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Radiological Decommissioning Activities with the Canadian Department of National Defence: A 10 Year Perspective

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ABSTRACT

In an effort to reduce overall operating costs within the Canadian Department of National Defence (DND), a number of bases, stations, and ships were declared surplus. These facilities were scheduled for closure and disposal. Part of the environmental qualification of closure includes radiological decommissioning. The handling, storage and transport of radioactive material within DND is under the jurisdiction of the Director General Nuclear Safety (DGNS). An independent review of radiological considerations with respect to facility closure is desirable because it removes the DND regulatory body (DGNS) from direct contact with the radiological decommissioning, and thereby removes any potential conflict of interest. This allows the DND regulatory body to make supportive claims to the Federal regulatory body, namely the Canadian Nuclear Safety Commission (CNSC). The ultimate goal is to ensure that, to the greatest possible extent, no radioactive material is transferred from DND to any subsequent, often civilian, owner.

Building on its strengths in nuclear engineering and science, SAIC Canada was awarded in 1994 a major contract (valued at approximately $1.8M) by the Department of National Defence (DND) to provide radiological decommissioning and decontamination services. Radiological surveys are one component of the process of preparing these facilities for disposal.

This contract was extended through to 2000. Approximately 100 individual tasks were carried out under this task. Each task generated a detailed decommissioning report, outlining the results of the decommissioning, the radiological status of the facility, and recommendations for further action. Of these 100 tasks, approximately 22 involved the characterization, removal, packaging and/or shipping of radioactive material (either discrete sources or contamination). The balance of the tasks were related to preliminary site investigations, surveying to identify sources or contamination, or tasks in support of the conduct of these operations.

This paper outlines some pertinent results obtained from reviewing the past ten years of radiological decommissioning performed by SAIC Canada for DND.

I. MASTER PLAN

Prior to undertaking radiological decommissioning activities, a detailed plan was developed which guided the prioritization of sites, selection of equipment, safety and survey protocol, recording and analysis of data, and reporting results to DGNS. The plan was entitled "Master Plan for Radiological Decommissioning" [Reference 1]. From time to time, this plan was modified to account for changes in equipment, procedural changes which often stem from "lessons learned' in the field, and regulatory changes. The Master Plan is currently at Version 6.0.

The basis for the development of the Master Plan was a statistical approach. Survey procedures were established to ensure that there was a high degree of confidence such that any radioactive material that may be present was detected. Likewise, the probability of falsely concluding that an area was contaminated must be kept acceptably small. When radioactive material and/or contamination were discovered, their removal or decontamination was carried out to remove levels to below regulatory limits and as low as reasonably achievable (ALARA), to a given statistical confidence level. Generally, confidence levels for field surveys and decontamination were set at 95%.

Actions taken within the scope of the Master Plan were determined in sequence. The chain of events with respect to radiological decommissioning of a closing DND facility was three-phased, as follows:

a. Phase I: Review and Preliminary Site Investigation;

b. Phase II: Site Survey; and

c. Phase III: Decontamination and Waste Disposal.

In Phase I, DND historical records are reviewed and relevant site personnel are interviewed. In this phase, it became evident whether or not a site survey would be required. If it was confidently stated that no radioactive material was ever held at a facility or part of a facility, then the Phase I recommended no further action taken. A Phase I may also have involved a Preliminary Site Investigation (PSI) to aid in determining the potential of radioactive material being held on site. This involved a visit to the closing facility. The preliminary survey priorities of all areas within a facility were established as part of the Review and/or PSI, and are assigned a numerical value from 1 through 4. The priorities are assigned based upon a qualitative assessment of the probability that equipment containing radioactive material was ever stored, used or maintained in that area, as follows:

a. Priority 1: *very likely*;

b. Priority 2: *likely*;

c. Priority 3: *unlikely*; and

d. Priority 4: *extremely unlikely*.

Additionally, a special tritium priority may be assigned if a facility is thought to have held tritium-bearing material. It is worthy to note that all priority assignments, other than priority 4, involve varying levels of effort in the field; a priority 1 requires the most effort with respect to number of readings and swipes taken, whereas a priority three requires the least effort. The Phase I stage aids in reducing the number of surveys, and even Phase IIs, performed by excluding facilities, buildings and rooms that have little potential of historically holding radioactive material (for instance living quarters, lavatories, administration offices, and the like). The overall benefit is cost reduction for the Government.

