite concentrate is mixed with alkaline (NaOH, KOH) in 4 ratios of 0.8-1.0-1.2-1.5. The mixture was baked in the Nabertherm L 9/12/P320 furnace at temperatures of 300-400-500-700°C (NaOH) and 200-250-300-400°C (KOH) for a variable period time of 0.5-1-2-3 hours. The mixture after baking was washed with water to remove all residual phosphate and alkaline. Then the residue was dissolved in acid HCl. The acid-insoluble residue (B) left after the dissolution process was analyzed by mass, XRD, and ICP-OES methods. The efficiencies were calculated as follows:

$$\text{Decomposition efficiency of monazite concentrate} = \left(1 - \frac{\text{Weight of residue (B)}}{\text{Weight of monazite concentrate}}\right) \times 100\% \quad (1)$$

The conversion efficiency of TREEs-U-Th

$$= \left(1 - \frac{\text{TREEs-U-Th content(\%) in residue (B)} \times \text{Weight of residue (B)}}{\text{TREEs-U-Th content(\%) in monazite concentrate} \times \text{Weight of monazite concentrate}}\right) \times 100\% \quad (2)$$

From the results of mass and ICP-OES analysis of B residue, determine the optimal conditions of NaOH and KOH are 1,2:1-400°C-1h and 1:1-250°C-0,5h, respectively. The efficiencies being shown in Table 1.

Table 1: The decomposition and conversion efficiency of TREEs-U-Th in optimal baking conditions

Agent	Decomposition efficiency (%)	Conversion efficiency (%)								
		LREEs					Y	TREEs	U	Th
		La	Ce	Pr	Nd	Sm				
NaOH	92,78	97,8	97,62	97,96	97,8	97,89	97,79	97,75	98,30	99,15
KOH	95,78	99,47	99,56	99,57	99,58	99,60	99,50	99,55	99,70	98,97

The comparison of optimal baking conditions for alkaline decomposition of NaOH and KOH in this study with some other studies is given in Table 2. The comparison results show many advantages of NaOH and KOH decomposition baking technology such as: saving investment and maintenance costs of crushing equipment; saving energy and time; reducing the risk of radioactive fallout; reducing the baking time (~8-20) that is suitable for many batches per day.

Table 2: Comparison of current research results on optimal conditions to other technologies

Technology Parameters	NaOH leaching (1991) – Vietnamese mona. conc.	NaOH (12,5M) leaching (2001-2002) – Vietnamese xeno. conc.	KOH (pellet) baking (2019) – Korean mona. conc.	NaOH (flake) baking (2021) – Vietnamese mona. conc.	KOH (flake) baking (2021) – Vietnamese mona. conc.
Particle size (mesh)	200 (54 μ m)		100-150 (100-150 μ m)	140 – 70 (100-200 μ m) non-crushing	
Object	NaOH, H ₂ O		KOH pellet	NaOH flake	KOH flake
Mass ratio (w:w)	0,9:1 (180%)	2:1 (400%)	1:1 (143%)	1,2:1 (240%)	1:1 (143%)
Temp. (°C)	135-140	200 (10,5atm) 240 (20atm)	250	400	250
Time (h.)	8-10	4	0,5	1	0,5
Efficiency (%)	93 (8h)	90 (10,5atm) 94,7 (20atm)	Phosphate: ~100	Monazite: 93-96 TREEs/U/Th: 98-100	

The alkaline baking technology flowchart in 100g/batch scale is proposed in Figure 2.

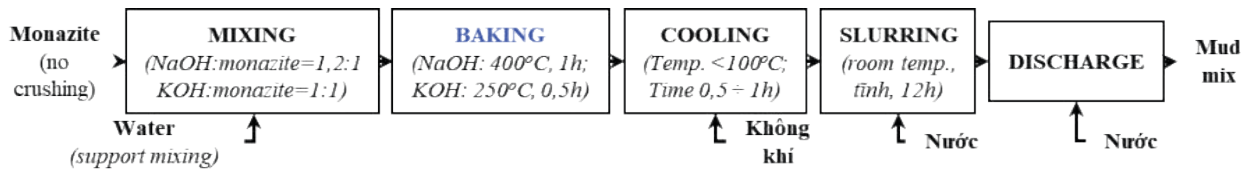


Figure 2: Alkaline baking technology flowchart for Vietnamese monazite concentrate

STUDY ON ESTABLISHING A PROCESS FOR SIMULTANEOUS PRODUCTION OF THE RARE EARTH PRODUCTS FROM DONG PAO BASNAZITE ORE

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Project information:

Project name: “Testing production of 95% total rare earth oxides in a scale of 25 tons/year and some other applied products from Dong Pao ore”.

Code: DA SXTN 12/18/VCNXH

Managerial Level: Ministry

Implementation time: 36 months (Jan 2018- Dec 2020); Extended to Jun 2021

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Published papers related to the project:

Nguyen Ba Tien, Luu Cao Nguyen, Le Xuan Huu, Nguyen Tien Quy. Study on establishing a process to simultaneous production products from Dong Pao basnazite ore; The 13th International Conference on Nuclear Science and Technology, Quang Ninh, Vietnam; Quang Ninh 2019. (in Vietnamese).

Nguyen Ba Tien. Problems managing for radioactive waste NORM/TENORM in facilities of mining and processing for minerals containing radioactive elements; The 13th International Conference on Nuclear Science and Technology, Quang Ninh, Vietnam; Quang Ninh 2019. (in Vietnamese).

Nguyen Ba Tien, Dau Tien Dung, Tran Van Lam, Nguyen Thi Hue, Le Hoang Kiet, Huynh Le Thien Tu, Hoang Van Giang, Trinh Thi Nga, Results of the application of rare earth fertilizers on crops ; The 14th Conference on Nuclear Science and Technology, Da Lat 20121. (in Vietnamese).

In the world, there existed many studies on the processing of Basnazite ore, but the products of these processes usually are the total rare earth oxides or rare earth chloride solutions. These materials were used for further processing of products. Vietnam is a country with a large of rare earth resources, which were unexploited. Many scientists and businesses have the demands to research and apply rare earths in the economic field, but it is rather difficult to get them with large quantity and at the low cost in Vietnam. The goal of this project is researching and building a process for processing Dong Pao Basnazite ore to recover some rare earth products, which initially stimulate the demand of rare earth applications in the domestically economic and technical fields.

The object of the study is Dong Pao Basnazite ore with total rare earth oxides (TREO) content ranging from 20.25 to 26.85%. The leaching agents used are acids: H_2SO_4 , HNO_3 and HCl ; the rare earth precipitating agents are: Na_2CO_3 , $NaOH$, NH_4HCO_3 . The main equipment used for the

establishing the process is: Hammer crusher with 10 kW capacity; vibrating sieve instrument with capacity of 7 kW; 200 liter mixing tank with agitator, 1 kW stirring motor; filter press REF 10.50 M; Furnace at 900°C; drying oven at 300°C and a number of laboratory-scale instruments and apparatus. The analysis of rare earth ingredients and products was carried out on ICP-MS instrument at the laboratory of Analytical Center, Institute for Technology of Radioactive Rare Elements. The process of simultaneously producing many kinds of rare earth products from Dong Pao basnazite ore was carried out according to the principle diagram as shown in Figure 1.

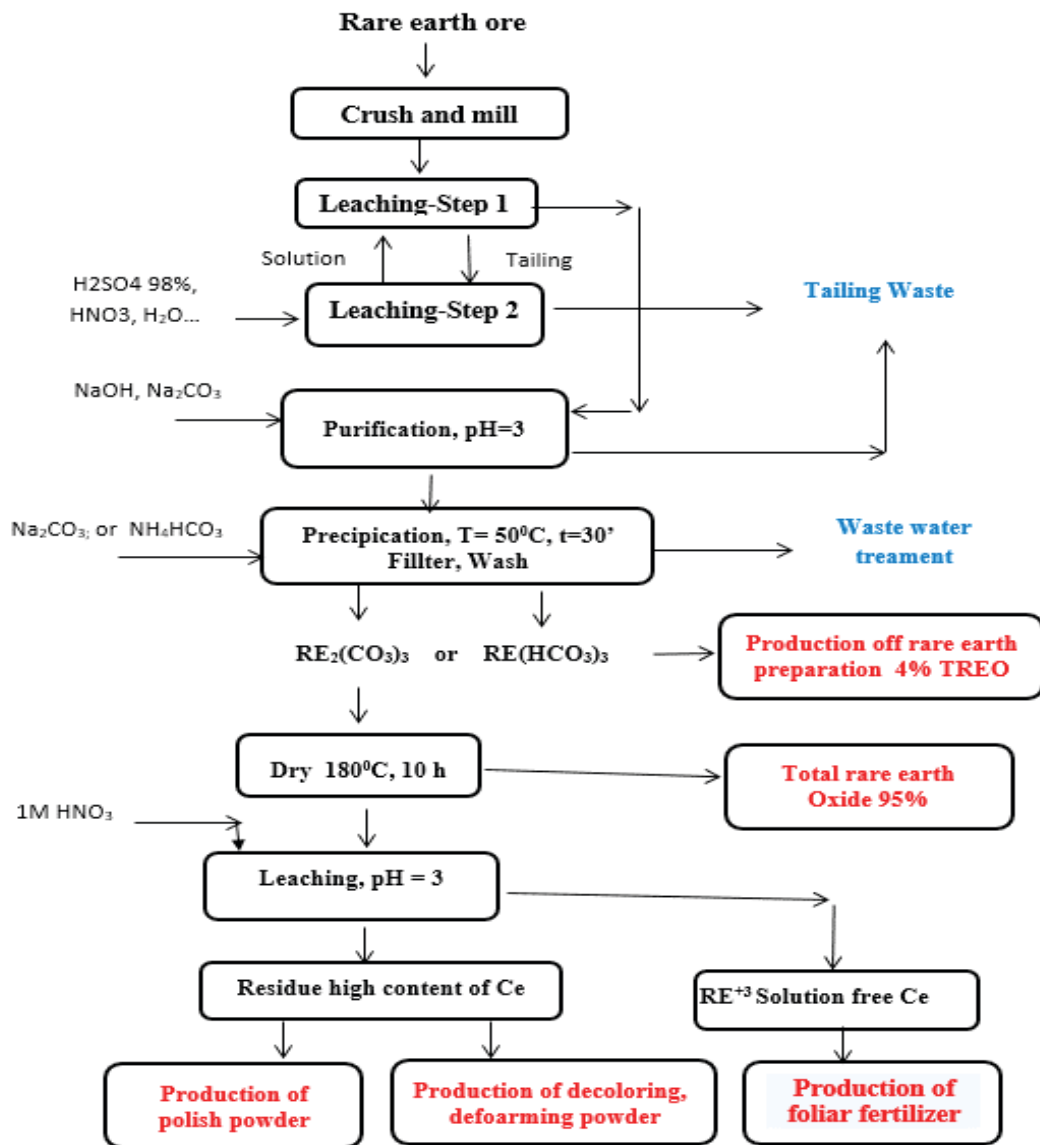


Figure 1: Simultaneous production diagram of 95% total rare earth oxide and other rare earth products

The studied process included of the ore leaching stages by the two steps counter-current leaching technique, the cleaning stage of impurities by the method of fractional precipitation, and the separation of impurities at pH = 3, followed by using various precipitating agents such as Na₂CO₃ to obtain the total rare earth carbonate, which was used for the production of total rare earth oxides or NH₄HCO₃ agent to obtain RE(HCO₃)₃, which was used as a raw material for

the production of fertilizers containing rare earth.

From rare earth carbonate, after drying at 180°C for 10 hours, total rare earth oxides will be obtained.

From rare-earth carbonate, the calcination was used at 650°C for 6 hours, then selectively dissolved trivalent rare-earth elements with 1M HNO₃ acid to obtain a rare-earth oxide residue containing rich cerium that was the glass polishing powder.

The de-foaming and de-colouring bleach powder for glass was made by mixing Ce-rich in total rare earth oxide product with silicon oxide additive in suitable dosage.

Rare earth additives for fertilizer production were made by mixing the RE(HCO₃)₃ intermediate product with a bentonite carrier at a certain pre-calculated dose to obtain 4% TREO rare earth additive product.

Foliar fertilizer solution containing 5% TREO was produced by leaching rare earth ores with nitric acid on a reversed 2-stages separator system. The solution obtained from the selective separation of trivalent rare earth element (in the production of glass polishing powder) was also used for the preparation of the foliar fertilizer solution containing 5% TREO.

Table 1 shows the composition of rare earth products manufactured according to the process.

Table 1. Analytical results of rare earth composition in the products

STT	Oxide	Rare earth composition of products (%)				
		TREO	Decolouring, de-foaming powder	Polishing Powder	Rare earth preparation for fertilizer	Rare earth solution for fertilizer
1	Yb ₂ O ₃	<0.0001	0.014	0.0003	0.0035	0.0055
2	Lu ₂ O ₃	<0.0001	<0.0001	0.0002	0.0005	0.0011
3	Eu ₂ O ₃	0.0815	0.048	<0.002	0.0074	0.0130
4	Tm ₂ O ₃	0.0009	0.001	0.0004	0.0006	0.0014
5	Y ₂ O ₃	<0.0001	0.099	<0.002	0.0616	0.1005
6	La ₂ O ₃	16.6738	7.096	15.381	1.2039	1.3556
7	Sc ₂ O ₃	<0.0001	<0.0001	<0.002	0.0114	0.0140
8	Er ₂ O ₃	<0.0001	0.011	0.0008	0.0043	0.0079
9	Dy ₂ O ₃	<0.0001	0.035	0.001	0.0123	0.0204
10	Gd ₂ O ₃	0.0672	0.095	0.002	0.0305	0.0515
11	Ho ₂ O ₃	0.0075	0.009	0.007	0.0020	0.0047
12	Tb ₄ O ₇	<0.0001	0.012	0.0004	0.0032	0.0067
13	Sm ₂ O ₃	0.0262	0.173	0.008	0.0238	0.0330

STT	Oxide	Rare earth composition of products (%)				
		TREO	Decolouring, de-foaming powder	Polishing Powder	Rare earth preparation for fertilizer	Rare earth solution for fertilizer
14	Nd ₂ O ₃	0.6460	1.927	0.384	0.1986	0.2289
15	CeO ₂	73.1799	12.193	76.315	2.4735	3.1214
16	Pr ₆ O ₁₁	4.5075	0.870	3.032	0.0720	0.0768
TREO		95.190	22.583	95.132	4.109	5.042

The process that can produce 5 products: Total rare earth oxide, glass polishing powder, glass de-foaming and bleaching powder, rare earth powder and rare earth solution as raw materials for the production of fertilizers containing rare earths or for the production of products for the treatment of aquaculture environment, supplementary products for animal feed has built in this project. It is possible to produce 25 tons/year of total rare earth oxides with TREO > 95% content and tens tons of rare earth powder with 4 % TREO content, tens thousands liters of rare earth solutions with 5% TREO concentration to provide for agricultural applications using this process.

However, the application in industry is still rather difficult because the enterprises are currently in the large quantity production, following strictly ISO standards, resulting in the requirement that rare earth products need to be supplied in stably large quantities that the capacity of a project could not be met.

In order to promote the strengths of Vietnam's rare earth resources, we hope that the Governmental offices such as the Ministry of Industry and Trade, the Ministry of Science and Technology and the Ministry of Agriculture and Rural Development will cooperate and support the businesses in terms of policy as well as scientific, technological and financial capacity for pushing the mining, processing and the application of rare earths into a spearhead economic sector, bringing great economic benefits to the country.

STUDY ON RECOVERY ABILITY OF COBALT AND LITHIUM FROM SPENT LITHIUM-ION BATTERIES BY SOLVENT EXTRACTION METHOD

Nguyen Dinh Viet, Tran Hoang Mai, Luu Xuan Dinh, Bui Cong Trinh, Ngo Quang Hien

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Project information:

- Project name: Study on recovery ability of cobalt and lithium from spent lithium – ion batteries by solvent extraction method
- Code: CS/21/03-02
- Managerial Level: Institute
- Implementation time: 12 months (Jan 2021 – Dec 2021)
- Published papers related to the project:
 1. Nguyen Dinh Viet, Bui Cong Trinh, Tran Hoang Mai, Ngo Quang Huy, Luu Xuan Dinh “Study on recovery ability of cobalt and lithium from spent lithium – ion batteries by solvent extraction method”;
 2. Nguyen Dinh Viet, Bui Cong Trinh, Tran Hoang Mai, Ngo Quang Huy, Luu Xuan Dinh “Study on recovery ability of cobalt and lithium from spent lithium – ion batteries by solvent extraction method”, Viet Nam conference on Nuclear Science and technology - 14, 9-10/12/2021

The widespread popularity of smartphones combined with the rapid growth of the electric vehicle industry has increased the demand for LIBs batteries (Lithium-ion batteries). Meanwhile, used LIBs accumulate, and recycling them is a serious challenge because used LIBs contain high concentrations of heavy metals and toxic electrolytes, incorrect disposal will risk the environment, mental health, and human health in the future... As a result, studying the procedures of recycling used batteries and recovering valuable metals from batteries is extremely important and urgent, especially given the present trend of increasing electronic battery discharge, but there is presently no efficient treatment and recycling solution. Based on the above issues, we conduct the following research “Study the possibility of extracting cobalt and lithium from used lithium-ion batteries using a solvent extraction method”. During the recovery of metals from a used lithium-ion battery’s cathode electrode, Co is separated by solvent extraction and Li is recovered as a Li_2CO_3 salt.

