Applications of Radioisotopes in Industry and Healthcare in Vietnam

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SUMMARY. Applications of radioisotopes have significant meaning in economic development, people health protection, as well as in scientific research in Vietnam. Radioisotopes have been used in various fields, especially in industry and health care. In this paper the present status and main applications of radiation and radioactive isotopes in industry and healthcare in Vietnam are reported.

In order to monitor and control industrial processes, the sealed source and radioactive tracer techniques have been utilized. Nucleonic control devices and gauges have been used in various industrial factories: liquid level gauges in steel industry, cement and beverage factories; density and moisture gauges in paper industry, etc. Tracer technique and sealed source applications have also been utilized for trouble-shooting and process control in industrial production plants and in the petroleum industry.

For medicine purpose, two departments of nuclear medicine were primarily established at the beginning of the 1970's. Up to now more than twenty nuclear medicine departments have been set up and equipped with advanced equipment. Main activities are focused on thyroid function studies, nuclear cardiology, brain scans, gastrointestinal studies, bone scans, etc. Radioisotopes and radiopharmaceuticals used in these departments are imported or produced at the Dalat nuclear research reactor. This reactor is today an important scientific tool in Vietnam for developing nuclear techniques and radioisotope applications for socio-economic progress. Utilization of the Dalat research reactor for radioisotope production is summarized in this paper.

1. INTRODUCTION

Nuclear technique was applied in Vietnam at the early 1950's by using sealed sources for diagnosis and therapy in the medicine field. But its applications were rapidly expanded only after the 1960's by using sealed source techniques in industry, in nuclear medicine as well as in scientific research. Tracer technique applications in medicine for diagnosis, therapy and biology research were started in 1971 based on the establishment of two nuclear medicine departments with relatively little equipment. For nuclear diagnostic, there were a rectilinear scanner, a renograph and some radiometers for measurements of thyroid uptake. Ten years later, especially after 1984 when the Dalat research reactor was reconstructed, the number of nuclear medicine departments were increased, some modern equipment have been acquired.

At that time, in the field of industry only sealed source techniques were utilized in the production sectors, such as paper factories, cement factories and in petroleum companies. It is estimated that there are some tens of such factories and companies where radiation sources have been used. Nowadays both sealed source and tracer techniques are utilized in industrial production plants, but the second one is still under development and poor in applications.

2. CURRENT STATUS AND MAIN ACTIVITIES IN INDUSTRY

At the present time, there are a lot of factories where nucleonic control systems (NCS) are utilized. But it is still difficult to make a statistics of the operating NCS systems in Vietnam. Moreover, most of industrial production factories in Vietnam were established by turnkey contracts with foreign companies. In that situation we tried to obtain

some degree of participation, for example in civil engineering and construction, or in some low-grade technology industry, so NCS and related systems for controlling and monitoring automatic processes are completion equipment in the technological lines. In general, the present status of NCS installations can be estimated as follows: some hundreds of liquid level gauges; about one hundred of density and moisture gauges; about 50 thickness gauges and a number of well logging units. They are installed and operated at the cement, paper and beverage factories, steel industry and in petroleum companies. In that case, the factory's technicians are responsible for the operation and maintenance works, while the repairing and renovation works are carried out by NCS specialists who usually work for the nuclear research institutions and have a good knowledge of nuclear technique applications.

For the last few years, attention was paid to the design and construction of domestic nucleonic gauges. A series of nucleonic gauges have been developed at various nuclear organizations in the country. Domestic products are focused on liquid level gauges used in beverage factories and glass production industry, basis weight and moisture gauges for paper industry, weight scales for on-line measurement of the material weight as well as ash content and the moisture levels in coal, etc.

For monitoring and detecting liquid level, one-level and two-level gauges were designed and manufactured. As usual, gamma ray absorption method is used successfully for liquid level gauges of sealed tanks and vessels. In this case, ^{137}Cs or ^{60}Co sources with relatively energetic gamma rays and NaI(Tl) or GM detectors are usually utilized. Digital electronics parts are designed based upon programmable logic controllers (PLC) or multi-purpose interface cards connected to personal computers (PC).