In Phase II, field surveys are carried out with respect to the priorities established in the Phase I. At this stage, priorities of areas may be modified as situation dictates. For instance, if a room had been established as a Priority 2 area, and contamination is found in the field survey, the area immediately becomes Priority 1. The level of effort required for a given field survey is dictated by the statistical confidence required. For instance, to achieve an overall confidence of 95% with respect to finding radioactive sources and/or contamination at a facility, the number of survey measurements or swipes taken depends upon the priority assigned. The Phase II stage may involve some minor waste removal or decontamination, however Phase III is often required in facilities where there are numerous sources pending disposal or when widespread contamination has been found.

In Phase III, radioactive waste characterization and disposal and/or decontamination are performed. The Phase III stage usually follows a Phase II, wherein radioactive sources, waste, or contamination has been identified. Occasionally, SAIC Canada has been requested by DGNS to perform Phase III activities at non-closing facilities (such as low-level radioactive waste storage rooms).

Since 1994, approximately 100 reports have been issued by SAIC Canada for DGNS. The report breakdown (by number of reports) is as follows: Phase I - 31%; Phase II – 44% and Phase III – 9%. The remainder (16%) are technical notes that are related to other activities. Over half of all reports generated involve surveying, waste identification/disposal and/or decontamination of DND closure facilities.

The Radiological Decommissioning reports submitted to DGNS by SAIC Canada provide details as to the historical background of decommissioned facilities, priority assignments, survey methodologies employed, radioactive material and/or contamination found, waste characterization/disposal details and results of decontamination exercises. The level of effort required for radiological decommissioning may be realized by the number of priority 1, 2 and 3 which are assigned. Over 4500 priority assignments, excluding priority 4, have been deemed necessary in the past five years. The percentage of priority assignments are distributed as follows: Priority 1 – 28%; Priority 2 – 24% and Priority 3 – 48%. It may be logically inferred that, on average, roughly half of radiological decommissioning resources for a given facility are expended on areas that are thought to have likely or very likely utilized, stored or otherwise have been in proximity to, radioactive material.

II. DECOMMISSIONING TOOLS

The most valuable tools with respect to radiological decommissioning are the personnel involved. Typically, a given facility decommissioning involves one nuclear specialist and from one to four radiation survey specialists. The nuclear specialists are scientists or engineers who have trained in radiation engineering and health physics. They provide a detailed knowledge base for planning and guiding the decommissioning activities. All nuclear specialists have advanced degrees in nuclear engineering or applied physics. The radiation survey specialists are individuals knowledgeable in DND radiation safety officer (RadSO) activities, radiation detection instrument usage, and nuclear, biological and chemical warfare (NBC) training. They perform the bulk of the site survey and data collection. All current radiation survey specialists have served in various branches of DND and have performed duties such as Base RadSOs, nuclear emergency response team (NERT) members, and NBC participants/instructors. In addition to the site survey personnel, management and administrative personnel round out the radiological decommissioning team.

Various types of radiation detection equipment are used during and after a radiological decommissioning site survey. The field survey instruments are in the form of alpha and beta probes (or an alpha/beta combined probe), gamma probes, and gamma survey (dose/dose rate) meters. A typical site survey makes use of enough equipment so that there is a redundancy for alpha, beta, and gamma detection. This allows for decommissioning activities to continue in case of instrument failure, and also allows for provision of instrument cross checking. The field survey meters are chosen for sensitivity, with a target for measurement below regulatory criteria. For instance, the alpha/beta probes and gamma survey meters are demonstrated to have measurement sensitivities below their respective regulatory limits.

In addition to the measurements made with field survey instruments, swipe testing is routinely performed to quantify any loose contamination. SAIC Canada has the ability to perform swipe counting in-house for most alpha and beta swipes not involving tritium. For low energy beta emitters, such as tritium, swipes are sent to a facility approved by DGNS for liquid scintillation counting (LSC).