The study’s content is presented below.

i). Materials: Table 1 shows the elemental composition of a used laptop LIBs battery cathode.

Table 1: The composition of the main elements in the Li-ion battery cathode

STT	Sample	Content (mg/kg)							
		Ni	Co	Al	Mn	Fe	Cu	Li	Sn
1	Catot battery	32091.2	225884.8	691.7	17414.2	55.5	8612.1	31375.5	43.3

ii). Equipment: Shaker; extractor funnel; PH meter; Furnace...

iii). The following is how the battery cathode is dissolved in sulfuric acid: Slowly pour the battery powder into the H_2SO_4 acid solution. The operation is carried out in stirring mode, the temperature is gradually increased to $90^\circ C$, and a little amount of H_2O_2 solution is added. The results show that the fission process is most efficient when the following conditions are met: H_2SO_4 acid concentration - 2M; reaction time - 2 hours; H_2O_2 concentration - 5%; reaction temperature - $90^\circ C$. The stirring speed did not affect separation efficiency.

The solvent extraction method was used to remove Co from Li under the following conditions: The extraction agent is PC88A, while the diluent is IP 2028. Separation funnel and shaker tests were carried out. Figure 1 shows the factors influencing the recovery process.

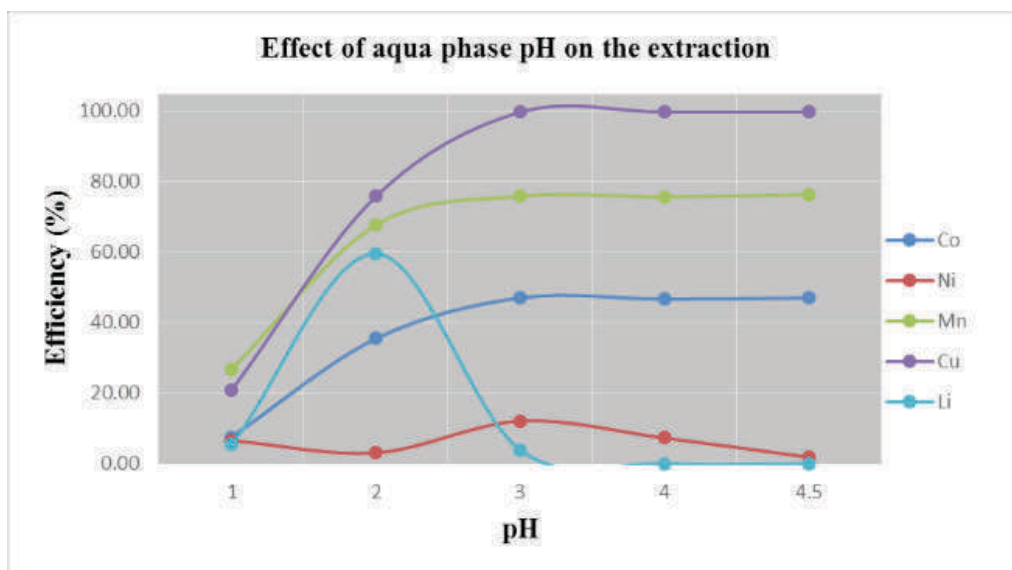


Figure 1: Factors affecting the extraction ability of Co/Li

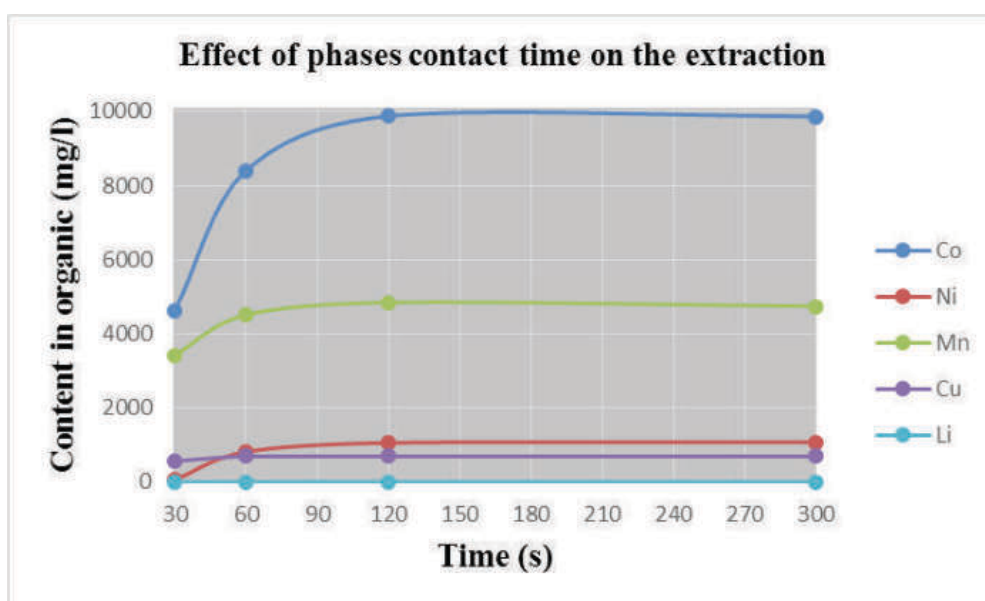


Figure 2: Factors affecting the extraction ability of Co/Li

After dissolving, salt ions in the solution are precipitated by a sufficient amount of NaOH. The precipitate was filtered and rinsed with distilled water numerous times. Following the precipitation calcination procedure, the resulting CoO and Li_2CO_3 products were purer than 96 and 97 %, respectively.

The project's study results are exhibited in 01 article has been approved for publication in the journal Chemistry and Applications in 2021; 01 reports to be presented at the 14th National Conference on Nuclear Science and Technology in December 2021; 01 methodology for recovering Co and Li from discarded LIBs batteries; 100g CoO with 96 % purity; 50g Li_2CO_3 with 97 % purity.

As a result, when compared to the description and the contract, the Project has finished the registration content and met the aim.

Request: The cleanliness of the product is still not very high (< 99 %). This is explained by the high Ni concentration of the LIBs. To obtain high-purity CoO and Li_2CO_3 products, the separation of Ni from Co in the separation solution must be studied further.

STUDY ON TECHNOLOGY FOR PREPARATION OF TERBIUM METAL USING $TbCl_3$ SOLUTION FROM RARE EARTH SOLVENT EXTRACTION PROCESS

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Cao Duy Minh, Tran Hoang Mai, Nguyen Dinh Viet

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Project information:

Project name: "Study on technology for preparation of Terbium metal using $TbCl_3$ solution from rare earth solvent extraction process"

Code: DTCB.10/20/VCNXH

Managerial Level: Ministry

Implementation time: 24 months (Jan 2020- Dec 2021)

Contact email: ntthuy.k51a@gmail.com

Published papers related to the project:

Nguyen Trong Hung, Nguyen Thanh Thuy, Le Ba Thuan, et al. (2021) "Anhydrous oxygen-free rare earth material preparation and characterization", *Materials Today Chemistry*, 22, 100608.

Nguyen Trong Hung, Nguyen Thanh Thuy, Le Ba Thuan, et al. (2020) "Separation of thorium and uranium from xenotime leach solutions by solvent extraction using primary and tertiary amines", *Hydrometallurgy* 198, 105506.

Nguyen Trong Hung, Nguyen Thanh Thuy, Le Ba Thuan, Nguyen Thi Lien "Preparation and dehydration of terbium fluoride hydrate salt for the terbium metal processing by wet method", *Vietnam Journal of Science, Technology and Engineering*, MOST (Article in press).

Nguyen Thanh Thuy, Nguyen Trong Hung, Nguyen Thi Lien (2021) "Study on the preparation of terbium metal by metallothermic reduction method using a vacuum induction furnace", *Proceeding of the 14th Conference on Nuclear Science and Technology*, VINATOM, Da Lat, Vietnam.

Nguyen Trong Hung, Nguyen Thanh Thuy et al., (2020) "Preparation and dehydration of terbium fluoride salt for terbium metal processing", *Proceeding of the 6th Conference on Nuclear Science and Technology for Young Researchers*, VINATOM, Ha Noi, Vietnam.

Terbium (Tb) is one of the high valuable heavy rare earth elements (HREEs). It is one of the components of Terfenol-D ($Tb_xDy_{1-x}Fe_2$; $x \sim 0.3$), which is the highest magnetostriction. Like other HREEs, terbium is obtained from ion adsorption clays (IACs) and xenotime exploitation. Ben Den IAC and Yen Phu xenotime (Vietnam) have high Tb contents of 0.64 % và 0.5 %, respectively.

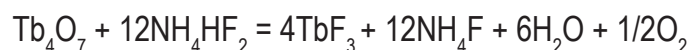
There are two main techniques to prepare the rare earth metals, including molten salt electrolysis and metallothermic reduction. Both techniques used anhydrous chloride or fluoride rare earth salt as the raw material. Metallic Tb is prepared by metallothermic reduction

of anhydrous fluoride (TbF_3) or chloride ($TbCl_3$) terbium, using calcium (Ca) or lithium (Li) as a reductant. However, disadvantage of the chloride rare earth salt is highly hygroscopic property; meanwhile the fluoride rare earth salt overcame this problem; and so in this study, anhydrous salt TbF_3 is used for preparation of metallic Tb. The project has three main contents including the preparation of anhydrous TbF_3 from $TbCl_3$ solution, the preparation of metallic Tb by calcinothemic reduction of the anhydrous TbF_3 and the refining (casting) of Tb metal to obtain higher purity metal ($\geq 95\%$).

Tb compounds used in this study are $TbCl_3$ solution (from rare earth solvent extraction process) and Tb_4O_7 ($[Tb]>95\%$); other chemicals such as Ca, NH_4HF_2 , HF, NH_4HCO_3 , $H_2C_2O_4$, HCl, H_2SO_4 ... are analytical reagents. Two main equipment using in this project are tube furnaces with a maximum operating temperature of $1000^\circ C$ (used for the preparation of anhydrous TbF_3) and a vacuum reduction furnace with a maximum operating temperature of $1900^\circ C$ (used for the calcinothemic reduction and the casting process).

Two methods were applied for anhydrous TbF_3 preparation. There are wet and dry methods. In the first one, $TbCl_3$ solution was precipitated with NH_4HCO_3 1M at pH=7. Then, terbium carbonate was recovered to TbF_3 by using a solution of HF 50%. After filtration and centrifugation, the solid was dried and heated in the tube furnace. Results of thermogravimetric analysis (TGA) and differential thermal analysis (DTA) show that anhydrous TbF_3 can be obtained at temperature of $600^\circ C$. XRD pattern and EDS spectrum indicate that a clear and pure phase of TbF_3 was formed.

In the second method (dry method), some mixtures of Tb_4O_7 and NH_4HF_2 with difference ratio of NH_4^+/Tb^{3+} were heated at high temperature. Results show that a NH_4^+/Tb^{3+} ratio of 3.5/1, a heating temperature in range of $350^\circ C$ to $450^\circ C$ and a heating time of 1-3hrs are enough to prepare anhydrous salt of TbF_3 . The fluorination of Tb_4O_7 can proceed through reaction as below:



XRD pattern from SIEMENS D5005 instrument and EDS spectrum from the JEOL JSM-IT100LV instrument show a clear and high purity phase of TbF_3 as following figure:

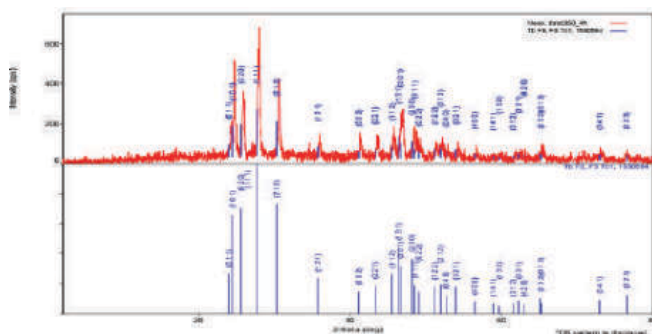


Figure 1: XRD pattern of anhydrous TbF_3 obtained from dry method.

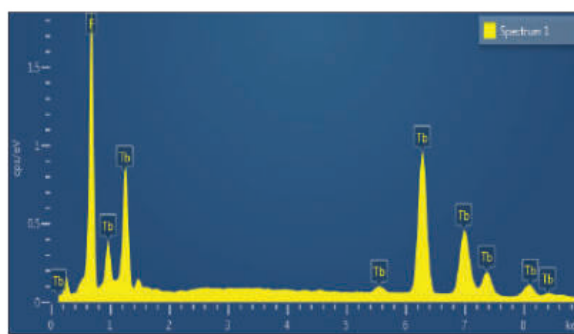
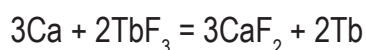


Figure 2: XRD pattern of anhydrous TbF_3 obtained from dry method.

The anhydrous TbF_3 was used as a material for the calcinothemic reduction to prepare the metallic Tb. The studies were implemented by using a vacuum reduction furnace. The calcinothemic reduction reaction is indicated as follows:



Factors affecting the calcinothemic reduction of TbF_3 , including reaction temperature and time, the molar ratio of Ca/TbF_3 and additives were investigated. The results show that the calcinothemic performance reached over 95% when the Ca/TbF_3 ratio was greater than or equal to 1.95 (30% excess calcium). The reaction temperature from 1450°C and the reaction time from 30 minutes is enough to react a high yield. Tb metal with purity ranging from 90 to 92% was obtained from this process. Additives such as LiF and $CaCl_2$ have the effect of reducing reaction temperature but also the purity of the product. However, their presence make it difficult to separate slag from the Tb metal.

To obtain higher purity Tb metal, the raw Tb obtained from the calcinothemic reduction needs to be refined using a casting process. The casting process was carried out in a vacuum induction furnace. The factors affecting the Tb casting such as casting temperature, time, and environmental pressure have been studied. Results indicated that the refining process of Tb metal should be carried out at a temperature greater than 1500°C, a pressure lower than ambient pressure and a time greater than 30 minutes. Under these conditions, the Tb purity can reach over 95%. The yield of the casting process under the above conditions is about 90%. Thus, the overall efficiency of the calcinothemic reduction and refining processes is over 80%.



Figure 3: Tb metal - after casting.

From the base results, the process of preparing Tb metal from $TbCl_3$ solution has been tested and established. 204g of $\geq 95\%$ metallic Tb was prepared in this project.

In addition to the main studies on the calcinothermic reduction and refining for obtaining high-purity Tb metal, studies on Tb recovery from tailings, treatment of flue gas from preparation of anhydrous TbF_3 salt have also been conducted. Tb recovery efficiency can reach 94%. The purity of the recovered product can reach 93% metallic Tb. The exhaust gas of the anhydrous TbF_3 preparation can be treated by adsorbing into two tanks containing a solution of clear lime water and clean water, respectively.

