

Development of an Integrated Radiological Waste Management and Environmental Surveillance Program at Dalat Nuclear Research Institute - 11166

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ABSTRACT

For the past several years a major focus at the Dalat Nuclear Research Institute (DNRI) has been the development and implementation of an integrated and comprehensive radiological waste management and environmental surveillance program. The DNRI waste management and environmental monitoring programs have historically involved relatively small scale activities with an emphasis on quantifying the environmental impacts and storage of waste associated with the operation of the 500-kW research reactor at the Institute.

This paper focuses on the progress that has been made to date, and the future needs associated with the establishment of an integrated radiological waste management and environmental surveillance program that meets international standards. Under a collaborative effort between the Ministry of Science and Technology of Vietnam and the United States Department of Energy (DOE), subject matter experts in environmental monitoring and waste management from the Oak Ridge National Laboratory (ORNL) have provided technical support and resources to DNRI staff charged with developing a modern, safe and compliant program.

The paper includes an introduction describing the DNRI site and activities carried out in support of research reactor operations. Associated waste management and environmental programs will be detailed and key accomplishments and future plans for integrating these programs will be highlighted. The acquisition of an evaporator to reduce the volume of liquid waste resulting from research reactor operations and of environmental sampling and monitoring will be discussed, along with associated process improvements and pollution prevention opportunities. This paper will also provide specific information on the integration of various program components including waste tracking, waste treatment, environmental radiological sampling to ensure the effectiveness of these tracking and treatment activities, and quality control and assurance.

INTRODUCTION

In developing a radioactive waste management program, and associated environmental protection measures, DNRI has adopted a proactive approach including building provisions for waste management into the design of its nuclear research facility. Since there is no final disposal option for radioactive waste in Vietnam all waste generated must be conditioned for interim storage.

DALAT RESEARCH REACTOR

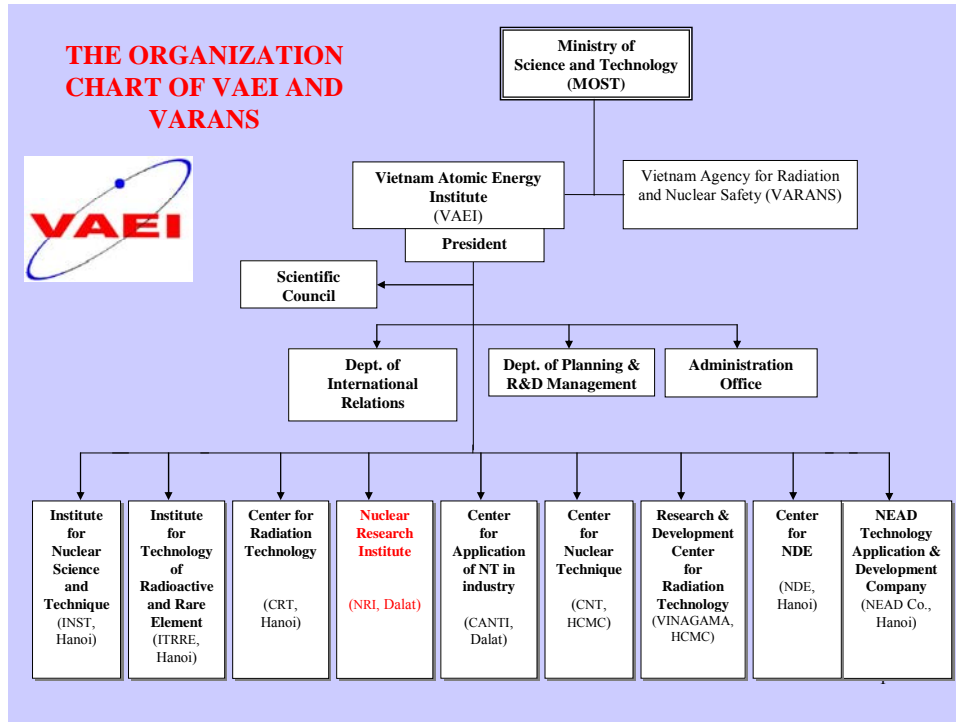


Fig. 1. Organization scheme of VAEI

DNRI belongs to Vietnam Atomic Energy Institute (VAEI) as shown in Fig.1. DNRI is located in Dalat city, Lam Dong Province, 300 km to the north east of Ho Chi Minh city (Fig. 2). Fig. 2 and Fig. 3 demonstrate the organizational structure of DNRI for the management, operation and utilization of the research reactor and for the waste and environment programs as well.