For identification of isotopes in the field, a portable multi-channel analyzer (MCA) is used in conjunction with a Sodium Iodide (NaI) detector. This system allows for gamma spectroscopy of relatively high energy photons. Field identification of beta or alpha emitters is not generally possible, although liquid scintillation counting may provide the information. Generally, the isotopes anticipated in a given radiological decommissioning are known through the Phase I review of the facility, and therefore educated hypothesis as to the constitution of unknown alpha and beta emitters may be made. For environmental radiation surveys, samples may be acquired of soil, sediment or ecosystem components and analyzed using high purity germanium detector (HPGe).spectroscopy.

The historical usage of phosphorescent paint in DND for dials and gauges is well known. Often, the phosphorescent paint contains either ^{3}H or ^{226}Ra. Radio-phosphorescent paint may be identified by observing the distinctive glow obtained from using an ultra-violet (UV, or black) light.

Occasionally, special equipment is required for a given decommissioning task. Some examples are portable air monitors/samplers, radon cartridges, portable tritium detectors, and neutron detectors/Rem-meters. The need for special equipment will usually be identified in the Phase I stage.

III. RADIATION SAFETY

Radiological decommissioning is, by definition, concerned with potential radioactive material. Prior to undertaking any field activities the safety of all personnel involved is evaluated. Although most facilities are generally not considered to be radiological hazards, *a priori* estimation of total biological dose and determination of exposure pathways are made. Consideration of the need for special equipment, such as coveralls and respirators, is given based on the task being performed. For instance, Phase II decommissioning activities do not generally require any special equipment whereas Phase III (especially decontamination) often do.

SAIC Canada has a comprehensive radiation safety program, and within this context provides dosimetry to field personnel. All surveyors are required to wear TLD dosimeters while performing decommissioning activities, and at least two direct reading (gamma) dosimeters are worn by the team. The TLDs are returned every quarter year for reading, and the direct reading dosimeters are recorded every day during facility surveys. Typically, both TLD and direct reading electronic personal dosimeters indicate background levels for radiological decommissioning activities. No cumulative whole body dose greater than 1 mSv in a given year has ever been recorded.

When high gamma radiation fields are expected, a complete gamma dose rate survey is performed. In cases when airborne contamination is suspected (such as airborne tritium or radon gas), urine samples may be requested before, during and after a decommissioning task for urinalysis.

IV. FACILITY STATISTICS

Numerous land sites and ships (termed here, in general, facilities) have been decommissioned over the past five years. The buildings have ranged in size from storage sheds to full bases and supply depots. The ships have ranged in size from yard auxiliary vessels to large fleet support ships. Approximately 85 land facilities (land and air element) and 8 ships have undergone radiological decommissioning. The land facilities include sites remotely located, such as radar installations (9 sites), and very large area facilities, such as supply depots (7 sites). As well, approximately 18 non-closure facilities have been visited. Duties at non-closure facilities typically involve radiological decommissioning of a radioactive waste storage room or a local closure initiative (for instance, a single building) of a non-closing base.

V. RADIOACTIVE MATERIAL (RAM) SUMMARY

The Department of National Defence is authorized through the Canadian Nuclear Safety Commission to manage, hold and use numerous articles of radioactive material Reference to radioactive material in this context concerns point sources of radiation identified by equipment markings and/or survey instrument readings. Multiple sources packaged together are also considered point sources in this context, as in the case of gauge dials having numerous points of radio-luminescent paint. The three most common uses of radioactive material within DND, both historically and currently, are (a) radio-luminescent paint, (b) smoke detector components and (c) vacuum tube components. A fourth most common use of material bearing radioactive isotopes is camping-style lantern mantles. Approximately 2700 sources of radioactive material have been found during routine radiological decommissioning activities.

Figure 1 is a chart showing the approximate constituent of the materials. In the legend, “CAM” stands for Chemical Agent Monitor and the radioisotopes not identified with particular applications refer to electronic tubes, check sources, research material, etc.