RESEARCH ON MN DOPING PROCESS IN NANOPHOSPHORS MATERIALS $K_2SiF_6:Mn^{4+}$ BY POSITRON ANNIHILATION LIFETIME SPECTROMETER

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Project information:

Project name: Research On Mn Doping Process in Nanophosphors Materials $K_2SiF_6:Mn^{4+}$ by Positron Annihilation Lifetime Spectrometer

Code: CS/21/02-01

Managerial Level: Institute

Implementation time: 12 months (Jan 2021- Dec 2021)

Contact email: lothaison@gmail.com

Published papers related to the project:

1. Lo Thai Son, Luu Anh Tuyen, Phan Trong Phuc, Pham Thi Hue, Nguyen Thi Ngoc Hue, Ngo Dang Trung, Nguyen Hoang Duy. Structure of the high quantum yield $K_2SiF_6:Mn^{4+}$: a study using positron life annihilation spectroscopy, Poster of the 13th Vietnam Conference on Nuclear Science and Technology (VINANST 14), Da Lat, Vietnam (in Vietnamese).
2. Lo Thai Son, Doan Thi Tuyet, Phan Trong Phuc, Pham Thi Hue, Nguyen Thi Ngoc Hue, La Ly Nguyen, Dinh Van Phuc, Tran Dong Xuan, Hoang Anh Tuan Kiet, Le Van Toan, Nguyen Hoang Duy, Nguyen Quang Hung, Luu Anh Tuyen. Positron annihilation study of lattice defects and nanoporous structures in Mn^{4+} doped K_2SiF_6 nanophosphors exhibiting high quantum yield. Radiation Physics and Chemistry.

Red light-emitting $K_2SiF_6:Mn^{4+}$ material is one of the important materials used in micro-LED manufacturing technology for applications of smart and ultra-thin displays. This material is often synthesized by chemical methods including Mn^{4+} doping to increase the quantum yield. However, until now, our understanding of the Mn^{4+} doping mechanism and the influence of the doping on the formation of defects and porous structures for increasing quantum yield has been still very limited.

In the present work, Mn^{4+} doped K_2SiF_6 (KSFM) red-emitting nanophosphors that exhibited high quantum yield (QY) were prepared using a sodium dodecyl sulphonate (SDS) surfactant and different solvents having different dielectric constants. The crystalline structure, particle size, concentration of doped Mn^{4+} ions quantum yield (QY) and photoluminescence excitation (PLE)/ photoluminescence (PL) spectra of the samples were investigated by using XRD, SEM,

ICP-MS, FLS and PMAS, respectively. In particular, the lattice defects, nanoporous structures and sites of doped Mn^{4+} in KSFM samples were examined in detail by the positron annihilation spectroscopies (PAS) that include the positron annihilation lifetime (PAL), Doppler broadening (DB), and electron momentum distribution (EMD) measurements.

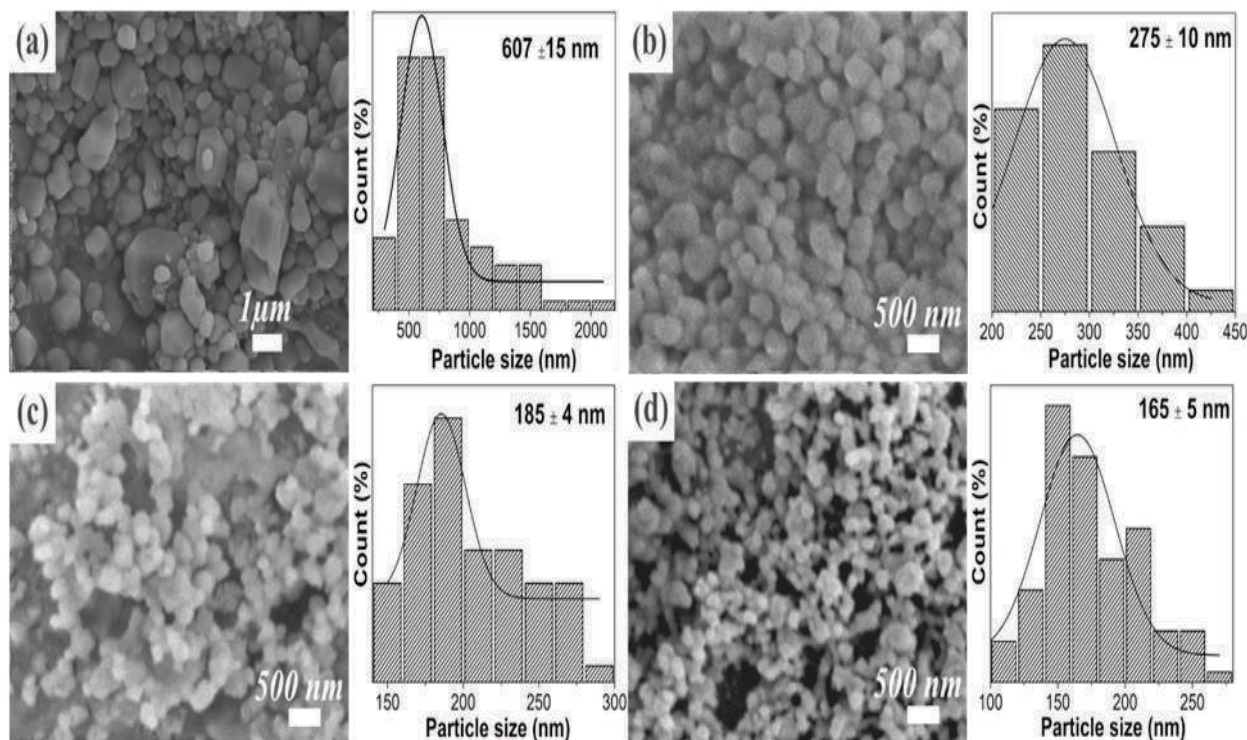


Figure 1. SEM images and particle-size distribution histograms of KSFM-Wa (a), KSFM-Iso (b), KSFM-Ea (c), and KSFM-De (d) samples.

Table 1. Doped Mn^{4+} concentration and QY of KSFM samples.

Sample	Mn^{4+} (% wt)	QY (%)
KSFM-Wa	2.80	61.8
KSFM-Ea	3.53	83.4
KSFM-Iso	3.85	84.1
KSFM-De	3.91	88.1

The obtained results showed that the particle size of KSFM samples decreased with decreasing the dielectric constant of the solvents. The occupation of dope Mn^{4+} to the sites of Si^{4+} in the SiF_6^{2-} octahedron structures of KSFM was explored by PAS. PAS also found the high concentration of lattice defects and the presence of nanopores with the average size of 0.390 – 0.621 nm in the KSFM samples that used isopropanol (Iso), and diethyl ether (De) solvents. In addition, as the concentration of doped Mn^{4+} was increased, the occupation of Mn^{4+} to the adjacent Si-vacancy and K-divacancy in KSFM samples decreased but the number of Si-vacancies the samples increased. Finally, by combining QY data with results of PAS

measurements, we found that the QY of Mn⁴⁺ doped K₂SiF₆ nanophosphors depended not only on the porous structures (nanopores) but also the concentration of doped Mn⁴⁺ in the sites of Si as well as the concentration of Si-vacancies presenting in the samples. This study, therefore, opens a new way towards the chemical doping engineering that can optimize the formation of defects and nanopores to obtain the nanostructure emitters with excellent quantum yield.

INVESTIGATION FOR SYNTHESIZED PROCESS OF RARE EARTH CITRATE AND APPLICATION AS ADDITIONAL FEED FOR BROILERS

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Project information:

- Project name: Investigation for synthesized process of rare earth citrate and application as additional feed for broilers

- Code: ĐTCB-13/19/VCNXH

- Managerial Level: Ministry

- Implementation time: 33 months (Jan.2019 to Sep. 2021)

- Contact email: thanhcaodinh257@gmail.com

- Papers published in relation to the project:

1. Cao Dinh Thanh et al. Investigation of citrate synthesized process from the rare earth carbonate processed from Dong Pao ore (in Vietnamese), 13th National Conference on Nuclear Science and Technology (VINANST 13), Ha long, Vietnam, Sep. 2019.

2. Cao Dinh Thanh et al. Investigation of citrate synthesized process in the equipment of 200L from the rare earth carbonate processed from Dong Pao ore (in Vietnamese), Journal of Chemistry and Application Number 03/9-2021

3. Tran Thi Bich Ngoc, Cao Dinh Thanh et al. Effect of organic rare earth elements on ability of nutritious digestion, morbidity rate and survival rate in broilers (in Vietnamese); Journal of Science and Technology for Animal - Number 267/7-2021

4. Tran Thi Bich Ngoc, Cao Dinh Thanh et al. Effect of organic rare earth citrate in Diet on growth performance and meat quality of broilers. (in Vietnamese); Vietnam Journal of Agricultural Science 2021, Vol 19. No11: 1453-1461

5. Tran Thi Bich Ngoc, Cao Dinh Thanh et al. Effect of organic rare earth citrate on growth performance, meat quality and morbidity rate in broilers; (in Vietnamese); 14th National Conference on Nuclear Science and Technology (VINNANST 14), Da Lat, Dec. 2021.

Rare earth products have used largely in the field of industry and agriculture, especially in agriculture. The application of rare earth with organic radical, like rare earth citrate in animal husbandry have been developed at China from 20 years ago and Western Europe in order to enhance animal growth and ability for resistance of diseases.

In Vietnam, this study is the first project on synthesization of REE citrate and application as supplement feed for broilers. The purpose of project is establishment of technological flowsheet for RE citrate synthesization (La, Ce) and investigation of effect of RE citrate as supplement feed for broilers.

Rare earth citrate was synthesized from the carbonate of rare earths processed from Dong Pao ore in the scale of laboratory and large scale of equipment 200L- 10 kg of product.

Firstly, investigation was conducted for determination of the parameters of flowsheet for REE-citrate synthesization in scale of laboratory, including dissolution of rare earth carbonate; precipitation of RE-hydroxide; and synthesization of REE-citrate.

The parameters of flowsheet for REE-citrate synthesization were determined such as:

- The dissolution of RE carbonate: temperature of laboratory; reaction time 2h; agitation rate 80 r/m; acid HCl concentration 15%.
- The precipitation of RE-hydroxide: temperature of laboratory; reaction time 2h; agitation rate 80 r/m; concentration of NH_4OH 8-10% and pH 8.5- 9.
- The synthesization of REE-citrate: time 5h; agitation rate 120 r/m; pH 3, temperature 90°C , ratio of acid/ $\text{RE}(\text{OH})_3$ is 1.3; efficiency of synthesization 95%. In order to synthesize to weak acid citric, it is necessary that acid citric were reacted with activated RE hydroxide (new formed).

Based on the results gain from experiments in laboratory, investigation was conducted in the equipment of 200L for determination of parameters of technological flowsheet. Experiment was conducted with 7 kg RE carbonate (dried) in the agitation equipment of 200L and synthesization of 10 kg of REE-citrate.



Figure 1. Equipment for synthesization of RE-citrate-200L

The technological flowsheet of RE citrate synthesization has been established on the scale of equipment of 200L (10 kg RE citrate). The technological flowsheet includes: dissolution of RE cacbonate with acide HCl 15% (odding 40%); precipitation of RE hydroxyd with NH_4OH 10% and pH = 9; REE synthesization with acide citric 4M, time 5 h, at pH=3, temperature 90°C, ratio of acid citric/ RE 1,25 and total efficiency 95.9%.This technological flow-sheet have been operated stably for 10 cycles. The REE citrate was analyzed by ICP method and the result was presented in Table 1.

Num.	Component	Unit	Content	Num.	Component	Unit	Content
1	Sc	mg/kg	0.44	11	Dy	mg/kg	3.70
2	Y	mg/kg	3.52	12	Ho	mg/kg	1.98
3	La	%	11.17	13	Er	mg/kg	4.66
4	Ce	%	18.09	14	Tm	mg/kg	1.75
5	Pr	%	0.45	15	Yb	mg/kg	1.84
6	Nd	%	0.15	16	Lu	mg/kg	1.86
7	Sm	mg/kg	7.06	17	Pb	mg/kg	6.68
8	Eu	mg/kg	<0.0001	18	Cd	mg/kg	0.03
9	Gd	mg/kg	<0.0001	19	As	mg/kg	4.36
10	Tb	mg/kg	35.81	20	humidity	%	2.04

The quality of product was good enough for supplement feed for broilers.

The experiment of REE-citrate as supplement feed for broiler and determination of adequate supplement is presented below.

Firstly, organic rare earth elements (REE-citrate) was applicated as supplemented feed for 50 mice with 150g and 200g per ton of feed. The results of these test improved active impact for growth performance and other numbers.

After that we used REE-citrate as supplemented feed for broiler diets. This study was conducted to evaluate the effect of the supplement of organic rare earth elements (REE-citrate) in broiler diets on growth performance, meat performance and quality, mortality, and morbidity rate. The experiment was done according to a completely randomized design on 1000 chicken from 1 day of age and divided equally males and females into 5 treatments (200 chicken/treatment) as follows: treatment 1 (control): KPCS; treatment 2: KPCS + 50 mg REE-citrate/kg feed; treatment 3: KPCS + 100 mg REE-citrate/kg feed; treatment 4: KPCS + 150 mg REE-citrate/kg feed; treatment 5: KPCS + 200 mg REE-citrate/kg feed.

The investigated parameters were the survival rate; diarrhea and respiratory disease; growth performance; daily weight gain and feed efficiency of broilers

When supplementation of 150 and 200 mg REE-citrate/kg feed, daily weight gain and feed

efficiency of broilers from 1 day of age to slaughter were improved 4.77 -12.47% and 4.48-12.60% respectively. Supplementation of REE-citrate did not affect the yield and quality of meat, however, the addition of 200mg REE-citrate/kg feed slowed down the decrease pH value in breast meat after 24 hours. Supplementation of REE-citrate in the broiler diets reduced the incidence of diarrhea and respiratory disease from 16.09 to 33.90% and from 17.76 to 36.67%, and increased the survival rate from 2.1 to 3.7%, respectively. Meat quality was safety: As: no discovered, Pb < 0.04 ppm. Finally, adequate supplement REE-citrate was determined for broiler feed about of 200 g per ton of feed.

The experiment for the use of REE-citrate as supplemented feed for 1000 of broilers

For evaluation of above investigated- results, study was conducted with large scale of 1000 broilers in order to consider the efficiency of breeding while REE-citrate as supplemented feed with 200 g per ton of feed.

The results of these experiments for 1000 broilers (Luong phuong x Mia) was given that improve body quality, FCR, the survival rate, diarrhea and respiratory disease, daily weight gain, feed efficiency of broilers.

Supplementation of REE-citrate to feed of broiler has improved the feed efficiency of broilers, production number and economical number.

The price of feed will be increased 0.85 to 1.05 %; The expendetrure of feed/ kg body increase will be decreas from 4.63% to 7.78%; The rate of weight body increase is 5.51%;

The dayily weight gain is from 3.83 - 6.40%; The survival rate is 96.67% in the experiments; The rate of diarrhea and respiratory disease were decreased correlatively 33.58% và 26.73%; Production number is increasing 13.50%; Economic number is increasing 20.37%; Content of Rare earth in meat is < 0.3 mg/kg; Content of Cd; Pb; As in meat is < 0.1 µg/kg; 4 µg/kg and 12 µg/kg.

The supplement of REE-citrate as feed for broilers has improved growth performance, anti-disease, production number, economic number and safely for human food.

To conclude, the technological flowsheet of RE citrate synthesization has been established on the scale of equipment of 200L (10 kg RE citrate). The supplement of REE-citrate as feed for broilers has improved growth performance, anti- disease, production number, economic number and safely for human food. The use of REE-citrate as supplemented feed for broilers will be economic prospect.

2.9. COMPUTATION AND OTHER RELATED TOPICS

STUDY ON DETERMINATION OF PCBs IN TRANSFORMER OIL BY GAS CHROMATOGRAPHY EQUIPPED WITH FID/ECD DETECTORS FOR FURTHER APPLICATION IN ELECTRON BEAM RADIATION DECOMPOSITION OF PCBs

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Project information:

- Project name: Study on determination of PCBs in transformer oil by gas chromatography equipped with FID/ECD detectors for further application in EB radiation decomposition of PCBs.

- Code: CS/21/03-03

- Managerial Level: Institute

- Allocated Fund: 85,000,000 VND

- Implementation time: 12 months (Jan 2021 – Dec 2021)

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- Published papers related to the project:

1. Nguyen Thi Hoa Mai, Nguyen Thi Hang, Nguyen Nho Lan, Do Thi Anh Tuyet “Comparison between alkaline hydroxide and sulfuric treatments in cases of determination of PCBs in transformer oil using a gas chromatograph with electron capture detector ECD”, Journal of Analytical Sciences, Vol , 2022 (in Vietnamese).