The Dalat Nuclear Research Reactor (DNRR) with nominal power of 500 kW has accumulated twenty six years of operation until March 2010 since its renovation from the previous 250 kW TRIGA-MARK II reactor. The reactor has totally operated about 34,500 hrs at nominal power and the total energy released is approximately 700 MWd. At present, the DNRR uses a mixed core of WWR-M2 fuel assemblies with 36 % (HEU- High Enriched Uranium) and 19.75 % (LEU- Low Enriched Uranium) enrichment. Each HEU and LEU fuel assembly contains about 40.2 g and 50 g of U-235 respectively.

Main missions of the DNRI:

1. To conduct research on energy, basic science, and nuclear techniques with the goals of the implementing a national nuclear relating power program and facilitating the use of nuclear techniques in different socioeconomic sectors of the country such as isotope production, and neutron activation analyses in various areas of the country.
2. To collect and properly manage the radioactive waste resulting from the use of the radioactive materials in Vietnam.

3. To prepare material and technical bases and manpower for future development of the DNRI and the nuclear sector; to take part in the research programs to introduce nuclear energy into Vietnam.
4. To ensure that all activities are performed in a manner that is protective of the workers, the public, and the environment.



Dalat city



DNRI site



Scheme of DNRI



DNRI

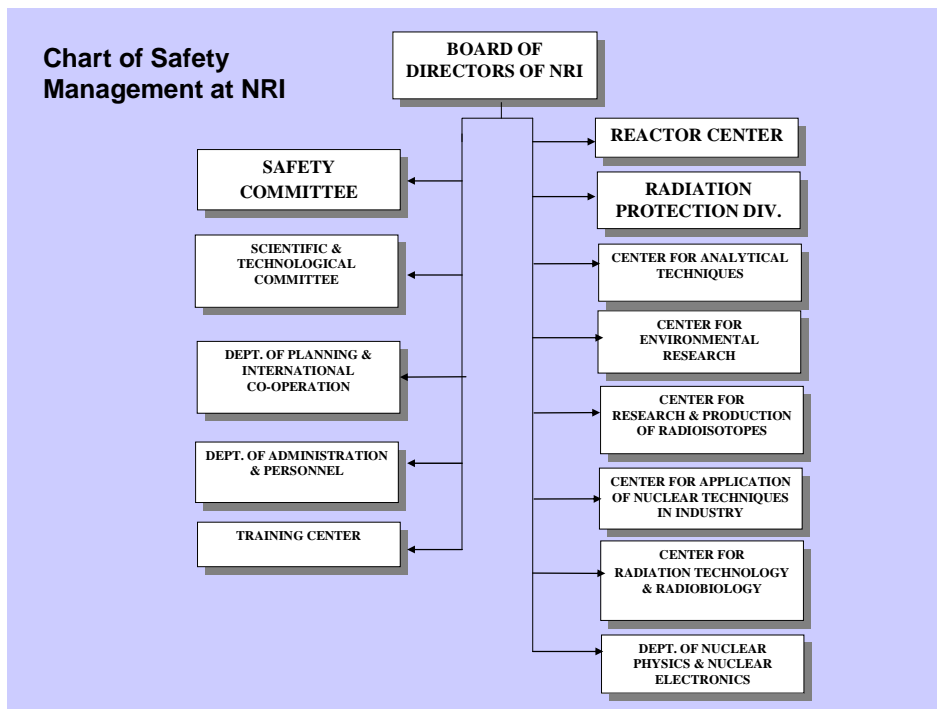


Fig. 2. DNRI Organizational Structure

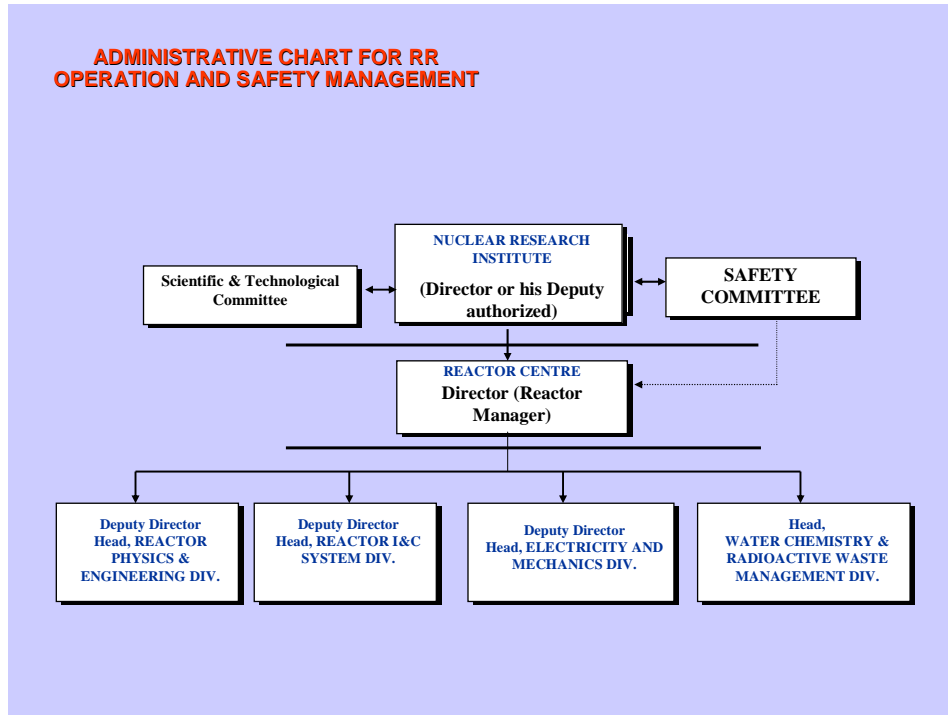


Fig. 3. Organizational dependence of Water chemistry & radioactive waste management division in Reactor center

GENERAL DESCRIPTION OF WASTE MANAGEMENT FACILITY