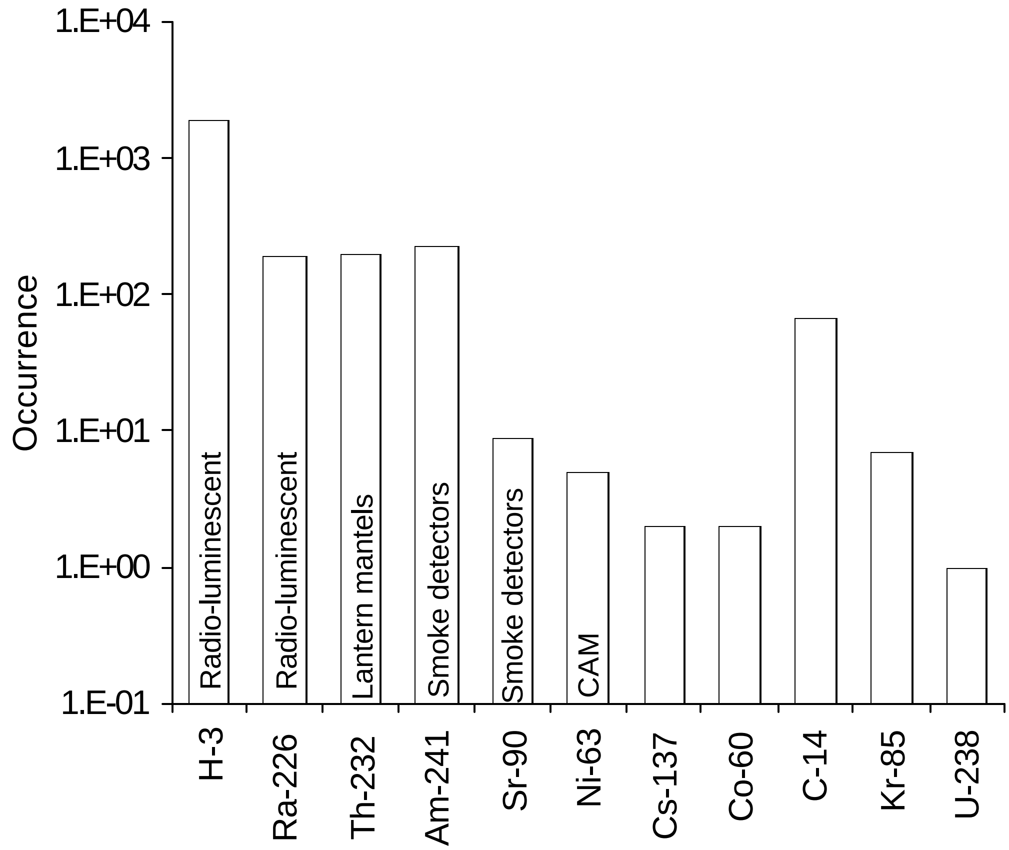

Figure 1 - Number of Radioactive Sources Found

VI. DECONTAMINATION SUMMARY

Historically, DND has held, used and repaired equipment bearing radioisotopes. Through equipment breakage, repair, refurbishing and research activities, areas of radioactive contamination may be found in various DND locations. Due to the fact that many facilities and holdings are to be turned over to Crown Assets and Canada Lands Corporation for commercial (typically civilian) development, it is necessary to decontaminate all affected areas to levels below regulatory criteria and ALARA.

Radioactive contamination is identified using field survey measurements (fixed/loose) and swipe analysis (loose) for radioisotopes other that tritium. To determine the presence of tritium contamination, liquid scintillation counting (LSC) is performed on swipes taken around candidate areas. Therefore, the determination of tritium contamination is *a posteriori* by nature.

During routine radiological decommissioning activities, over 600 different areas have been identified as having various levels of contamination (fixed and/or loose). The three primary radioisotopes found are tritium, ^{226}Ra, and ^{232}Th (see Figure 2). In general, the relatively large number of incidents of tritium contamination found are due to both the large quantity of tritium based radio-luminescent equipment used in DND and the fact that tritium (a hydrogen isotope) readily binds with other atoms and molecules making it highly transportable. The discovery of ^{226}Ra contamination is due primarily to historical usage of this isotope in radio-luminescent paint. The second largest contributor to contamination found is ^{232}Th. This isotope is found in some (Coleman[tm]) lantern mantels, and correspondingly the contamination is associated with the storage, use and repair of these lanterns.