2. Nguyen Thi Hoa Mai, Nguyen Thi Hang, Nguyen Nho Lan, Do Thi Anh Tuyet, Nguyen Thi Tuoi “Comparison between alkaline hydroxide and sulfuric treatments in cases of determination of PCBs in transformer oil using a gas chromatograph with electron capture detector ECD”, Viet Nam conference on Nuclear Science and Technology - 14, 9-10/12/2021;

Polyclobiphenyls (PCBs) is one of 22 groups of persistent organic substances (POPs) that will not be used by 2020 as specified in the Stockholm Convention. The PCBs will be safely destroyed by 2028 in Vietnam. The PCBs are toxic xenobiotic pollutants that are also called carcinogens. Though Vietnam is not a producer, during 1960-1990, Vietnam imported many PCB-containing machinery and equipment, containing about 30,000 tons of transformer oil, from Romania, China, and the former Soviet Union. Most of this oil has not been safely processed but is mainly stored in the warehouses of Vietnam Electricity. Because PCBs are potentially hazardous substances, that adversely affect human health and the ecosystem. Therefore, it is very necessary to perform the analysis of PCBs in the transformer oil samples using gas chromatograph GC8890 equipped with ECD/FID detector installed at the Institute of Rare Radiation Technology.

This study has established two processes for treating transformer oil samples (cleaning and extraction) in the quantification of PCBs including (1) H₂SO₄ treatment, (2) 1M KOH + H₂SO₄ treatment (Figure 1). The samples after treatment were quantified by gas chromatography equipment GC 8890 detector ECD. The obtained chromatograms are shown in Figure 2. The obtained results showed that both sample treatment procedures gave 90-110% recovery efficiency, the corresponding chromatograms showed clearly separated peaks. Therefore, both processes used are satisfactory for the treatment of transformer oils in PCBs determination.

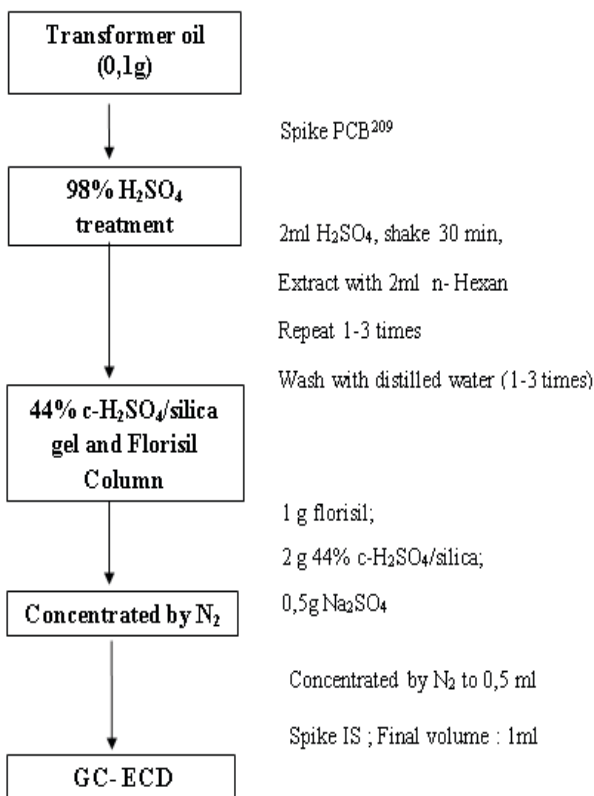


Figure 1a. Schematic of the treatment procedure for the analysis of PCBs in transformer oil with concentrated H₂SO₄

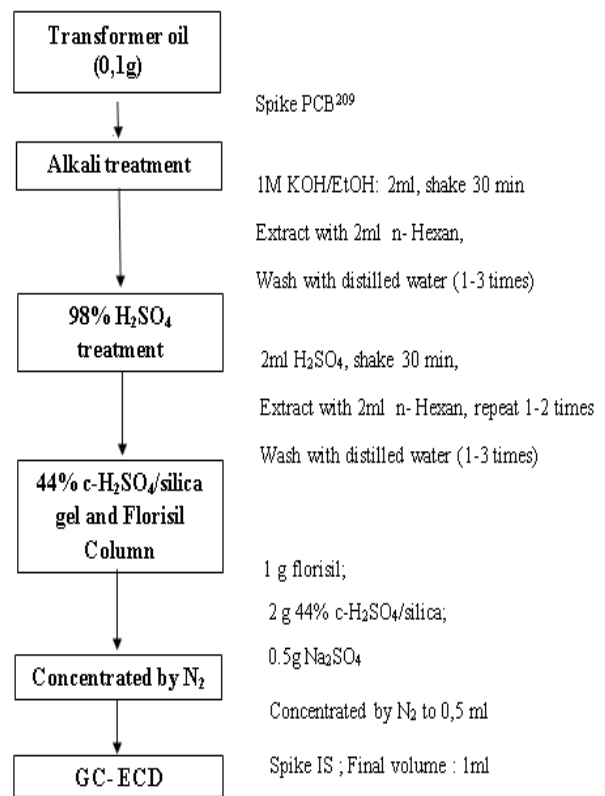
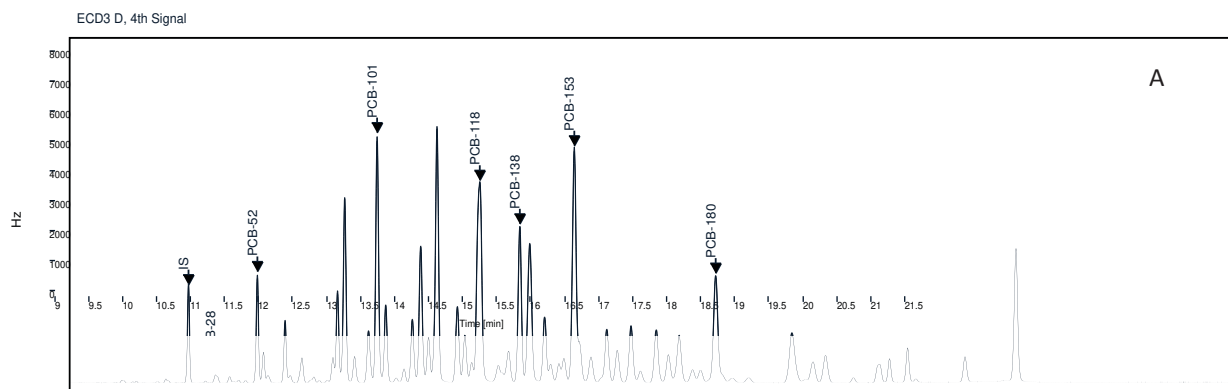


Figure 1b. Schematic of the treatment procedure for the analysis of PCBs in transformer oil with KOH 1M and concentrated H₂SO₄



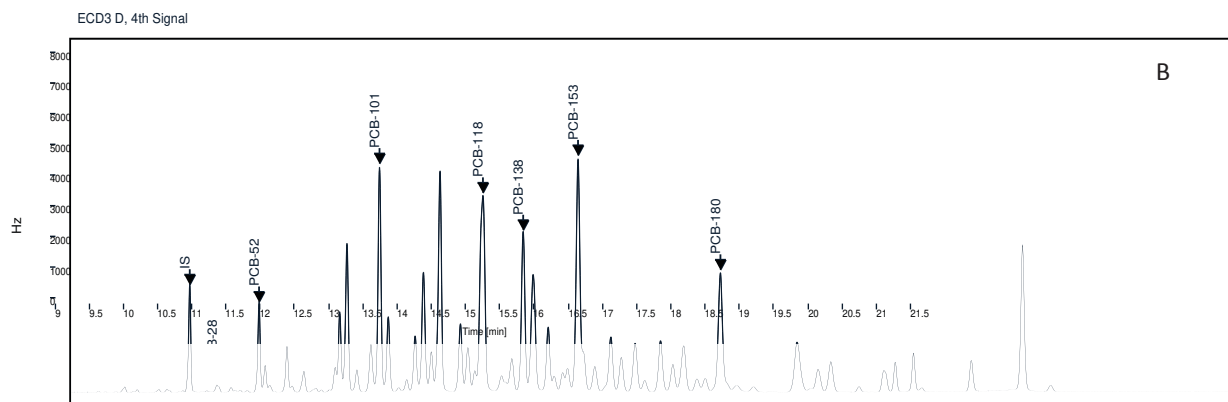


Figure 2: (A) GC/ECD chromatogram of PCB congeners in transformer oil (A): treated with concentrated H_2SO_4 (B): treated with KOH + concentrated H_2SO_4

In addition, the specifications of the gas chromatograph GC-8890 are optimized for the quantification of PCBs. The results obtained are as follows: Initial column temperature is $40^\circ C$, heated at $20^\circ C/min$ to $230^\circ C$, continue to heat at $5^\circ C/min$ to $260^\circ C$, heat $40^\circ C/min$ to $300^\circ C$. Total time is 23 minutes; The flow rate of mobile phase nitrogen is $1.2 ml/min$, electron capture detector ECD.

Finally, the study evaluates the analysis process of PCBs in transformer oil using gas chromatography GC 8890- detector ECD. The results obtained by this procedure have the limit of detection of LOD and limit of quantification of LOQ of $0.30 mg/kg$ and $1.00 mg/kg$, respectively. These meet the requirements of analysis and assessment of PCBs content in vegetable oil as regulated in QCVN 07:2009/BTNMT on hazardous waste thresholds stipulates that the maximum value of PCBs in waste is $5 mg/kg$. The correlation coefficients R^2 are all greater than 0.995. The relative standard deviations (RSD) obtained in these assessments are both less than 4% for retention times and less than 7% for peak areas. The accuracy is expressed through the recovery efficiency value on the real sample, in the range of 90 - 110%.

In general, this study has optimized and established a procedure for analyzing PCBs in transformer oil samples using gas chromatographic equipment GC 8890, meeting the requirements for assessment of PCBs content according to QCVN 07:2009/BTNMT. This procedure will be used for future studies to evaluate the decomposition of PCBs in transformer oil samples under the effect of electron beams at the Institute of Rare Radiation Technology.

From the research results, 01 paper was accepted for publishing in the Journal of Analytical Sciences (in Vietnamese) in 2021, 01 report at the 14th Nuclear Science and Technology Conference, December. 2021, 01 analytical procedure of PCBs in transfer oil determination. Hence, the project achievement has been fulfilled as registered in a project proposal.

RESEARCH AND USE THE SIMULATION SOFTWARE ARGOS TO ASSESS THE SCOPE AND LEVELS OF RADIATION EFFECT FROM THE FANGCHENGGANG NUCLEAR POWER PLANT HYPOTHETICAL ACCIDENTS TO VIET NAM

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Project information:

Project name: Research and use the simulation software ARGOS to assess the scope and levels of radiation effect from the Fangchenggang nuclear power plant hypothetical accidents to Viet Nam

Code: CS/21/04-03

Managerial Level: Institute

Implementation time: 12 months (Jan 2021- Dec 2021)

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Published papers related to the project:

Duong Duc Thang et al., "Using ARGOS to simulate radioactive dispersion in the atmosphere from Fangchenggang nuclear power plant to Viet Nam", Vietnam Conference of Nuclear Science and Technology (VINANST 14), Da Lat, Viet Nam, 2021 (in Vietnamese).

Duong Duc Thang et al., "Using ARGOS to simulate radioactive dispersion in the atmosphere from Fangchenggang nuclear power plant to Viet Nam", accepted by Nuclear Science and Technology, 2022.

In recent years, China's nuclear power industry has developed rapidly. In 2020, China had 49 nuclear reactors in operation with a total capacity of 47.5 GW and 14 reactors under construction with 14.2 GW. Notably, many Chinese nuclear power plants (NPPs) have been built near the northern border of Viet Nam, such as Fangchenggang NPP in Guangxi province and Changjiang NPP in Hainan Island. These nuclear power plants use 2nd generation nuclear reactor technology with low safety factor requirements. Currently, units 1 and 2 of Fangchenggang NPP (with a capacity of 1000 MW each) are in commercial operation. The distance from Fangchenggang NPP to Quang Ninh province of Viet Nam is only about 50 km in the upstream wind direction. Therefore, the risks from the NPP to Viet Nam is available, especially on days with the Siberian high pressure in the winter.

In the face of that problem, there is a lot of software or programs (collectively referred to as software) to calculate radioactive dispersion in the air in both regular operation and accident of NPP that is quite popular in the world, such as HYSPLIT, FLEXPART, AERMOD, CALPUFF,

NRC Dose72, RASCAL, ROSDOS, and ARGOS. Recently, in Viet Nam, there have been many studies on simulation software to assess atmospheric radioactive dispersion. For example, NRC Dose72 software has been used to assess radioactive emissions under normal operating conditions, serving NPP licensing. In addition, FLEXPART has been used to simulate long-range radioactive dispersion from NPPs near the border of Viet Nam. This study used ARGOS software to simulate and assess atmospheric radioactive dispersion from the Fangchenggang NPP in the hypothetical accidents to Viet Nam.

The hypothetical accident scenarios were developed based on the guidance document of The International Nuclear and Radiological Event Scale (IAEA). The absolute source terms were predicted by RASCAL 4.3, a software developed and used by the Office of Nuclear Security and Incident Response of the United States Nuclear Regulatory Commission. Radionuclides released into the environment in the event of a level 4, 5 and 6, is showed in Table 1. The accident time is at 12:00:00 UTC on 15/10/2020, when the wind direction and intensity affect strongly from Fangchenggang NPP to Viet Nam. The release is during 1 hour, the prognosis length is 72 hours, the NWP meteorological data was collected in the range of longitude 90–127° E and latitude 3–29° N. The RIMPUFF/LSMC module in ARGOS 9.9 was used to simulate radioactive dispersion in the atmosphere from Fangchenggang nuclear power plant to Viet Nam.

Table 1. Radionuclides released into the environment in the level 4, 5 and 6 accidents by RASCAL 4.3.

Nuclide	Level 4 (Bq)	Level 5 (Bq)	Level 6 (Bq)
Cs-134	3.4E+12	2.6E+13	6.2E+14
Cs-137	2.4E+12	1.8E+13	4.3E+14
I-131	1.9E+13	1.1E+14	2.5E+15
Equivalence to I-131	1.7E+14	1.3E+15	3.0E+16

On the accident behaviour, the radioactive plume releases from Fangchenggang NPP reached Quang Ninh province after 2 hours and totally move out after 20 hours. However, the radiological consequences are long-term because of the deposition processes depend on level of accidents. After 7 days, the total effective doses are showed in Figure 1. The magnitude and area of the level 6 accident is greatest, and gradually decrease at level 5 and level 4.

On the detail results, Circular 25 “Regulations on preparedness and responses to nuclear and radiological emergencies, formulation and approval for plans for responses to nuclear and radiological emergencies” by Ministry of Science and Technology, 2014, was used to compare and decide the plans for emergencies. Intervention levels for urgent protective actions and Intervention levels for activities of relocation and termination of relocation are not necessary in all accident levels. For Operational intervention levels (OIL):

In Level 6 Case: Total gamma dose rate from plume and ground is higher than 1 $\mu\text{Sv/h}$ after 2 hours in Quang Ninh province; 6 hours in Bac Giang province, 9 hours in Ha Noi and neighboring provinces; 10 hours in some Northwest provinces (Tuyen Quang, Yen Bai, and Hoa Binh). Due to

the deposition process, the activity concentrations on ground surface of I-131 is greater than 10 kBq/m², of Cs-137 is greater than 2 kBq/m², in Quang Ninh province after 3 hours, Hanoi after 10 hours, and some Northwest provinces after 11 hours to 1 day. And hence, immediately stop consumption of food and milk in the area until the result of sample examination is available. The area where dose rate in the air is higher than 1 µSv/h, can extend to 3888 km² at 01:00 UTC on 16/10/2020.

In level 5 case: Dose rate in the air is not higher 1 µSv/h; the activity concentrations of I-131 is greater than 10 kBq/m², of Cs-137 is greater than 2 kBq/m², appears firstly in Hanoi and adjacent provinces after 9 hours; the affected area can be larger than 2392 km² at 01:00 UTC on 16/10/2020.

In level 4 case: There are no violations in Circular 25.