In order to safely and effectively carry out the missions discussed above, provisions for controlled and contained waste management facilities were incorporated into the initial design phases of the DNRI. The facilities were designed in such a way as to give maximum flexibility in waste management operations for both current and future waste streams. Building air from the treatment facility is filtered through a series of HEPA and carbon filters prior to discharging to the environment, and sampling of environmental media in areas of potential impacts from this facility are sampled to ensure no adverse environmental effects. A key component of the waste management strategy is to provide for safe and secure long-term storage of radioactive waste until a national decision can be made on the final disposition. This is accomplished through the selection of conditioning and treatment technologies that both reduce volume and provide for a stable retrievable waste form. Another key component is the inclusion of analytical capability in two laboratories located in the waste treatment buildings. One analytical laboratory allows for in-process testing ensuring the acceptability of incoming waste and the effectiveness of waste treatment operations. The other analytical laboratory is used for research relating to geological disposal.

DNRI is responsible for the management of radioactive waste at the national level in Vietnam, and collects, transports, treats, conditions, and stores radioactive waste generated from operations throughout the country. In order to carry out this mission, DNRI has employed a system for radioactive waste management based on the former USSR regulations valid since the beginning of the 1980s. This system was renovated and modified during the years of 1995-1997 by IAEA TC projects and national projects. After conditioning, the waste drums are stored in building 5 (radioactive storage building). The Institute generates a total of about 100-150 m³ of radioactive

liquid waste and around 5 m³ of dry and wet solid radioactive waste each year, mainly from reactor operation and radioisotopes production activities.