In order to measure the weight of materials as well as the ash content and moisture levels in coal, the on-line radiometric conveyor weight scale based on transmission technique with ^{137}Cs source was designed and manufactured. It is well known that in the region of 0.5 - 5 MeV, Compton effect is the main process and the total cross section is a function of density ρ as described by formula: $\sigma = \sigma_k \rho (Z/A) L_A$ (where $L_A = 6.023.10^{23}$; σ_k - cross section of Compton effect). Information about transmitted radiation from counter is collected and stored into a PC, where processing and calculation procedures are realized. Based on specialized programmes and calibration curves, these gauges can be used for weight measurement of different materials, such as rock, soil, sand, cement, etc. as well as for measuring ash content of coal.

A paper basis weight monitoring gauge based on backscattering method using Am-241 source with gamma ray energy of 60 KeV was designed and installed in a paper-making factory as prototype. A PC-based system is utilized for on-line measurements, calculations as well as control of experimental processes. The measuring range is 20 - 600 g/m^2.

Gamma ray radiography is one of the most popular applications of the sealed source techniques in industry. Activities in this field have been carried out successfully during the past fifteen years for inspection of various types of welded structures.

It is easy to recognize that research and application of radiation technology are a very important in peaceful uses of nuclear energy in Vietnam as radiation has been utilized in a wide variety of fields such as industry, agriculture, medical treatment and scientific research.

The first research ^{60}Co irradiator with activity of 16.5 kCi was installed and put into operation in 1981 at the Dalat Nuclear Research Institute. Based on this facility the R&D programmes on radiation chemistry, radiation sterilization, food irradiation and biomass conversion have been established and carried out during the last fifteen years. Research activities in radiation chemistry have been carried out in radiation polymerization, radiation crosslinking of polyethylene and natural rubber, radiation vulcanization of natural rubber latex, preparation of wood-polymer composite, etc. The results obtained from the researches will be used for industrial applications of radiation technology in the near future. These investigations have led to knowledge and experience accumulation in a very promising field serving the industry development of our country. Basing on the

obtained results, feasibility studies for the first industrial irradiation centre in the Ho Chi Minh city were carried out a few years ago. This industrial irradiation centre equipped with ^{60}Co source of 300 kCi activity is under construction and will start its operation in the next year.

Compared to the sealed source techniques, radiotracer applications are still poor. The main reason is that activities in tracer technology have just begun since the last decade. Some applications of tracer technology have been carried out successfully during the last few years. The most remarkable activities in this field were concentrated in sedimentology and hydrology studies based on national research projects, technical co-operation projects of IAEA, as well as contracts with end-users. Most of the current sedimentology studies are involved with the optimization of dredging operations or the verification of transport models of bed sediments at the shipping access channels of Hai-phong harbour. ^{46}Sc and ^{192}Ir labelled sands produced at Dalat reactor have been utilized as radioactive tracers to conduct field experiments. Applications of tracer techniques in hydrology have permitted us to solve a number of problems in the field of water resource assessment and hydraulic construction. ^{131}I solution has been used for these studies.

In industry, several experiments using radiotracer techniques for studying material mixing/blending processes were done at a glass production factory a few years ago. The three main parameters of interest in mixing are maximum obtainable homogeneity, optimum mixing time and segregation. Basing on the obtained results, we could utilize these techniques to respond to the requirements of industry in the near future.

For trouble-shooting assessment purposes, studies on leak detection and blockage location in buried pipelines and other industrial systems were carried out several years ago. But so far these studies do not find wide applications in local industry.

It is necessary to emphasize that, the applications of radiotracer for studying industrial processes in Vietnam are not strongly developed yet. In order to realize this task, tracer users must be trained to acquire necessary knowledge on modelling applications such as resident time distribution, flow rate, mixing studies, etc. Since the beginning of the 1990's, some members of our staffs have been sent abroad to attend training courses on industrial applications of radiotracers.