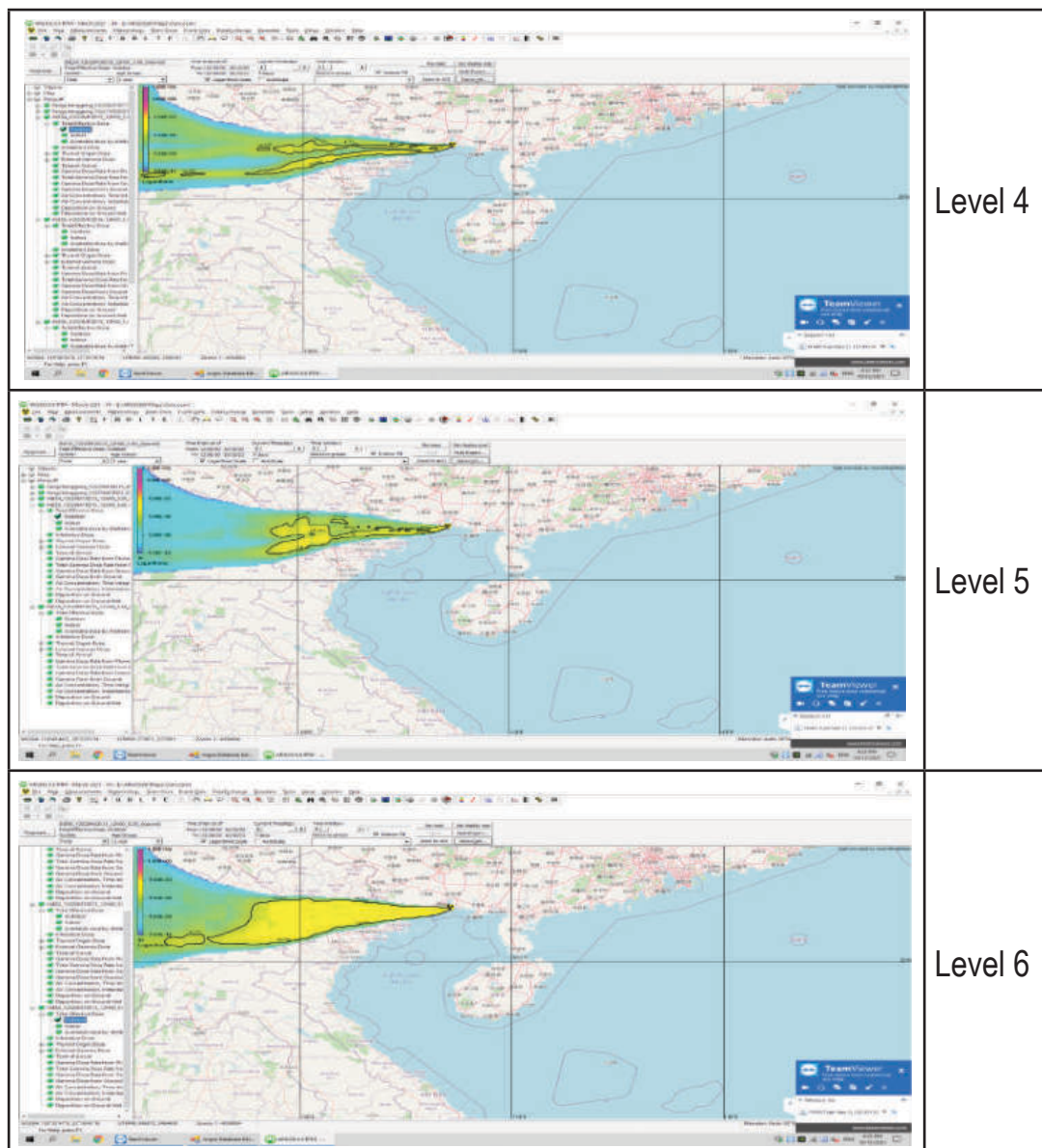


Figure 1. The total effective dose after 7 days in the accidents

APPLYING MACHINE LEARNING METHOD IN PARTICLE IDENTIFICATION ACCORDING TO PULSE SHAPE

Le Xuan Chung¹, Vi Ho Phong², Le Tuan Anh¹, Nguyen Duc Ton¹,
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Project information:

Project name: "Applying machine learning method in particle identification according to pulse shape"

Code: CS/21/04-02

Managerial Level: Institute

Implementation time: 12 months (Jan 2021- Dec 2021)

Contact email: chungxl@vinatom.gov.vn

Published papers related to the project:

1. Le Xuan Chung et al., "Applying machine learning method in neutron and gamma identification according to their pulse shapes", accepted by Nuclear Science and Technology, 2021.
2. Le Xuan Chung et al., "Applying machine learning method in neutron and gamma identification according to their pulse shapes", Proceedings of the 14th Vietnam Conference on Nuclear Science and Technology (VINANST 14), Dalat, Vietnam, 2021

Artificial intelligence (AI) is widely applied in many aspects of society. It aims to enable computers to simulate human intelligence based on logic, rules, decision trees, and machine learning. In, machine learning (ML) is an AI subfield including deep learning which contains a stack of hidden layers. The operation of ML can be based on an artificial neural network (ANN), which mimics the human brain. In this manner, the ANN is trained by sufficiently enormous normalized data (given inputs with given outputs). Afterward, it can find out the logic and be able to predict the outputs of new inputs. Therefore, the ANN has the advantage that it does not require an unambiguously mathematical input/output relationship. In nuclear physics study, machine learning has been applied for decades and recently became intensive thanks to the computer's fast calculating speed and large storage. The ANN models were applied to derive successfully nuclear charge radii, nuclear mass in a neutron star, mass and binding energy, ground-state energy, and the ground-state point-proton root-mean-square radius along with their extrapolation uncertainties.

Concerning neutron and gamma, much nuclear structural information, such as spin and parity, half-life time, et cetera, can be obtained by detecting them. In such studies, the detection of the neutron is normally accompanied by gamma rays. This fact demands identification for them. The well-known method is charge comparison (CC) which relies on the neutron and gamma pulse shape difference (almost in the tail components) as seen in Fig. 1. In this method, the charge ratio of the tail-to-total waveform was calculated. According to these differences, neutron and gamma can be identified.

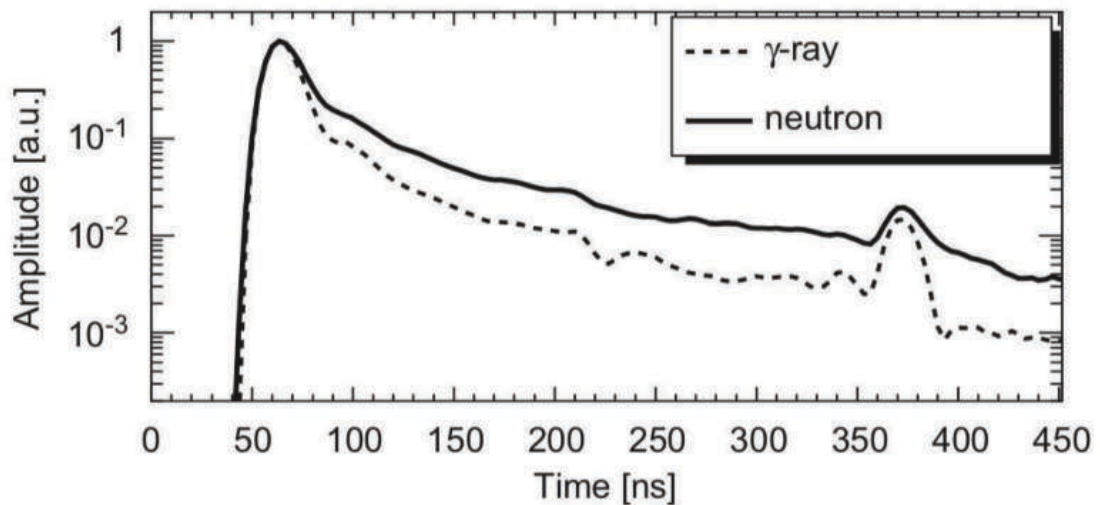


Figure 1: Example of neutron and gamma pulse shapes normalized to the same amplitude. The difference appears in the tail components at about 70 ns.

In the framework of “Applying machine learning method in particle identification according to pulse shape” project, the ML method was applied in neutron and gamma identification via their waveform difference. Firstly, an experiment to measure neutron and gamma signals was performed. Thanks to the experimental availability, their waveform data were digitized suitable for applying ML method. At the same time, neutron and gamma time of flights (TOF) in about 1.2 m were measured to identify them accordingly. An ANN was constructed consisting of 2 hidden layers of 80 and 20 neurons, respectively. The ANN input size was 400 and the sigmoid function was used as neuron transfer function. 15729 data samples were used to train the ANN and 43460 left for testing. The results were compared to those obtained from the CC method.

Fig. 2 presents the TOF of neutron events selected by ANN and CC methods. The true neutron events are with TOF higher than $2.5 \mu\text{s}$ otherwise are the gamma events (false identification). The accuracy is defined as the ratio of true-to-total numbers. It is seen that the ANN accuracy (89.26 %) is much better than the CC's (79.60 %). This result proves the applicability of ML method in the analysis of nuclear data.

The ML method is an effective tool for big data problems and should be applied in nuclear data as well as predicting physics quantities in the region of lacking data. Before the application, a

set of normalized data (sample) should be prepared. The accuracy of the method depends on the size of the normalized data which will be used to train the ANN. Therefore, the sample size is important and should be studied in advance.

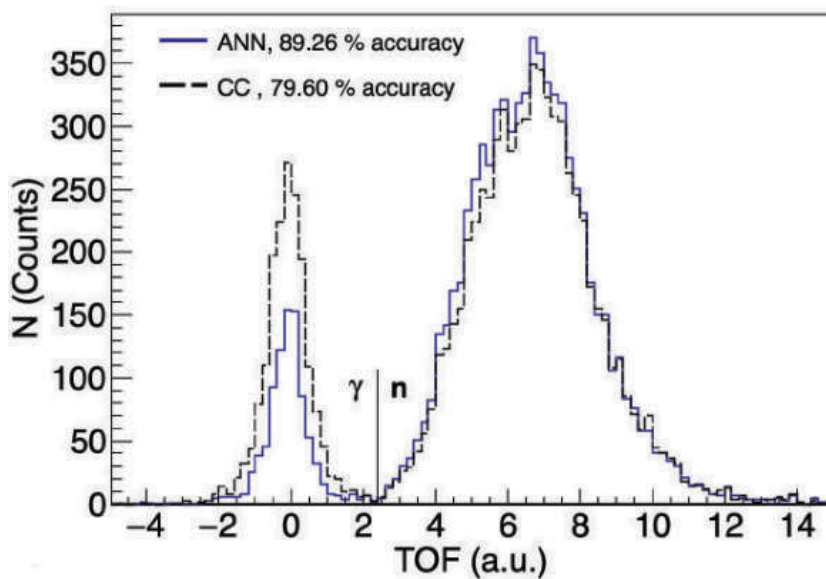


Figure 2: TOF of neutron events selected by ANN and CC methods.

3- FOTOBOK

A Wrap-up of VINATOM significant events in 2021

3.1 - NUCLEAR RESEARCH INSTITUTE, DA LAT



The Training Course "Application of DELFT 3D program to simulate processes in the marine environment"



The trainees of the training course practiced the simulation in the research area



The Workshop on the new research reactor of the CNST



The group photo of the Workshop at NRI

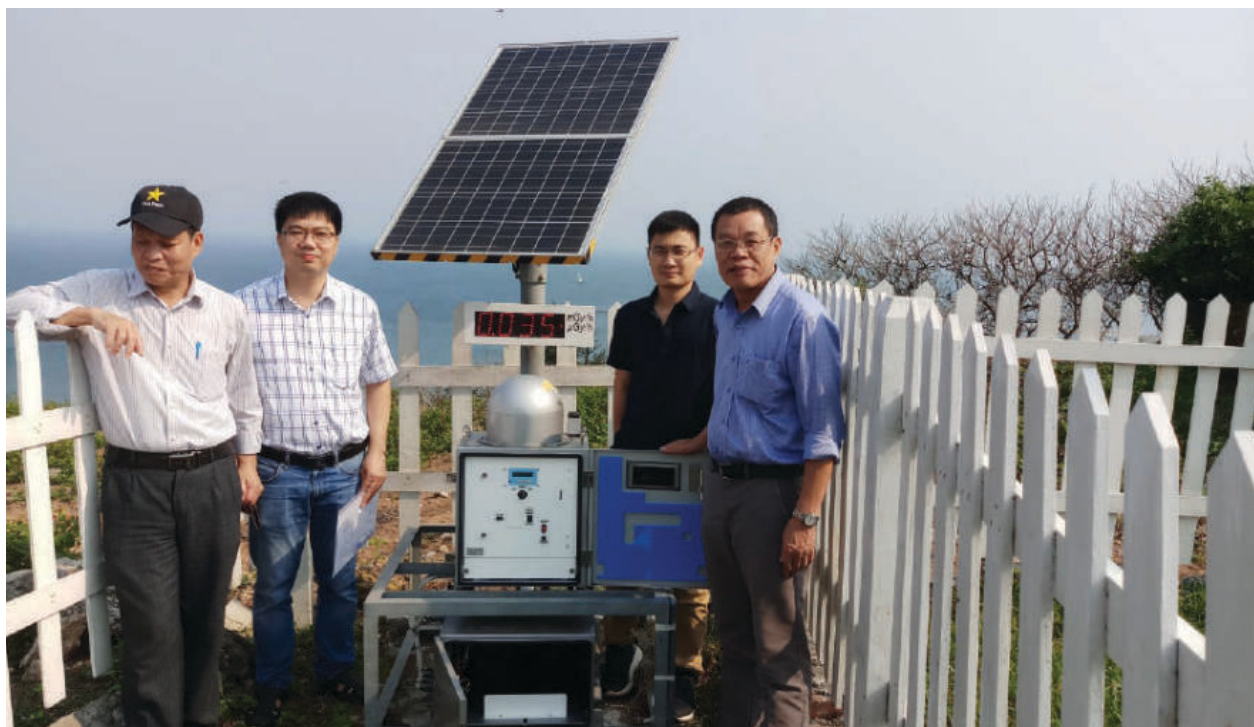
3.2 - INSTITUTE OF NUCLEAR SCIENCE AND TECHNOLOGY, HA NOI



The 30th Anniversary of the Institute of Nuclear Science and Technology (1991 - 2021)



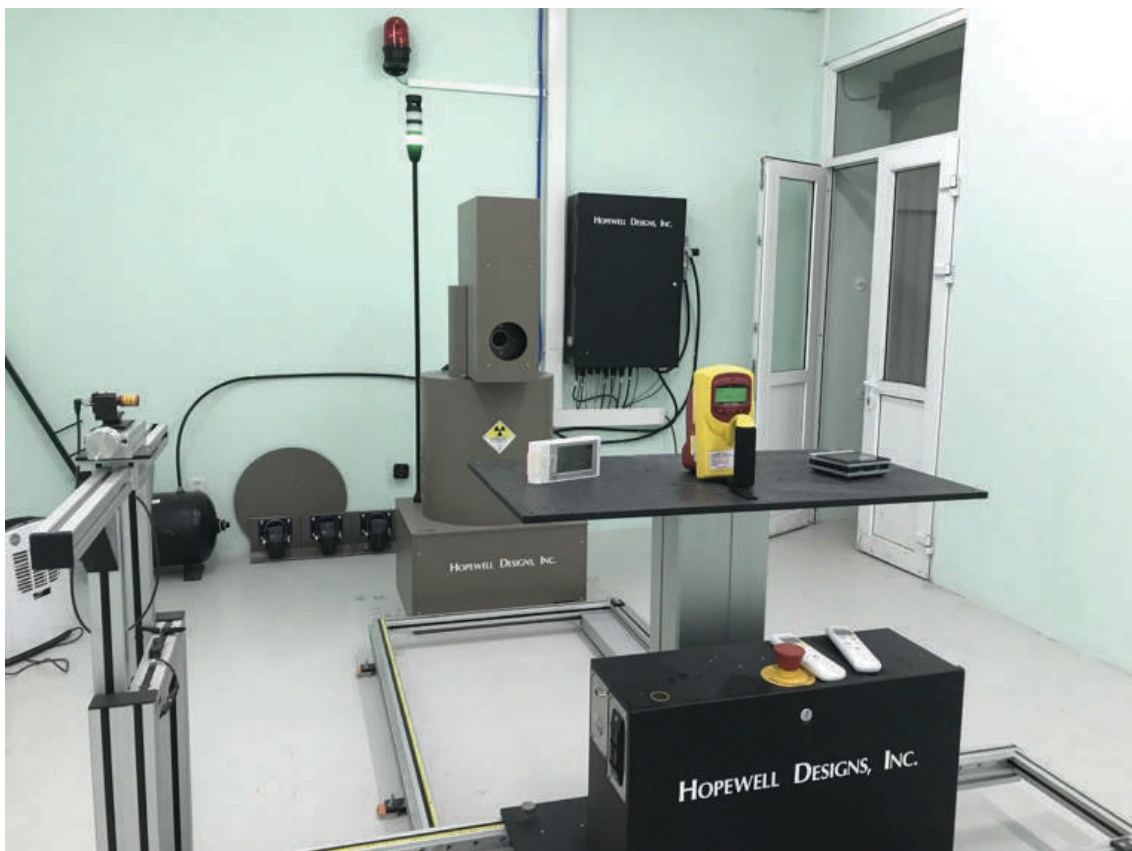
Dr. Tran Chi Thanh, President of VINATOM handed over the decision on the appointment of Dr. Pham Ngoc Dong - Deputy Director of the Institute for Nuclear Science and Technology