The system for radioactive waste management at DNRI consists of 2 main buildings:

- The radioactive liquid waste treatment station is located underground at minus 4 m, and includes storage tanks, an evaporation system (currently installing), and a distilled water system. There are also two Laboratories, and a control room on the ground floor.
- An interim storage building (referred to as Building 5) has a compaction system, and eight concrete cells for storage.

The present DNRI treatment facility contains:

- An evaporator unit in construction
- A mortar injection system used to condition the sludge generated from evaporator operations in 200-liter drums
- A drum tumbler to ensure all free radioactive liquid waste in the sludge will be conditioned.
- Four stainless steel storage tanks for residual sludge and another four for primary radioactive waste liquid waste
- A drum compactor for compactable waste
- A glove box to sort solid waste
- An analytical laboratory to characterize radioactive waste
- A laboratory to investigate radioisotope-absorbing characteristics of Bentonite serving for geological disposal.

RADIOACTIVE WASTE MANAGEMENT

The principles: The basic goals of radioactive waste management at DNRI are: establishment of national laws, regulations and standards on radioactive waste management; minimization of the generation of radioactive wastes; restricting the release of radio nuclides into the environment and protecting the all environmental media; keeping exposure to both the public and DNRI staff as low as reasonably achievable; and restricting burdens on future generations. The achievement of these goals will require the DNRI staff to complete the following studies and tasks: feasibility studies, safety analyses, environmental impact assessment; establishment and implementation of quality assurance and control systems, and an emergency response plan; and establishing organizational roles and responsibilities. Therefore, the success of the DNRI radioactive waste management program is based on the minimization of generated radioactive waste (both liquid and solid forms). In order to minimize the volume of radioactive waste, the following principles are applied:

- Segregation of contaminated waste from liquid waste susceptible to contamination
- Segregation of waste contaminated by short lived isotopes from those contaminated by long lived isotopes at the point of origin.
- Solid waste is sorted at origin according to their nature (compactable or non-compactable), radioactivity, half life, and collected in shielded bins or plastic bags.

Legal Framework: The legal system includes laws, regulations and standards. Applicable laws include elements of the Atomic Energy Act (2008). This is a basic law on radioactive waste management and has been approved by the National People's Congress.

Institutional control

Responsibility: VAEI is an R&D organization and VARANS (Vietnam Agency for Radiation And Nuclear Safety) which oversee the national nuclear industry sector and also responsible for management of radioactive waste as follows: establishing a national planning of radioactive waste management and treatment, disposal, and decommissioning nuclear facilities; issuing the professional regulations and standards for radioactive waste management; organizing the research and development of radioactive waste management; reviewing and approving the feasibility study and design of radioactive waste management facilities; managing emergency response to nuclear accidents; protecting the public and the environment; and establishing the financial system for radioactive waste disposal.

DNRI participates in not only in the regulation and supervision of radioactive waste management from the environmental protection point of view but also nuclear safety surveillance of radioactive waste management. DNRI supports VAEI and VARANS in establishing a national policy for radioactive waste management, issuing the state regulations, rules and standards concerning radioactive waste; taking part in the emergency response programs; reviewing and approving the environmental impact assessment and safety analysis reports, and inspecting the simultaneous construction of nuclear installations with auxiliary projects of radioactive waste treatment and conditioning.

Implementation: DNRI staff takes responsibility of the management of their own waste meanwhile the environmental protection center is responsible for the supervision. Therefore, the environmental protection center and radioactive waste generators work together to safely implement radioactive waste management policies and activities. To achieve an effective management of all risks, the radioactive waste is managed from two directions to prevent the radioactive nuclides from the release of radionuclides into the environment: 1) safely controlling all stages of radioactive waste management: waste generation, treatment, conditioning, storage, transport; and 2) adopting necessary procedures, examining, and approving the environmental impact assessment and safety analysis reports and environmental monitoring.