3. CURRENT STATUS AND MAIN ACTIVITIES IN MEDICINE

Up to now, there are more than twenty nuclear medicine departments in Vietnam. Some of them have been equipped with modern equipment and are in good working condition. The number of SPECT, gamma cameras increased from one in 1992 to more than ten nowadays. Main activities in nuclear medicine field comprise the following:

1. Thyroid Function Studies and Therapy

Diagnoses of thyroid disease are being the main activities in all nuclear medicine departments in Vietnam. The measurements of thyroid uptake have been performed almost with ^{131}I isotope, which are imported or produced at the Dalat reactor. The in-vitro diagnostic method is still restrained due to lack of equipment and the irregular supply of radioimmunoassay kits for T_3, T_4, TSH. In recent years, the thyroid uptake and the thyroid scanning with ^{99m}Tc have been performed in some nuclear medicine departments equipped with gamma camera or SPECT. Moreover, the radionuclide therapy of Graves's disease with ^{131}I isotope has been realized in some nuclear medicine departments and hundreds of Graves's disease patients are treated successfully every year.

2. Nuclear cardiology

Nuclear cardiology is a quite new technique in Vietnam. In some modern hospitals where gamma camera or SPECT is available, two procedures have been developed for cardiology studies: the first-pass study and the equilibrium gated blood pool study. The imaging and non-imaging results such as end-diastolic volume, end-systolic volume, ejection fraction, wall motion, chamber size, emptying and filling rates, emptying and filling times, regurgitation index, etc. have given new

significant information for the estimation of cardiac status.

3. Brain Scans

Nuclear brain scanning has been performed in some nuclear medicine departments. The radiopharmaceuticals used were ^{99m}Tc-DTPA and ^{99m}Tc-pertechnetate. The nuclear brain imaging can help us to distinguish malignant tumour meningeoma from other brain tumour, such as astrocytoma, glioblastoma, etc. This method is non-invasive and the obtained results can reach a high estimation in clinical practice.

4. Gastrointestinal Studies

The quantitative studies of gastrointestinal function were developed in the past few years at some departments of nuclear medicine. Gastric motility, gastric emptying studies and scintigraphic measurement of hepatic function have been performed by gamma camera and SPECT. Gamma camera and SPECT imaging provide useful information about a variety of important diseases, such as liver cirrhosis, hepatic tumour and other complications of malaria or viral hepatitis.

There were some investigations of alpha-feto-protein on chronic liver disease patients. However, this procedure cannot be widely applied because of the high cost and irregular delivery of imported RIA-kits.

5. The Genitourinary System

Nuclear medicine diagnoses in renal disorders have become a routine technique and are highly valued. With multi-probe system for radiorenography with ^{131}I - Hippurat produced at the Dalat reactor, two renograms were simultaneously registered and analyzed with or without computer assistance. In other departments equipped with gamma camera or SPECT, new methods for renal study have been performed. The renogram is useful in measuring the contribution of each kidney to total renal function. It is becoming a standard technique for evaluating renal function.

6. Bone Scans

Nuclear bone scanning can give good results although it is recently applied in Vietnam. The radiopharmaceuticals used are ^{99m}Tc-diphosphonate and ^{99m}Tc-pertechnetate produced at the Dalat reactor. The tracer is taken up by osteoblastic activity and is also dependent on bone blood flow. The three-phase study comprises a flow phase, a blood pool image and standard static views. The sensitivity of bone scanning in detecting osseous metastases is about 98 percent.

It is well known that industrial application of radiation sterilization is expanding throughout the world. Recognizing this application, the R&D programmes on radiation sterilization of medical disposables and pharmaceuticals produced in Vietnam have been carried out in co-operation between nuclear research institutions and medicine facilities including medical factories and hospitals. Medical products to be sterilized in the past fifteen years include surgical gloves, plastic syringes, serum packaging, gauze, cotton, etc. and several kinds of pharmaceuticals such as traditional drug, physiological saline, lactate ringer, etc. These medical disposables and pharmaceuticals are sterilized at the ^{60}Co irradiator in the Dalat Nuclear Research Institute and at the irradiation centre in Hanoi. In the framework of an IAEA technical co-operation project entitled "Food irradiation", the Hanoi irradiation centre equipped with a semi-commercial scale irradiator of ^{60}Co source with 110 kCi activity has been established and put into operation since July 1991. Although the facility was designed for food preservation purpose, it has been successfully used as a multi-purpose one. Besides food preservation, sterilization of medical products, disinfestation of medicinal herbs, modification of polymeric materials, etc. studies on gamma sterilized human tissue for surgical treatment have been also carried out at this centre. The results obtained show that freeze drying and radiation sterilization were successfully applied for the production of such tissue grafts as biomembrane and human bone. The achievement in tissue graft preservation and applications for health care in Vietnam during the past ten years are considerable.