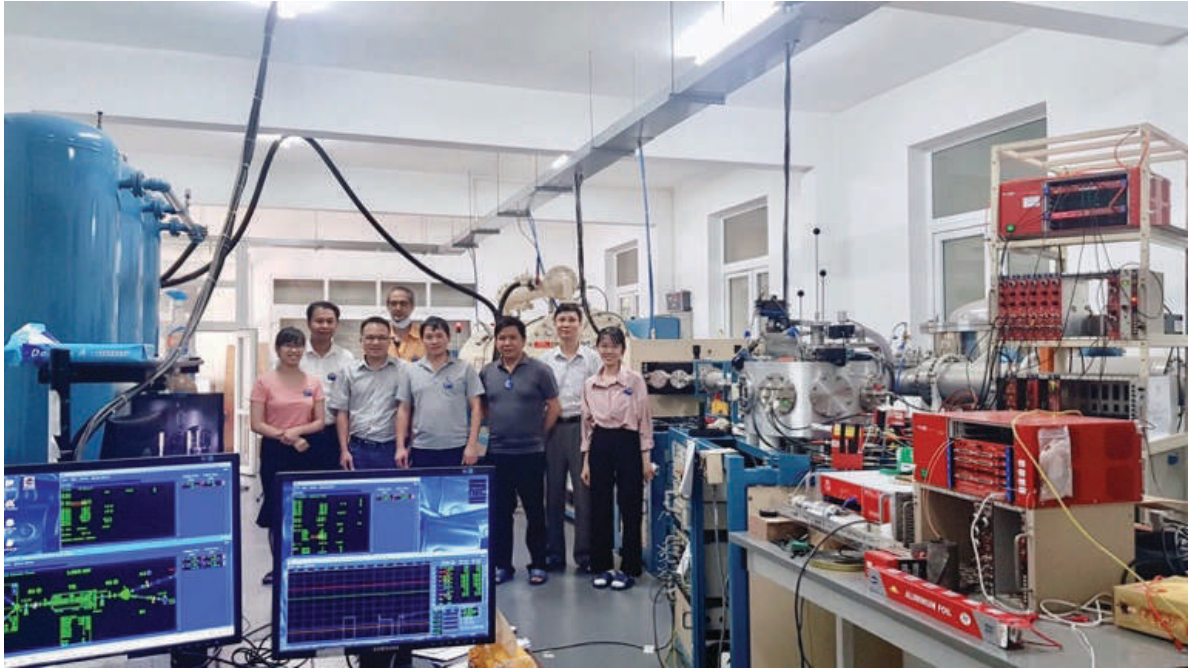
Checking the radiation monitoring system at Bach Long Vi island



Siting the radiation monitoring station of the EC- ASEANTOM project



New multigamma-ray calibration sources (^{60}Co and ^{137}Cs) and X-ray beam irradiator are in operation at Calibration rooms, INST



The research team of the Center for Nuclear Physics, INST conducted an experiment at the Hanoi University of Science, 2021



*Discussion about COsmic-ray Soil Moisture Observing System (COSMOS)
COSMOS is a soil moisture measurement system based on cosmic-ray neutrons researched and manufactured by Center for Nuclear Techniques of Institute for Nuclear Science and Technology within the framework of a ministerial project (DTCB.08/21/VKHKTHN)*

Researcher participating in scientific conferences

Ms. Ha Lan Anh, a researcher of Center for Nuclear Techniques participated in the seminar (online) on “Application of atomic energy for economic - social development” which organized by the youth union of the Ministry of Science and Technology



Defending the doctoral thesis of the officials of the Center for Nuclear Energy, INST in 2021



The seminar on “Study of the structure of neutron-rich nuclei using particle accelerators” at INST

3.3. CENTER FOR NUCLEAR TECHNIQUES IN HO CHI MINH CITY



Collaborative research seminar on air pollution between Center for Nuclear Techniques in Ho Chi Minh City (CNT) and The Faculty of Environment - University of Science (VNUHCM-US)

Event: Introduction to the Second Standard Dosimetry Laboratory (SSDL) – Center for Nuclear Techniques in Ho Chi Minh City (CNT)

Address: 405-407 Cach Mang Thang Tam Street, Ward 13, District 10, Ho Chi Minh City.



Facility 2 – Center for Nuclear Techniques in Ho Chi Minh City – where Laboratory for Nuclear Calibrations (LNC) is located.



Standard dosimetry laboratory using Cesium-137 Gamma Source



Standard dosimetry laboratory using X-ray generator equipment.



Title: SuperMAX electrometer and basic Ionization chambers.



Training course on Estimation of uncertainty for testing & calibration laboratories ISO 17025 at Center for Nuclear Techniques in Ho Chi Minh City



Journey to the source to visit Cu Chi tunnels - the Youth Union, Center for Nuclear Techniques in Ho Chi Minh City.



3.4 - CENTER FOR APPLICATION OF NUCLEAR TECHNIQUES IN INDUSTRY (CANTI), DA LAT



Deployment of Flooded member detection (FMD) inspection service at Chim Sao mine



Sample analysis activities of the Department of Physical and Chemical Engineering



Tracking techniques in petroleum engineering



Researching and manufacturing the fast SPECT device

3.5 - NON-DESTRUCTIVE EVALUATION CENTER, HA NOI



*Corrosion testing of pipes at Gas Distribution Center (GDC),
Tien Hai District, Thai Binh Province*



Training course within the framework of ministry-level projects: "Building up a quality system for training NDT technicians according to ISO 9001: 2015 and ISO 25108"



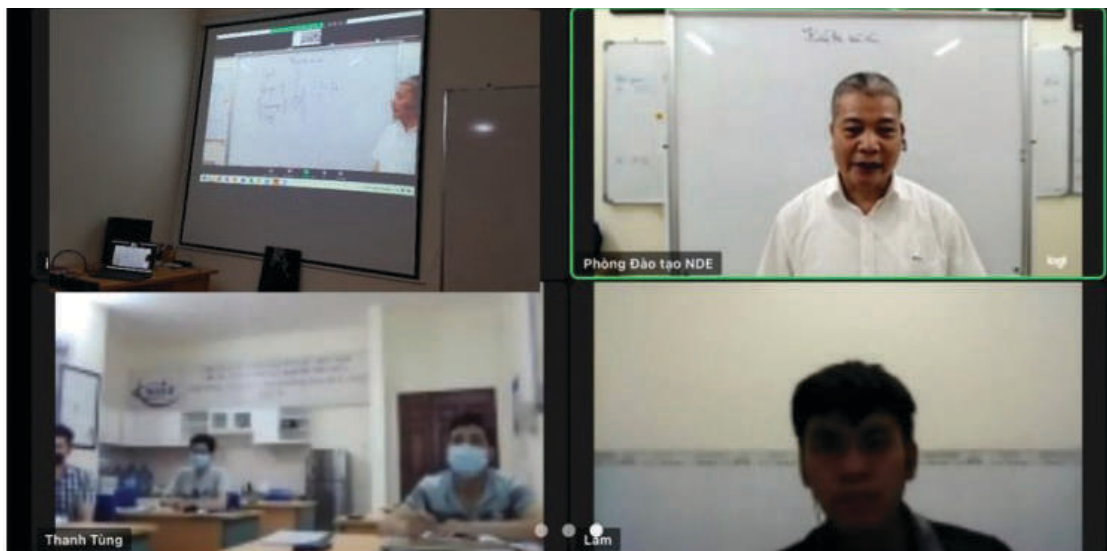
Ultrasonic inspection (Phased Array Ultrasonic Testing -PAUT) of welds after cutting and replacing the boiler pressure pipelines at thermal power plant Nghi Son 1



Strengthening cooperation in inspection and maintenance of thermal power plants of Power Generation Corporation 1



Advanced RT Method Training for Defense Industry Units



Developing online training in the context of the COVID-19 epidemic



Online training course on Non-Destructive Testing methods for Cambodian officers



Meeting of Advisory Council for Evaluation and Acceptance of Science and Technology Projects in accordance with the Protocol "Supporting the Lao Ministry of Science and Technology" to build the Center of Non-Destructive Testing and Nuclear Engineering



Handover Ceremony of Equipment within the framework of Science and technology tasks under the Protocol "Supporting the Lao Ministry of Science and Technology to build the Center of Non-Destructive Testing and Nuclear Engineering"



Quality inspection and evaluation of large-thickness castings for special materials by high-energy gamma source (Co-60)

3.6 - INSTITUTE FOR TECHNOLOGY OF RADIOACTIVE WASTE AND RARE ELEMENTS, HA NOI



Using vacuum induction furnace to prepare rare earth metals



Field work at Ben Den rare earth mine - Lao Cai

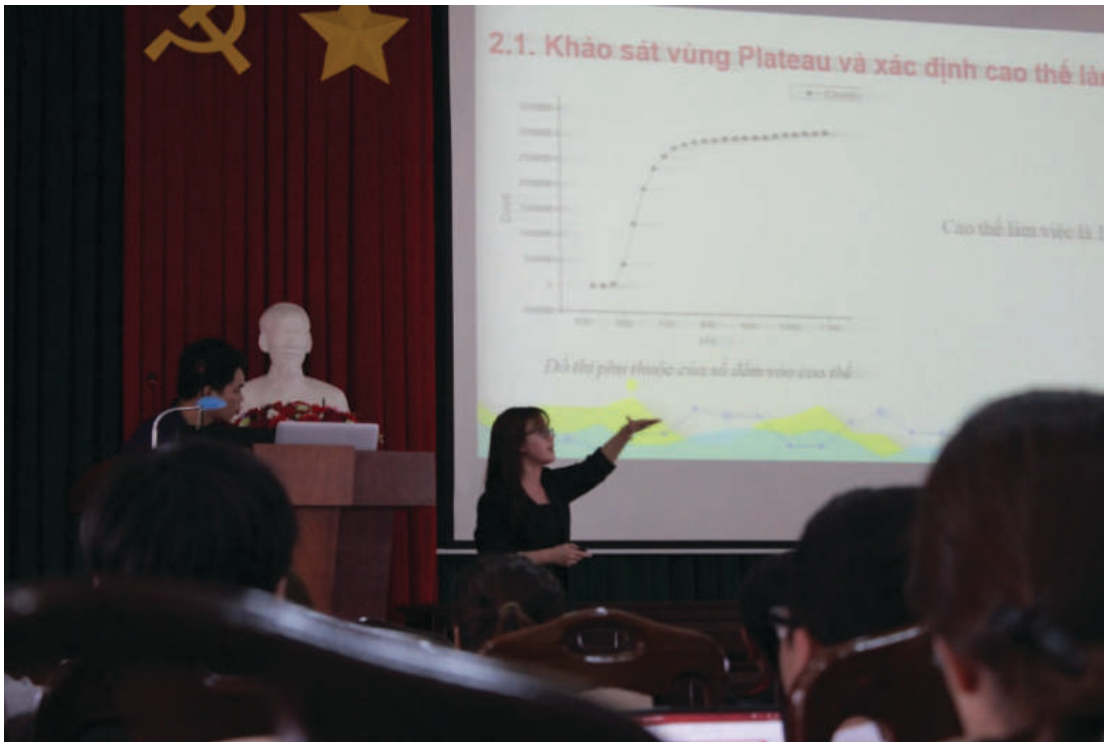


Report on the proposal of ministerial-level projects



Report of the 14th National Conference on Nuclear Science and Technology

3.7 - NUCLEAR TRAINING CENTER, HANOI



Organizing orientation internships and professional internships for undergraduate students at NRI – Da Lat, April 05-16, 2021



The institutional defense ceremony of PhD thesis of PhD student Tran Viet Phu - Hanoi, October 09, 2021



The institutional defense ceremony of PhD thesis of PhD student Bui Duy Linh - Hanoi, October 10, 2021



The institutional defense ceremony of PhD student Nguyen Huu Quyet - Hanoi, October 12, 2021



Teachers' Gratitude Ceremony and PhD Award Ceremony in 2021 – Nov 17, 2021



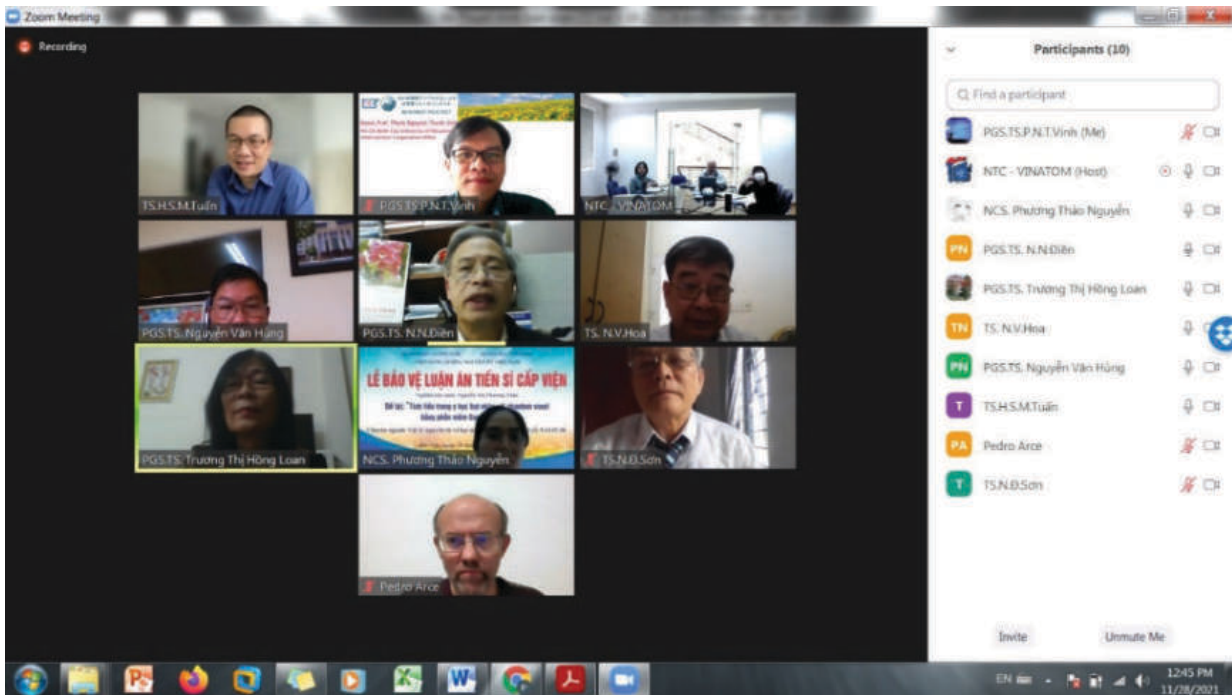
Training course on "N-O & C-O stable isotope ratio analysis in environmental research and climate change" – Hanoi, 22-26 Nov, 2021



VINATOM-PECC2 Training course on “Light-Water nuclear power plant technology and Generation-IV reactor technology” – Hanoi, Nov 27, 2021



Training course on “Using ultrasound technology and ANSYS/Mechanical simulation software in measuring and evaluating materials” – Hanoi, Nov 29 – Dec 03, 2021



The Institute-level defense ceremony (online) of PhD thesis of PhD student Nguyen Thi Phuong Thao - Hanoi, Nov 28, 2021



The Institute-level defense ceremony of PhD thesis of PhD student Nguyen Van Dung - Hanoi, Dec 29, 2021

3.8 - HEADQUARTERS, HA NOI



The meeting on "National key science and technology programs in the period of 2016-2020" hosted by the Project leader, Dr. Nguyen Hao Quang



The 11th Vietnam – Japan Forum on Nuclear Technology



The 11th Vietnam – Japan Forum on Nuclear Technology (continuing)



Product launch event between VINATOM and ATOMFEED VIETNAM JSC. on the brand “Braised fish of my home” (“Cá kho nhà mình” in Vietnamese)



Product launch event between VINATOM and ATOMFEED VIETNAM JSC. on the brand "Braised fish of my home" (continuing)



Meeting with Ambassador Extraordinary and Plenipotentiary of the Russian Federation to Vietnam



Meeting with Ambassador Extraordinary and Plenipotentiary of the Russian Federation to Vietnam (continuing)



Meeting with Ambassador Extraordinary and Plenipotentiary of the Russian Federation to Vietnam (continuing)