Environmental surveillance program

DNRI has the responsibility for implementing a comprehensive program of the environmental radiological monitoring, sampling, radioanalysis, and quality assurance. This program includes: 1) Field monitoring and sampling; 2) Laboratory radioanalysis; 3) Radiation Detection Instrumentation with calibration and maintenance; and 4) Integrated program of Quality Assurance (QA) and quality control (QC) following Vietnam Standards ISO/IEC 17025:2005. The program ensures that all monitoring, sampling collections, laboratory activities, measurements and derived analytical data are scientifically defensible, of acceptable known quality, and in consistent units. The original copy of all data forms is documented and archived in the data base which will be comprehensive and traceable; contains all radiological data; be applicable to immediate review and evaluation; meets Vietnamese Environmental Protection Agency's legal and long-term retention requirements; and contains complete descriptive information to allow reconstruction of the radiological situation at some future time.

Radiochemistry analyses are managed similarly to the field monitoring data. Analytical data is reviewed for completeness, and correctness. Analytical techniques are available including low gamma-ray spectroscopy, gross alpha and beta measurement, and liquid scintillation counting.

Quality assurance (QA): QA includes the identification of the authenticity and/or traceability of all radioactive standards used for calibration instrument, quality control (QC), the identification and establishment of the authenticity and validity of all data collected, an accountability of all related documentation. Examples of documentation include method of collection, field monitoring and sample collection forms, sample control forms, standard operating procedures, and all QA/QC records.

The monitoring and analysis manual ensure consistency and completeness of the monitoring and analytical data produced. A methodology and procedures manual is under development. The manual will include procedures for field monitoring during radiological emergencies, environmental sample collection, preparation, analysis, standard reporting units, quality assurance, and monitoring instrumentation calibration and maintenance. The methods are chosen because they are scientifically defensible, simple, and applicable to deployment in DNRI.

THE MANAGEMENT SYSTEM FOR RADIOACTIVE LIQUID WASTE AND ACQUISITION OF AN EVAPORATOR

Low level liquid waste is collected in tanks located 4 m underground. After characterization, the waste is transported in an appropriate container to the treatment building to be treated in a waste water evaporator system. After treatment, the clean water is collected in a separate tank for discharge. The sludge is conditioned in 200 liter drums with mortar for long-term storage.

The total amount of radioactive liquid waste generated at DNRI is approximately 100-150 m³ annually [2]. The characteristics of the low level waste water are shown in table 1 [3]. The radioactive liquid waste treatment station collects water from the reactor operations, radioisotope production and laboratory operations. The current treatment methods are coagulation and precipitation, mechanical filtration and ion-exchange. The radioactive liquid waste treatment station includes:

- four storage tanks (5 m³ each) for liquid waste collection and precipitation
- eight ion-exchange and 2 mechanical filters
- four sludge reservoirs
- four storage tanks for containing alkaline-acid solution.
- a waste water evaporator system.

Table 1: Characteristics of secondary liquid waste at DNRI [3]

Type	Origin	pH	Conductivity, mS/m	Surface dose rate, μGy/h	Total β activity, Bq/l	γ activity, Bq/l			Sludge amount after 48h, %
						Co-60	Cs-134	Mn-54	
A	Cleaning of filters	6-8	6-50	5-15	370-3700	370-740	37-370	18.5-37	10-15
B	Precipitation processing	7-9	100-1000	5-20	740-3700	740-1850	370-740	74-110	20-30
C	Regeneration solution	1-11	100-5000	15-50	3700-37,000	7400-18,500	740-11,000	185-296	2.0-5.0

Treatment methods: Liquid waste streams in the reactor building are collected in the four storage tanks. It is precipitated using chemicals. Then, it is pumped to the mechanical filters prior to going through the ion-exchange. The resulting solution is always checked pH and radionuclide concentrations before discharging into the environment. The decontamination factor (DF) is

approximately 1000. The sludge is transferred to Building 5 to await treatment. After treating the volume reduction of the secondary liquid waste, the sludge must be conditioned. The sludge from the storage tank and the ion-exchange regeneration solutions are mixed together and pumped to the feeding tank for the cementation process.