4. UTILIZATION OF THE DALAT REACTOR FOR RADIOISOTOPE PRODUCTION

The Dalat reactor was inaugurated in March 1984 and has been operated since then

to realize objectives in the fields of radioisotope production, neutron activation analysis, scientific research and training. For optimal utilization of such low power reactor, its core is equipped with more neutron irradiation channels and with a neutron trap at the center of the core for improving thermal neutron flux. In addition, the reactor characteristics are more useful as far as radioisotope production and neutron activation analysis are concerned, i.e., the cadmium ratio in neutron irradiation positions being rather high in the neutron trap and in the rotary specimen rack and rather low in the fast neutron irradiation channels. For radioisotope production the neutron trap and 40 holes of rotary specimen rack are used for thermal neutron irradiation and one vertical channel for fast neutron activation.

Since its reconstruction and inauguration, the Dalat reactor has been operating for a total duration of more than 18,000 hrs (approximately 1350 hrs per year) mostly at nominal power of 500 kW. The main regime of operation is 100 hrs of continuous run every three or four weeks, largely for radioisotope production and neutron activation analysis. The remaining time is devoted to maintenance work or to short runs for physics experiments. About 90 percent of reactor operation time is utilized for production of radioisotopes and radiopharmaceuticals for nuclear medicine, agriculture, oil exploitation, sedimentology and hydrology studies and other scientific research. The radioisotope production at the Dalat reactor has concentrated on the following radionuclides:

- ^{32}P in injectable orthophosphate solution and ^{32}P applicator for skin disease therapeutics

- ^{131}I in NaI solution

- ^{99}Mo - ^{99m}Tc generator

- ^{51}Cr in injectable sodium chromate solution and Cr-EDTA

- Other radionuclides such as ^{60}Co, ^{65}Zn, ^{64}Cu, ^{24}Na, ^{86}Rb, ^{46}Sc, ^{71}Ge, ^{55}Fe, ^{192}Ir, etc., have also been produced in small amounts when requested.

In order to support the application of ^{99m}Tc isotope in clinical diagnosis, the preparation of radiopharmaceuticals for labelling with ^{99m}Tc (kit) has been started in parallel with the development of ^{99m}Tc generator systems. The following kits are regularly prepared at the Dalat reactor: Phytate, Gluconate, Pyrophosphate, Citrate, DMSA, HIDA, DTPA, Maccroggregated HSA and EHDP. The annual production rate is about 1000 bottles for each kit which is equivalent to 5000 diagnosis doses.

The annual amount of radioisotopes produced at the Dalat reactor has generally increased with time. Up to now the total output has reached more than 1300 Ci. The yearly amount of radioisotopes produced at the Dalat reactor is about 150 Ci and is not enough to meet the needs of society, especially in medicine field. So, a large quantity of radioisotopes for medicine purpose has to be imported every year.

5. CONCLUSION

The applications of radiation and radioactive isotopes are a very important in peaceful uses of nuclear energy in Vietnam, and have made substantial contributions towards improving not only the national living standard, but also the public acceptance of nuclear power programme. This is because radioisotopes have been utilized successfully in various socio-economic fields, especially in industry, agriculture and health care. During the last ten years, based on national research projects in the nuclear field and through the technical co-operation projects of IAEA, a number of nuclear laboratories and facilities have been set up and equipped with necessary equipment, a large number of nuclear scientists and technicians have been educated and trained. Since then, due to the successfully economy reform and renovation, the growth rate of GDP and the national living standard rapidly increase, we are convinced that Vietnam will soon to strengthen nuclear technology to meet the needs of society and to introduce nuclear power for ensuring the country's future development.

6. REFERENCES

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