Dr. Tran Chi Thanh introduced about the history of VINATOM to Ambassador Extraordinary and Plenipotentiary of the Russian Federation to Vietnam



Dr. Tran Chi Thanh made a speech at Review Conference on “National key science and technology programs in the period of 2016-2020”



Professor Pham Duy Hien made a speech at Review Conference on “National key science and technology programs in the period of 2016-2020”



The minister Tran Van Tung made a speech at Review Conference on “National key science and technology programs in the period of 2016-2020”



Dr. Tran Chi Thanh was interviewed by the journalists at the Conference on “National key science and technology programs in the period of 2016-2020”



Posters and product sampled displayed at the Conference on “National key science and technology programs in the period of 2016-2020”



The participants



Group photo at the Conference on "National key science and technology programs in the period of 2016-2020"

4- APPENDICES

4.1. LIST OF VINATOM'S INTERNATIONAL SCIENTIFIC PUBLICATIONS IN 2021

No	Name of publications	Authors	Journals
1	Elastic α transfer in the $^{16}\text{O}+^{12}\text{C}$ scattering and its impact on the nuclear rainbow	Nguyen Hoang Phuc, Dao Tien Khoa, Nguyen Tri Toan Phuc	The European Physical Journal A (2021) 57:7. Published: 05 January 2021
2	Suppression of the nuclear rainbow in the inelastic nucleus-nucleus scattering	Nguyen Hoang Phuc, Dao Tien Khoa, Nguyen Tri Toan Phuc, Do Cong Cuong	The European Physical Journal A (2021) 57:75. Published: 24 February 2021
3	Equation of state of asymmetric nuclear matter and the tidal deformability of neutron star	Ngo Hai Tan, Dao Tien Khoa, Doan Thi Loan	The European Physical Journal A, Vol. 153 (2021). Published: 29 April 2021
4	Investigation of the ground-state spin inversion in the neutron-rich $^{47,49}\text{Cl}$ isotopes	B. D. Linh, ..., L.X. Chung, N.D. Ton et al.	Physical Review C 104 (4), 044331. Published: 29 October 2021
5	Pairing Forces Govern Population of Doubly Magic ^{54}Ca from Direct Reactions	F. Browne, ..., L.X. Chung, B.D. Linh et al.	Physical Review Letters, 126 (2021) 252501. Published: 23 June 2021
6	First spectroscopic study of ^{63}V at the N=40 island of inversion	M. M. Juhász,, L.X. Chung, B.D. Linh et al.	Physical Review C, 103 (2021) 064308. Published: 8 June 2021
7	First spectroscopic study of ^{51}Ar by the (p,2p) reaction	M. M. Juhász,, L.X. Chung, B.D. Linh et al.	Physics Letters B. Volume 814, 10 March 2021, 136108
8	Success-history based adaptive differential evolution method for optimizing fuel loading pattern of VVER-1000 reactor	Viet Phu Tran, Giang T.T. Phan, Van Khanh Hoang, Haidang Phan, Nhat Duc Hoang, Hoai Nam Tran	Nuclear Engineering and Design. Volume 377, June 2021, 111125
9	Monte Carlo calculation of the organ equivalent dose and effective dose due to immersion in a ^{16}N beta source in air using the ICRP reference phantoms	José M Gómez Ros, Montserrat Moraleda, Pedro Arce, Duc Ky Bui, Thi My Linh Dang, Laurent Desorgher, Han Sung Kim, Dragana Krstic, Michal Kuć, Ngoc Thiem Le, Yi-Kang Lee, Ngoc Quynh Nguyen, Dragoslav Nikezic, Katarzyna Tymieńska, Tomas Vrba	Radiation Measurements. Volume 145, July 2021, 106612
10	Neutron Balance Features in Breed-and-Burn Fast Reactors	Odmaa Sambuu, Van Khanh Hoang, Jun Nishiyama, Toru Obara	Nuclear Science and Engineering (2021). Published online: 4 Oct 2021

No	Name of publications	Authors	Journals
11	Feasibility of Sodium-Cooled Breed-and-Burn Reactor with Rotational Fuel Shuffling	Van Khanh Hoang, Odmaa Sambuu, Jun Nishiyama, Toru Obara	Nuclear Science and Engineering (2021). Published online: 29 Jul 2021
12	Study of nonlocality effects in direct capture reactions with Lagrange-mesh R-matrix method	Nguyen Hoang Phuc, Nguyen Tri Toan Phuc and Do Cong Cuong	International Journal of Modern Physics E. Vol. 30, No. 9 (2021) 2150079. Published: 30 September 2021
13	Nuclear matter distributions in the neutron-rich carbon isotopes $^{14-17}\text{C}$ from intermediate-energy proton elastic scattering in inverse kinematics	A.V. Doborovolsky, ..., L.X.Chung et al.	Nuclear Physics A. Volume 1008, April 2021, 122154
14	Development of a PARCS/Serpent Model for Neutronics Analysis of the Dalat Nuclear Research Reactor	Viet Phu Tran, Kien Cuong Nguyen, Donny Hartanto, Hoai Nam Tran, Vinh Thanh Tran, Van Khanh Hoang, Pham Nhu Viet Ha	Nuclear Science and Techniques 32, 15 (2021). Published: 15 February 2021
15	Neutronics study on small power ADS loaded with recycled inert matrix fuel for transuranic elements transmutation using Serpent code	Thanh Mai Vu, Donny Hartanto, Pham Nhu Viet Ha	Nuclear Engineering and Technology. Volume 53, Issue 7, July 2021, Pages 2095-2103
16	Cylindrical neutron spectrometer system: design and characterization	Ngoc Thiem Le, Ngoc Quynh Nguyen, Huu Quyet Nguyen, Duc Khue Pham, Minh Cong Nguyen, Van Loat Bui, Van Chung Cao, Van Hao Duong, Trung H Duong, Hoai Nam Tran	The European Physical Journal Plus. Volume 136, 690 (2021). Published: 25 June 2021
17	A Comparison Study of Chemical Compositions and Sources of $\text{PM}_{1.0}$ and $\text{PM}_{2.5}$ in Hanoi	Pham Duy Hien, Vuong Thu Bac, Nguyen Thi Hong Thinh, Ha Lan Anh, Duong Duc Thang, Nguyen The Nghia	Aerosol and Air Quality Research. Volume 21, Issue 10, October 2021
18	Tracing N-Nutrient and Organic Carbon Sources in Surface Water of Nhue River Sub-Catchment in Vietnam Using Stable Isotope Fingerprinting and Related Techniques	Dang Duc Nhan, Nguyen Thi Tuoi, Ha Lan Anh, Mai Duc Kien, Vu Hoai, Adu-Gyamfi Joseph, Lee Heng.	Water, Air, & Soil Pollution, volume 232, Article number: 243 (2021). Published: 05 June 2021

No	Name of publications	Authors	Journals
19	Characteristics of radionuclides in soil and tea plant (<i>Camellia sinensis</i>) in Hoa Binh, Vietnam	Van Hao Duong, Duong Nguyen Thanh, Loat Van Bui, Thanh Tien Kim, Thang Duc Duong, Duc Huu Hoang, M. Saiyad Musthafa, Quyet Huu Nguyen, Tibor Kovacs & Hoai Nam Tran	Journal of Radioanalytical and Nuclear Chemistry, volume 329, pages 805–814 (2021). Published: 25 June 2021
20	Natural radionuclides and assessment of radiological hazards in different geological formations in Khammouan province, Laos	Loat Bui Van, Van Hao Duong, Nguyen Thanh Duong, Somsavath Leuangtakoun, Thang Duong Duc, Hung Vu Anh, Duc Vu Anh, Hoai Nam Tran, Van Dung Nguyen & Huyen Trang Vuong Thi	Journal of Radioanalytical and Nuclear Chemistry, volume 329, pages 991–1000 (2021). Published: 26 June 2021
21	Spatial and temporal variations of the $PM_{2.5}$ concentrations in Hanoi metropolitan area, Vietnam, during the COVID-19 lockdown	Quang Tran Vuong, Sung-Deuk Choi, Vuong Thu Bac, Hoang Minh Thang, Nguyen Thi Hue, Tran Thu Lan, Duong Thi Hanh, Trinh Van Tuyen, Phan Quang Thang	International Journal of Environmental Analytical Chemistry. Published online: 24 June 2021
22	Biomonitoring of chemical element air pollution in Hanoi using <i>Barbula indica</i> moss	Nguyen Huu Quyet, Le Hong Khiem, Trinh Thi Thu My, Nguyen Thi Bao My, Marina Frontasieva, Inga Zinicovscaia, Nguyen An Son, Tran Thien Thanh, Le Dai Nam, Khuat Thi Hong, Nguyen Ngoc Mai, Trinh Dinh Trung, Duong Van Thang, N. T. Thuy Hang	Environmental Engineering and Management Journal, May 2021, Vol.20, Issue 5, pages 791-800
23	Normalizing the enhanced generalized superfluid model of nuclear level density	Vu Duc Cong, Tran Dong Xuan, Nguyen Xuan Hai, Pham Dinh Khang, Le Hong Khiem, Nguyen Quang Hung, Nguyen Ngoc Anh	The European Physical Journal A, (2021) 57:304
24	A Composite Method for Improving the Pulse Shape Discrimination Efficiency of a Scintillation Detector Using EJ-301.	Phan Van Chuan, Nguyen Xuan Hai, Nguyen Ngoc Anh, Pham Dinh Khang, Nguyen Quang Hung, Truong Van Minh & Nguyen Duy Ly	IEEE Transactions on Instrumentation and Measurement, Vol 70, Article Sequence Number: 6005611
25	Flexible and low-cost FPGA-based multichannel analyzer for handheld measurement devices	Cao Van Hiep, Dinh Tien Hung, Nguyen Thi Thoa, Nguyen Khanh Hung, Pham Dinh Khang, Nguyen Xuan Hai, Nguyen Ngoc Anh, Nguyen Tien Anh	Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

No	Name of publications	Authors	Journals
26	Level scheme of ^{164}Dy obtained from $^{163}\text{Dy}(n_{\text{th}}, 2\gamma)$ experiment	Nguyen Kim Uyen, Kyung Yuk Chae, Nguyen Ngoc Duy, Soo Mi Cha, Minsik Kwag, Kim Du hyun, Le Tan Phuc, Nguyen Quang Hung, Pham Dinh Khang, Nguyen Xuan Hai, Ho Huu Thang, Nguyen Ngoc Anh	Nuclear Physics A, 1007(3):122136, (2021)
27	Efficacy of nimotuzumab (hR3) conjugated with ^{131}I or ^{90}Y in laryngeal carcinoma xenograft mouse model	Nguyen Thi Thu, Ho Anh Son, Nguyen Thi Khanh Giang, Nguyen Thi Ngoc, Bui Van Cuong, Nguyen Thanh Binh, Dang Ho Hong Quang, Nguyen Dang Khoa, Nguyen Thanh Nhan, Nguyen Linh Toan	International Journal of Radiation Biology, (Volume 97, 2021 issue 5, pp: 704-713)
28	Steady-state thermal-hydraulic analysis of the LEU-fueled Dalat Nuclear Research Reactor	Nguyen Kien Cuong, Le Vinh Vinh, Huynh Ton Nghiem, Luong Ba Vien, Nguyen Nhi Dien	Science and Technology of Nuclear Installations, Vol 2021, ID 6673162
29	Interim storage of the Dalat Nuclear Research reactor: Radiation safety analysis	Nguyen Kien Cuong, Le Vinh Vinh, Huynh Ton Nghiem, Luong Ba Vien, Nguyen Nhi Dien, Tran Hoai Nam	Science and Technology of Nuclear Installations, (Vol: 2020, ID: 7327045), 6 pages, (2020).
30	Proton entropy excess and possible signature of pairing reentrance in hot nuclei	Balaram Dey, Srijit Bhattacharya, Deepak Pandit, N. Dinh Dang, Nguyen Ngoc Anh, L. Tan Phuc, N. Quang Hung	Physics Letters B, 819, 136445, (2021).
31	Role of exact treatment of thermal pairing in radiative strength functions of $^{161-163}\text{Dy}$ nuclei	L. Tan Phuc, N. Quang Hung N. Dinh Dang, L. T. Quynh Huong, Nguyen Ngoc Anh, N. Ngoc Duy, L. Ngoc Uyen and N. Nhu Le.	Physical Review C, 102, 061302(R), (2021).
32	Re-investigation of heat capacity and pairing phase transition in hot 93–98 Mo nuclei	Le Thi Quynh Huong, Tran Dong Xuan, Nguyen Ngoc Anh, Nguyen Quang Hung	The European Physical Journal A, (2021) 57:109
33	Resonant states in ^7H : Experimental studies of the $^2\text{H}(^8\text{He}, ^3\text{He})$ reaction	I. A. Muzalevskii, ..., Mai Quynh Anh	Physical Review C, 103, 044313, (2021).
34	Stable dispersion of graphene oxide–copolymer nanocomposite for enhanced oil recovery application in high-temperature offshore reservoirs	Nguyen Thi Lieu, Hoang Anh Quan, Nguyen Phuong Tung, Luu Anh Tuyen, Pham Duy Khanh, Dinh Van Phuc, Nguyen Quang Hung, Le Van Toan, Nguyen Tran Hai, Luong Thi Bich	Colloids and Surfaces A: Physicochemical and Engineering Aspects, 628, 127343, (2021)

No	Name of publications	Authors	Journals
35	Determination of some elements in the nails in patients with colon cancer using total reflection X-ray fluorescence	Huynh Truc Phuong, Nguyen An Son, Nguyen Thi Nguyet Ha, Nguyen Thi Minh Sang, Nguyen Thi Truc Linh, Dinh Thanh Binh, Truong Thi Hong Loan, Ho Manh Dung, Tran Tuan Anh, Nguyen Van Dong	Spectrochimica Acta Part B: Atomic Spectroscopy, 182, 106234, (2021)
36	RENEB Inter-Laboratory Comparison 2017: limits and pitfalls of ILCs	Eric Gregoire, Joan Francesc Barquiner, Gaetan Gruel, Mohamedamine Benadjaoud, ..., Pham Ngoc Duy	International Journal of Radiation Biology, (Volume 97, Issue 6, 2021)
37	Liposomal silibinin as a potential radioprotector for human lymphocytes in treating non-small-cell lung cancer	Nguyen Minh Hiep, Pham Ngoc Duy, Che Quang Tuan, Nguyen Thi Huynh Nga, Vu Ngoc Bich Dao, Tran Thi Ngoc Mai, Trinh Kieu Thanh, Trinh Ai Ngoc, Pham Bao Ngoc, Le Dong Van	International Journal of Radiation Research
38	Anhydrous oxygen-free rare earth material preparation and characterization.	Nguyen Trong Hung, Nguyen Thanh Thuy, Le Ba Thuan, Le Thu Huong, Dang Thi Thanh Le, and Nguyen Van Tung	Materials Today Chemistry 22 (2021) 100608. Journal of Chemistry, Volume 2021, Article ID 6689590, 9 pages.
39	Synthesis of Colloidal Silicon Quantum Dot from Rice Husk Ash.	Le Thu Huong, Dang Thi Thanh Le, and Nguyen Van Tung	Journal of Chemistry. Volume 2021, Article ID 6689590, 9 pages.
40	Application of Water Stable Isotopes for Hydrological Characterization of the Red River (Asia).	Nho Lan Nguyen, Thu Nga Do and Anh Duc Trinh	Water.
41	Trace Metal Element Analysis in Some Seafood in the Coastal Zone of the Red River (Ba Lat Estuary, Vietnam) by Green Sample Preparation and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS).	Nhu Da Le, Thi Thu Ha Hoang, Vu Phong Phung, Thi Lien Nguyen, Thi Thuy Duong, Le Minh Dinh, Thi Mai Huong Pham, Thi Xuan Binh Phung, Tien Dat Nguyen, Thanh Nghi Duong, Thi My Hanh Le, Phuong Thu Le, and Thi Phuong Quynh Le.	Journal of Analytical Methods in Chemistry. Volume 2021, Article ID 6649362, 14 pages
42	Unsubstituted and Methylated PAHs in Surface Sediment of Urban Rivers in the Red River Delta (Hanoi, Vietnam): Concentrations, Profiles, Sources, and Ecological Risk Assessment.	Anh Quoc Hoang, Shin Takahashi, Nhu Da Le, Pham Thi Mai Huong, Nguyen Tien Dat, Phung Thi Xuan Binh, Nguyen Thi Anh Huong, Phung Vu Phong, Le Thi Phuong Quynh.	Bulletin of Environmental Contamination and Toxicology, volume 107, pages 475–486 (2021). Published 24/3/2021.