After the waste is mixed, the pH-value and chloride, sulfate and phosphate concentrations are checked. Next, the amount of liquid waste and cement per 200 liter drum are determined. Then, the waste is mixed using a mixer before cementation. Prior to interim storage, all labeled drums are checked surface dose rate and Gamma total activity and the information is recorded in the inventory.

However, the treatment method and procedures for liquid waste treatment is currently old and not economical benefits, particularly at a tourist city. Therefore, to obtain much higher volume reduction, with the aid of the Oak Ridge National Laboratory and VAEI, we are now in the progress of installing an evaporator system. The work is expected to be completed in 2011.

THE MANAGEMENT SYSTEM FOR SOLID RADIOACTIVE WASTE

Disposal facilities: Eight concrete pits are constructed for the disposal of low level radioactive waste. Each pit is 6 m long, 6 m wide and 3.4-5.7 m deep, with the wall thickness of 0.4 m [2]. The volume of all pits is 896 m³. In Building 5, missions such as general service, interim sludge storage, waste conditioning, and decontamination are carried out. The solid waste is collected in plastic bags at the generating places and then transported to the disposal facilities twice a week after being surveillance. According to the IAEA classification, most of the radionuclides are short- lived.

Equipment:

- Sorting box;
- Surface dosimeter (RAM DA-3);
- Total gamma monitor (CONDOR): used for waste bags of 20-60 kg in weight;
- Gamma spectrometry system with NaI(Tl) detector;
- Gamma spectrometry system with HPGe detector of 85 m³ in volume and 15 % in relative efficiency;
- Compactor.

The majority of solid waste is combustible and/or compactable (80-85 wt-%) and the surface dose rate is less than precaution 900 µGy/h [4]. Each year, DNRI generates about 5 m³ of solid radioactive waste (Table 2) including ion exchange resin, radioactive liquid organic waste, disused sealed sources and contaminated protective clothing.

Ion exchange resin

This resin is derived from the purification circuit of the reactor. After neutralization the resin is conditioned. The resin is placed into a drum and mixed with cement to a predetermined optimized ration. The drum is then thoroughly mixed on the drum tumbler, after conditioning, the drum is placed into interim storage.

Sludge

The sludge generated from final step of liquid waste treatment is injected in a 200 liter drum and mixed with mortar. The mixing operation uses stones placed in the drum. The rotation of the drum is conducted on a drum tumbler.

Sealed Sources

Spent sealed sources are conditioned in 200 liter drums according to their overall size. They are immobilized within a concrete matrix.

Contaminated Protective Clothing

The clothes contaminated by short lived isotopes are stored for decay and then washed. Those heavily contaminated are considered waste and compacted prior to interim storage.

Table 2: Description of radioactive solid waste types managed

Waste type	Description	Maximum volume, %	Direct dose rate, $\mu\text{Gy/h}$	Radioactive Isotopes
Compactable solid waste	Paper, cotton, gloves, small metallic pieces.	70-75	15-450	Cs-134; Co-60; Eu-152; Eu-154; Zn-65; Sc-46; Mn-54; Fe-59; Ag-110; Ta-182;
Non-Compactable solid waste	Metals, glasses	15-20	45-12,000	
Normal waste	Envelope, cigarette cover, packaging, notebooks	5-7	5-1000	

Sharp material is separately stored in a metal container or a sturdy cardboard box to avoid any exposure or sticks. Solid waste is collected in plastic bags from the generator’s areas then held for decay. After the decay period, it is classified, checked for total gamma radioactivity, weighed and compacted. After that, it is immobilized by cementation. Finally, before being labeled it is packaged by sealing with a cover and painted overall for rust prevention.