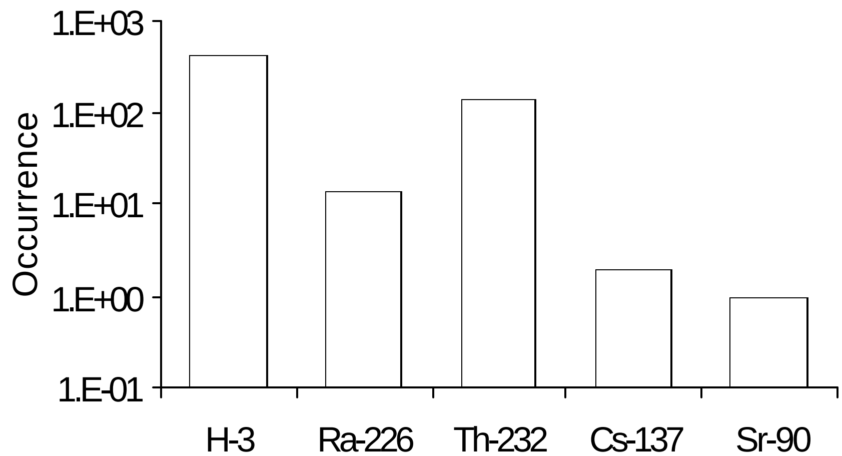

Figure 2 - Number of Instances of Contamination Found

It is interesting to note the correspondence between finding tritium sources (73% of all sources found) and finding tritium contamination (72% of all contamination found). It is also worthy to note that although lantern mantels make up only 8% of all sources found, lantern mantels are responsible for the 25% of all ^{232}Th contamination found. The suggestion is that although non-thorium bearing mantels are now currently in use by DND, the contamination caused by broken mantels was persistent.

When large-scale contamination is found in Phase II Radiological Decommissioning, often a Phase III is performed. Described previously, Phase III is used for decontamination and/or waste identification and disposal. Over 25 decontamination procedures have been performed in various DND facilities. Of all decontamination procedures performed, approximately 65% took place in well-defined areas where contamination could be expected. Radioactive waste storage rooms and laboratories account for 26%, work benches where repair/refurbishing of radioactive material-containing equipment occur account for a further 17%, and weapon storage vaults where storage and repair of radio-luminescent equipment takes place account for 22%. The remaining 35% of decontamination procedures take place in clothing stores or areas that are not typically associated with radioactive material.

In many Phase II radiological decommissioning surveys, minor decontamination is performed. This is the most cost-effective means for small areas of easily removable contamination. For the Phase III tasks outlined above, the contamination is any combination of being (a) wide-spread, (b) fixed, or (c) tritium (since the discovery of tritium contamination is usually *a posteriori*). The breakdown of isotopes considered for Phase III decontamination (Figure 3 shows that isotopes used in radio-luminescent paint are the most significant contributors. The relatively small proportion of ^{232}Th decontamination procedures performed compared to contamination found shows that either contamination was removed in a Phase II task or contaminated material was declared surplus and sent for radioactive material disposal.