No	Name of publications	Authors	Journals
43	Preparation and Effect of Selenium Nanoparticles/ Oligochitosan on the White Blood Cell Recovery of Mice Exposed to Gamma-Ray Radiation	Duy Ngoc Nguyen, Phu Van Dang, Quoc Anh Le, Lan Thi Kim Nguyen, Hien Quoc Nguyen, Ngan Thi Thu Tran, Ha Le Bao Tran, Tuan Dinh Phan, Ha Manh Bui	Journal of Chemistry, 2021, 6635022, 9 pages, 2021. Environmental Technology & Innovation, 21 101315, 2021.
44	Degradation of tricyclazole from aqueous solution and real wastewater by electron-beam irradiation	Duy Ngoc Nguyen, Hieu Trung Nguyen, Thanh-Luu Pham, Cong Tien Nguyen, Huong Thi Giang Duong, Hien Quoc Nguyen, Yi-Ching Chen, Hiep Nghia Bui, Thi-Dieu-Hien Vo, Van-Truc Nguyen, Ha Manh Bui	Environmental Technology & Innovation, 21 101315, 2021.
45	Facile Synthesis of Carboxymethyl Cellulose Coated Core/Shell SiO ₂ @Cu Nanoparticles and Their Antifungal Activity against <i>Phytophthora capsici</i>	Nguyen Thi Thanh Hai, Nguyen Duc Cuong, Nguyen Tran Quyen, Nguyen Quoc Hien, Tran Thi Dieu Hien, Nguyen Thi Thanh Phung, Dao Khac Toan, Nguyen Thi Thu Huong, Dang Van Phu, Tran Thai Hoa	Polymers, 13, 888, 2021
46	Role of e-beam irradiation treatment on detemplation and structural hierarchy of ZSM-5 zeolite	Phuong T. Ngo, Phuong N.X. Vo, Loc P. Trinh-Le, Duc T. Pham, Phuong D. Phan, Chung V. Cao, Tri V. Tran, Thuy N. Luong, Quan L.M. Ha, Phuc L. Nguyen	Microporous and Mesoporous Materials, 315 (2021) 110928. posted on, 30/01/2021
47	Treatment of dose non-uniformity inside star apples irradiated by 10 MeV electron beam	Cao Van Chung, Nguyen Thi Ly, Pham Thi Thu Hong, Doan Thi The, Luc Han Tuong, Phan Nhut Huan, Phan Thi Thu Giang, Duong Trung, Trang Hoai Nam	Journal of Radioanalytical and Nuclear Chemistry. Online version, posted on 20/01/2021
48	Depth-dose profiles in continuous and discontinuous materials of food products and medical devices irradiated by 10 MeV electron beam	Cao Van Chung, Vo Tuan Anh, Le Quang Thanh, Le Ngoc Thiem, Duong Trung, Trang Hoai Nam	Journal of Radioanalytical and Nuclear Chemistry. Online version, posted on 18/09/2021
49	Intercomparison of Geant4 low energy electromagnetic models in ⁹⁰ Y dosimetry	L. T. Anh, P. V. Cuong, N. H. Ha, H. T. Thao	Applied Radiation and Isotopes, Volume 178, December 2021, 109938
50	Isomeric ratios in neutron capture reaction induced by thermal, resonant and mixed thermal-resonant neutrons on ¹¹⁴ Cd and ¹¹⁶ Cd	Bui Minh Hue, Tran Duc Thiep, Truong Thi An, Phan Viet Cuong, S. M. Lukyanov, S. Mitrofanov	Nuclear Instrument and Method in Physics Research B, Volume 502, 1 September 2021, Pages 46-53.

No	Name of publications	Authors	Journals
51	HTDMA-modified bentonite clay for effective removal of Pb (II) from aqueous solution	Dinh Van Phuc, Nguyen Phuong Tung, Tran Minh Chien, Luu Anh Tuyen, Nguyen Quang Hung, Luu Thi Thuy, Ha Tuan Kiet, Mai Xuan Truong, Luong Thi Bich, Nguyen Thi Lieu, Ho Thi Thu Hien, Nguyen Duy Khoi, Pham Duy Khanh, Hoang Anh Quan, Le Van Toan, Nguyen Thi Chuong	Journal: Chemosphere, Number 286, 2021
52	Morphological characterization of grafted polymer electrolyte membranes at a surface layer for fuel cell application	Lam Hoang Hao, Tran Duy Tap, Dinh Tran Trong Hieu, Ekaterina Korneeva, Nguyen Van Tiep, Kimio Yoshimura, Shin Hasegawa, Shin-ichi Sawada, Tran Van Man, Nguyen Quang Hung, Luu Anh Tuyen, Dinh Van Phuc, Le Quang Luan, Yasunari Maekawa	Applied Polymer Science, 2021; e51901.
53	Investigation of the effects of chemotherapy on trace element contents in the nails in patients with colorectal cancer	Huynh Truc Phuong, Dinh Thanh Binh, Nguyen Thi Truc Linh, Truong Thi Hong Loan Thi, Nguyen Van Hanh, Ho Manh Dung, Nguyen Van Dong, Tran Tuan Anh	Journal of Radioanalytical and Nuclear Chemistry (2021), Volume 328, 1173–1180. https://doi.org/10.1007/s10967-021-07734-8
54	Food Waste in Da Nang City of Vietnam: Trends, Challenges, and Perspectives toward Sustainable Resource Use	Trinh Anh Duc, Pham Bao Ngoc, Do Thu Nga, Tran Van Quang, Cheliu, Caixio Mao	Sustainability 2021, 13, 7368
55	Global patterns of nitrate isotope composition in rivers and adjacent aquifers reveal reactive nitrogen cascading	Trinh Anh Duc, Ioannis Matiatos, Leonard I. Wassenaar, Lucilena R. Monteiro, Jason J. Venkiteswaran, Daren C. Gooddy, Pascal Boeckx, Elisa Sacchi, Fu Jun Yue, Greg Michalski, Carlos Alonso-Hernández, Christina Biasi, Lhoussaine Bouchaou, Nandana V. Edirisinghe, Widad Fadhillah, Joseph R. Fianko, Alejandro García-Moya, Nerantzis Kazakis, Si-Liang Li, Minh T. N. Luu, Sakhila Priyadarshanee, Viviana Re, Diego S. Rivera, Asunción Romanelli, Prasanta Sanyal, Fredrick Tamoooh, Duc A. Trinh, Wendell Walters & Nina Welti	NATURE

No	Name of publications	Authors	Journals
56	Water quality in an urbanized river basin impacted by multi – pollution sources: From comprehensive surveys to modelling	Trinh Anh Duc, Luu Thi Nguyet Minh, Do Thu Nga, Truong Duy Dinh	Scienceasia 47(2021): 86-95
57	Thermodynamics and Kinetics Research of the Fluorination Process of the Concentrate Rutile	Vladimir A. Karelin, Son H. Le, Nadezhda V. Karelina, Alexander N. Strashko, Alexander V. Sazonov, Huong M. T. Le	Metals 2022, 12, 34. ISSN / eISSN: 2075-4701 https://doi.org/10.3390/met12010034 IF: 2.351
58	Method for treatment of red mud after processing alumina with tailing red mud and mother liquor	Nguyen Hoang Bach, Nguyen Tuan Dung, Vu Xuan Minh, Le Thi Mai Huong, Tran Van Bien	GPHI Number 2706 Patent for Inventions/ Utility Solution
59	Temperature glass and conductivity behavior of epoxy deproteinized natural rubber in ternary blend of EDPNR/ PMMA/LiCF ₃ SO ₃	Trinh Thi Hang, Putu Mahendra, Tran Manh Thang, Seiichi Kawahara, Phan Trung Nghia	Progress in Rubber Plastics and Recycling Technology XX(X). (2021). 1-10. Received 19 January 2021; accepted 12 June 2021
60	Effect of gamma irradiation and pyrolysis on indigestible fraction, physicochemical properties and molecular structure of rice starch	Nguyen Duy Lam, Tran Minh Quynh, Tran Bang Diep, Nguyen Thi Binh, Tran Dai Lam	Journal of Food Processing and Preservation, 45 (10), 2021.
61	Variation of TiO ₂ /SiO ₂ mixed layers induced by Xe ⁺ ion irradiation with energies from 100 to 250 keV	Tran Van Phuc, Phan Luong Tuan, Miroslaw Kulik, Le Hong Khiem, Afag Madadzada, Marcin Turek, Dorota Kotodowska, Nguyen Ngoc Anh, Mai Quynh Anh, Nguyen Van Tiep, Krzysztof Siemek	Materials Science and Engineering: B, Volume 277, March 2022, 115566
62	Inter-comparison of transboundary atmospheric dispersion calculations: A summary of outputs from the ASEAN NPSR benchmark exercise	Kampanart Silva, Piyawan Krisanungkura, Narakhan Khunsrimek, Wasin Vechgama, Tang Jia Hao, Vitesh Krishnan, Pham Kim Long, Tom Charnock, Somboon Rassame, Tay Bee Kiat, Chung Keng Yeow, Hoang Sy Than, Nguyen Hao Quang, Pham Duy Hien (2021)	Progress in Nuclear Energy, Volume 135, 2021, 103718.

4.2. LISTS OF INTERNATIONAL PROJECTS 2021

4.2.1 - List of VIE projects 2021

(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 2021

(Implemented by VINATOM)

Code	Project Title	Start Year	Finish year	Budget (Euro)	Field code	Project Counterpart
INT9186	Sustaining Cradle-to-Grave Control of Radioactive Sources - Phase II	2020	2024	1,653,718.75	Hoang Nhuan	ITRRE
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 2021

(Participated by VINATOM and other Vietnam organizations)

Field	Project Title	Project Coordinator
Research Reactor Utilization Development	Research Reactor Utilization	Dr. Duong Van Dong Director, Center for Research and Production of Radioisotope, Nuclear Research Institute (NRI), Vietnam Atomic Energy Institute (VINATOM)
Radiation Utilization Development (Industrial Utilization/Environmental Utilization)	Mutation Breeding	Dr. Le Duc Thao Deputy Director General Agricultural Genetics Institute (AGI)
	Radiation Processing Polymer Modification for Agricultural, Environmental and Medical Applications Project	Dr. Nguyen Ngoc Duy Head of Research and Development Department, Research and Development Center for Radiation Technology, Vietnam Atomic Energy Institute (VINATOM)
	Research on Climate Change using Nuclear and Isotopic Techniques	Dr. Nguyen Trong Ngo Deputy Director, Nuclear Research Institute, Vietnam Atomic Energy Institute (VINATOM)
Radiation Utilization Development (Healthcare Utilization)	Radiation Oncology	Dr. Nguyen Cong Hoang Head of General Radiation Oncology Department National Cancer Hospital (K Hospital)
Nuclear Safety Strengthening	Radiation Safety and Radioactive Waste Management	Assoc. Prof. Dr. Le Thi Mai Huong Deputy Director Nuclear Training Center Vietnam Atomic Energy Institute (VINATOM)
Nuclear Infrastructure Strengthening	Nuclear Security and Safeguards	Ms. Bui Thi Thuy Anh Acting Director of Nuclear Security and Safeguards Division Vietnam Agency for Radiation and Nuclear Safety (VARANS)

4.2.4 - List of RAS projects 2021

(Participated by VINATOM and other Vietnam organizations)

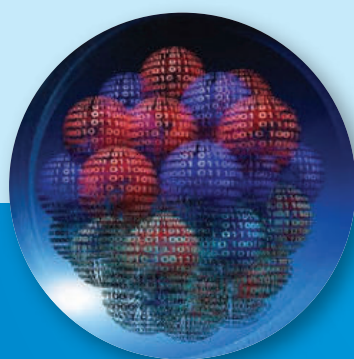
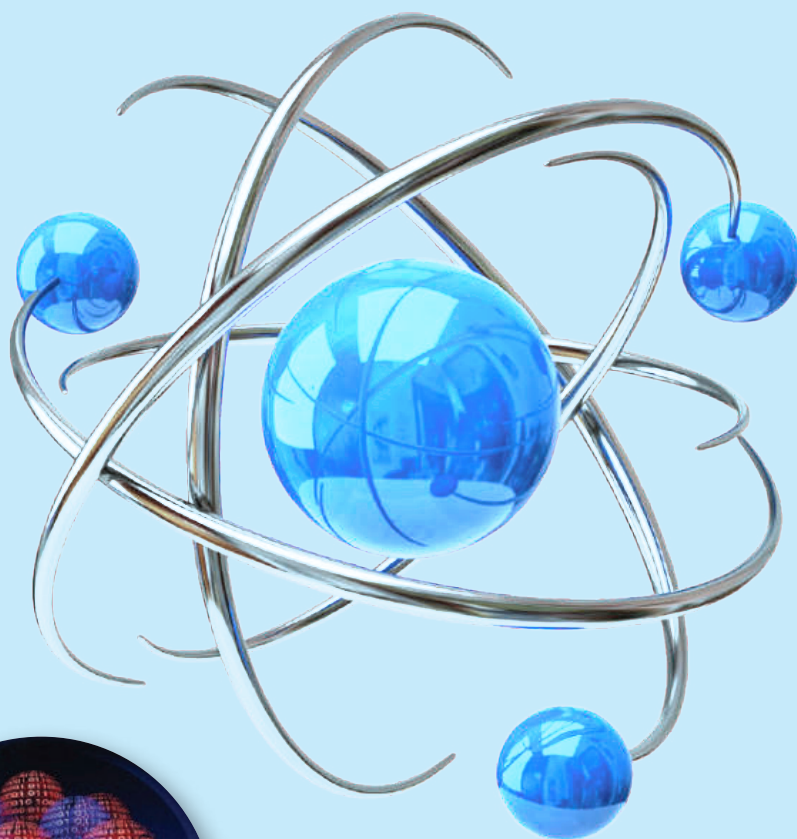
Code	Title	Year of approval	Budget (EUR)	Project Type	Project Coordinators
RAS1022	Strengthening Regional Capacity in Non-Destructive Testing and Examination Using Nuclear and Related Techniques for Safer, Reliable, More Efficient and Sustainable Industries Including Civil Engineering (RCA)	2019	558.600,00	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 Huong 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
RAS5088	Enhancing Crop Productivity and Quality through Mutation by Speed Breeding (RCA)	2021	425.250,00	RCA	Le Duc Thao Agricultural Genetics Institute
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 Nuclear Medicine and Oncology Center Bach Mai Hospital

Code	Title	Year of approval	Budget (EUR)	Project Type	Project Coordinators
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 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 Central Military Hospital 108
RAS6096	Empowering Regional Collaboration among Radiotherapy Professionals through Online Clinical Networks (RCA)	2020	201.000,00	RCA	Bui Quang Bieu Central Military Hospital 108
RAS6097	Enhancing Capacity and Capability for the Production of Cyclotron-Based Radiopharmaceuticals (RCA)	2020	445.200,00	RCA	Mr Nguyen Quang Anh Hanoi Irradiation Center
RAS7028	Enhancing Regional Capabilities for Marine Radioactivity Monitoring and Assessment of the Potential Impact of Radioactive Releases from Nuclear Facilities in Asia-Pacific Marine Ecosystems (RCA)	2016	790,222.85	RCA	Nguyen Van Phuc Nuclear Research Institute, 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) 2021

(Implemented by VINATOM)

Topical Group	National Coordinator	Topical Group Member	Institution
Asian Nuclear Safety Network (ANSN)	Tran Ngoc Toan		VINATOM
Regulatory Infrastructure (RITG)		Cao Hong Lan	Department of International Cooperation, VINATOM
Education and Training (ETTG)		Duong Thanh Tung	Nuclear Training Centre, VINATOM
Sitting (STG)		Bui Trung Thong	Department of International Cooperation, VINATOM
Safety Assessment (SATG) (OS)		Pham Quang Huy	Nuclear Research Institute, VINATOM
SATG (SA)		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)		Nguyen Kien Cuong	Nuclear Research Institute, VINATOM
Communication (CTG)		Hoang Sy Than	Department of International Cooperation, VINATOM
Self-Assessment Coordination Group (SACG)		Cao Hong Lan	Department of International Cooperation, VINATOM
IT Support Group (ITSG)		Le Anh Tuan	Department of International Cooperation, VINATOM
Radiation Protection and Transport Safety (RTTG) (RP)		Pham Khac Tuyen	Department of International Cooperation, VINATOM
RTTG (TS)		Nguyen Huu Quyet	Institute for Nuclear Science and Technology, VINATOM



The **ANNUAL REPORT** for **2021**

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