- **Compaction:** This method has been considered because of its reliability, simplicity, and low operational cost. A low-pressure compactor is used; the compactable solid waste is fed manually into the compactor and compressed into a 200 l drum. The compaction process provides a volume reduction factor between 3 and 5.
- **Conditioning:** The solid waste resulting from the highest volume reduction is then routed to the appropriate conditioning step where the final package for interim storage is obtained. Conditioning includes operations that produce a waste package suitable for subsequent management steps. The immobilization of radioactive waste to obtain a stable form is the most important step to minimize the potential for migration or dispersion of radionuclides into the environment. The choice of immobilization in a cement matrix has been based on the physical and chemical nature of the waste, low cost, suitability for sludge, good thermal, chemical and physical stability, and good compressive strength of the waste forms [6]. The immobilized waste is then packed in waste packages that meet the shielding and containment requirements for handling, storage, transportation and finally waste disposal site requirement in future.
- **Storage:** Storage is an integral part of the waste management system. The main functions of a storage facility are to provide safe custody of the waste packages and to protect both operators and the general public from any radioactive waste. The DNRI storage has been

designed to facilitate inspection and monitoring of stored waste, keep exposure to personnel as low as reasonably achievable (ALARA), and provide adequate environmental conditions to ensure proper conservation of waste packages during their tenure at the facility.

Waste tracking

Receipt of radioactive materials: Tracking of radioactive materials at DRNI is cradle-to-grave; all materials are accounted for from the moment they are generated on the DRNI campus until they leave as waste or are transferred to another site. All items containing radioactive materials are received at the Division of Radioactive Waste Management. Only this Division is permitted to open radiological packages. The procedure for receiving radioactive waste is as follows:

- Perform all manipulations wearing a lab coat and disposable gloves
- If material is volatile, place the package in the fume hood. If the package contains high energy beta, gamma or X ray emitters, place the package behind appropriate shielding prior to proceeding
- Wipe test the external surface of the package for contamination
- Check the package contents for possible damage and if damage is discovered, isolate it to prevent contamination
- Wipe test the interior surface of the original package, the vial and the vial holder, if present
- If contamination is found on the external packaging, consult the waste regulations to determine disposed method
- Record wipe test results, bag number, volume or weight, radioactivity, half-life, catalogue number, generator, destination date. Issue a unique identifying sticker for each item
- Enter the item in the inventory data book.

Inventory Control:

- Maintain an ongoing record of received package/sources
- Track each aliquot removed by weight or volume from the origin bags
- Estimate the activity delivered to each waste stream
- Note dates on received bags.

Records of use are readily accessible for inspections and not discarded without prior approval of the Radiation Safety Officer. In the case of sealed sources, an inventory number is issued and they are placed in a special cell.

ENVIRONMENTAL SAMPLING AND MONITORING

Liquid waste: The radioactive effluent is sampled after the homogenization of the tank and analyzed to check for compliance with the requirements established by the radioactive waste management unit. The distillate from evaporations will be also sampled and analyzed before discharge to the environment. Limits for treated aqueous waste being discharged to surface waters are specified in a Decree signed by the Minister of Health, Minister of Natural resources and Environment.

Solid waste: Sampling is performed to verify that the waste meets waste acceptance criteria and to ensure the proper segregation of solid waste. The conditioned waste is visually verified to determine compliance with requirements for stable interim storage. Representative samples are also subjected to a series of physical test to ensure long-term stability.

QUALITY CONTROL AND ASSURANCE

A considerable amount of solid radioactive waste has been generated in DNRI from a variety of nuclear technology applications in research, medicine and industry. All waste management activities including treatment, conditioning, and storage are conducted under a Quality Assurance Program (QAP). The QAP ensures that required elements of the operations are being correctly executed and that safety objectives are being achieved.

All stages of waste processing have been considered, starting with waste generation, through sorting and treatment, up to long-term storage of waste (in the future). An increased implementation of QA and understanding its role in waste management is helping to manage the waste stream in a more efficient way. The implementing QAP includes all activities that affect the quality of the waste packages, and includes the following:

- Raw waste characterization: Characterization is made directly or indirectly and characterization data are documented in sufficient detail including physical and chemical characteristics, volume, identities, activities and concentrations of major radionuclides, characterization date, and generating source.
- Transportation: The radioactive solid wastes are transported to Building 5 to be treated and/or conditioned. The waste transportation meets the Vietnam transportation regulations, general safety principles, activity limits, and testing requirements for transportation containers.
- Waste treatment and storage: The radioactive solid waste treatment and storage facilities are confined and included a ventilation system. It has monitoring capabilities to provide rapid identification of failed confinement or other abnormal conditions.
- Waste conditioning and packaging: Solid waste is packaged for the duration of the expected storage period and until disposal is achieved; containers are marked such that their contents can be identified.
- Organizational structure and functional responsibilities: The Division is responsible for ensuring the regulated management of all radioactive solid wastes in DNRI to protect the health and safety of the public and the environment. This includes activities such as transportation, treatment and storage. The managers have the role of management and integration of the radioactive waste management and are responsible for establishing, implementing, and ensuring compliance with the requirements of the QAP, with duties including: 1) assisting with the QAP planning, development and implementation; 2) establishing, planning policies to ensure that QA matters are reflected in characterization, treatment, conditioning, storage; 3) ensuring that all staff are aware of and compliant with the requirements of the policy; 4) reporting quality problems to the Director of the Reactor Center. All waste management staff are responsible for the implementation of the QAP and reporting any quality problems to the head of the waste management Division.
- Organizational interface: The QAP and associated procedures are provided for the recognition and control of both internal and external interfaces whenever they occur. This includes the detailed description of the responsibility transfer point and operational control transfer point. The internal interfaces include interfaces between different management units such as treatment operators, conditioning operators, storage operator.

The external interfaces include interfaces between the waste management division and the waste generators.

- Personnel qualification and training: qualification and training processes ensure that personnel achieve and maintain the required capabilities to perform their work. Each staff is responsible for requesting training and qualification processes to make sure that they are well-qualified for their position and meet the appropriate requirements. In addition, policies that describe personnel selection, training and qualification requirements including applicable requirements such as education, experiences, skill level and physical conditions are established and complied. Management ensures all the staff satisfying these requirements before they work independently. Training plan is prepared by management.
- Documents: The QAP is documented with written policies, plans, procedures, and instructions and is implemented and maintained throughout the system. These documents identify the scope of activities covered and provide for performing work under controlled conditions and by qualified personnel. Activities are described and performed in accordance with documented instructions, procedures, or drawings, which may include criteria for determining that activities have been satisfactorily accomplished.
- Non-conformance and corrective action: corrective action is the identification of cause and the effective resolution of a quality problem after its occurrence to prevent its recurrence. The root cause influencing the quality is determined, corrected to prevent recurrence, properly documented, and reported to the head of the waste management division in a timely manner. When a waste package fails to satisfy the requirement of waste acceptance criteria, arrangements are made for it to be identified as non-conforming and segregated. Any non-conforming waste is reported and evaluated to assess if it could be accepted or it could be over-packed to bring it into conformance. The head of the unit is involved from the identification of the adverse conditions to the implementation of corrective action and is guaranteed that resources are available to resolve the identified problems in a timely manner.

THE PROJECT WITH THE UNITED STATES UNDER THE SISTER LAB PROGRAM:

DNRI and ORNL (Oak Ridge National Laboratory) have participated in an international cooperation agreement for more than four years. To date, significant progress and sharing of information has taken place between DOE and VAEI and several IAEA fellowships and US visitors by Vietnamese scientists have been hosted by DOE. This has been effective in providing hands-on experience in various programs in DOE facilities and in providing opportunities to make contacts with subject matter experts in a variety of disciplines. This program is expected to continue with future focus directed toward liquid and solid waste management and environmental radiological sampling to ensure the safe, effective, and efficient completion of nuclear activities in Vietnam

FUTURE PLANS

As is the case in many countries, the discharge of effluents from nuclear installations is subject to not only substantial regulatory oversight but also to intense public scrutiny. In the future, routine discharges of waste water and ventilation air will need to be made and the success of the nuclear

program will depend on all releases being below regulatory or public health standards. DNRI has developed an approach to sampling and analyzing all waste that will be released to the environment and documenting that it is below applicable authorized limits. In addition, DNRI has worked with both regulators and the public to ensure that a common understanding is reached and the true risks are adequately discussed. This has been and is expected to continue to be an area of significant activity for the waste management program in DNRI.

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