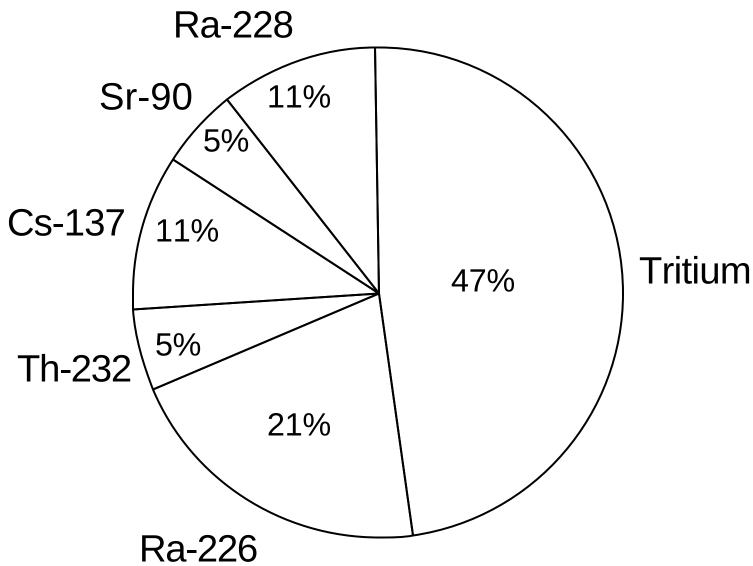

Figure 3 - Breakdown of Radioisotopes Decontaminated

By comparing the percentages of isotopes decontaminated with the isotopic contamination found, it may be concluded that tritium contamination tends to be in the form of numerous sources uniformly distributed. This is consistent with the transportability of tritium. In contrast, ^{226}Ra contamination tends to be highly localized, which is why the percentage of tritium (47%) versus ^{226}Ra (32%) decontamination procedures is similar. That is to say, a tritium decontamination procedure involves numerous instances of tritium, whereas a ^{226}Ra decontamination procedure typically involves a localized area of contamination. The high transportability of tritium coupled with the relatively high instances of contamination found lead SAIC Canada to develop a specialized protocol for tritium decontamination. The tritium protocol is an integral part of the Master Plan.

VII. WASTE DISPOSAL SUMMARY

For most radiological decommissioning activities involving facility closure, relatively little radioactive waste is discovered or generated. Instances where radioactive waste is likely to be found include research establishments of repair facilities. Also, waste may be generated from decontamination activities. SAIC Canada occasionally assists DND with packaging and disposing of radioactive waste in non-closing facilities. An example is when a radioactive material storage vault is being closing (or re-tasked) on a non-closing base; in this scenario the radioactive material in the vault would be identified and packed for disposal and the vault, if necessary, decontaminated.

SAIC Canada has assisted in over 10 radioactive waste disposals compromising numerous waste packages of over 6000 total items. The total activity of the disposed radioactive material is over 5 TBq (135 Ci). The breakdown of radioactive waste occurrences is depicted in Figure 4.

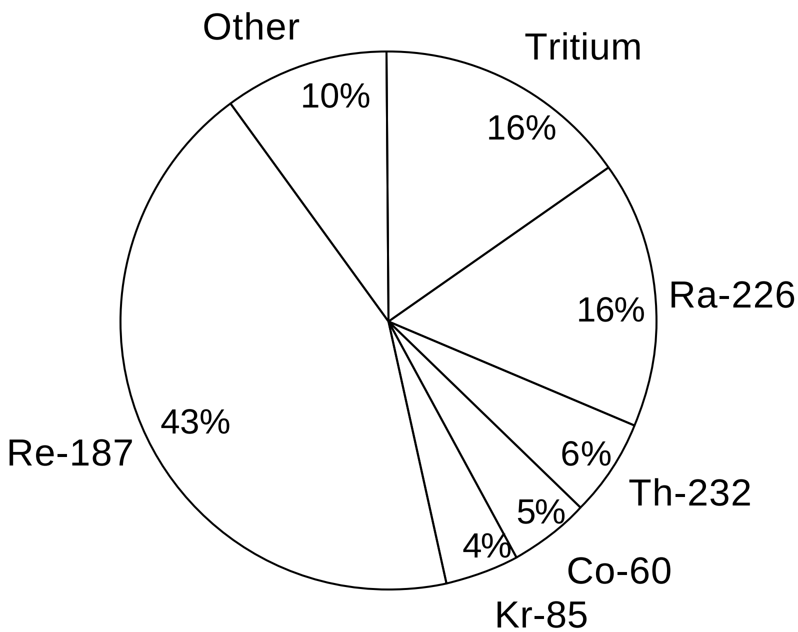

Figure 4 - Breakdown of Radioactive Waste Occurrences

Although ^{187}Re was disposed in the greatest quantity (electronic tubes), it is seen in Figure 5 to be amongst the lowest in total activity. Since tritium is needed in relatively high activity for radio-luminescence (compared to ^{226}Ra), it is a major contributor to the disposed activity. In addition, numerous high activity ^{137}Cs Radiac calibrators have been declared surplus and disposed in the last 10 years, thereby making the activity of disposed ^{137}Cs relatively high. The tritium and ^{137}Cs make up about 99% of the disposed activity

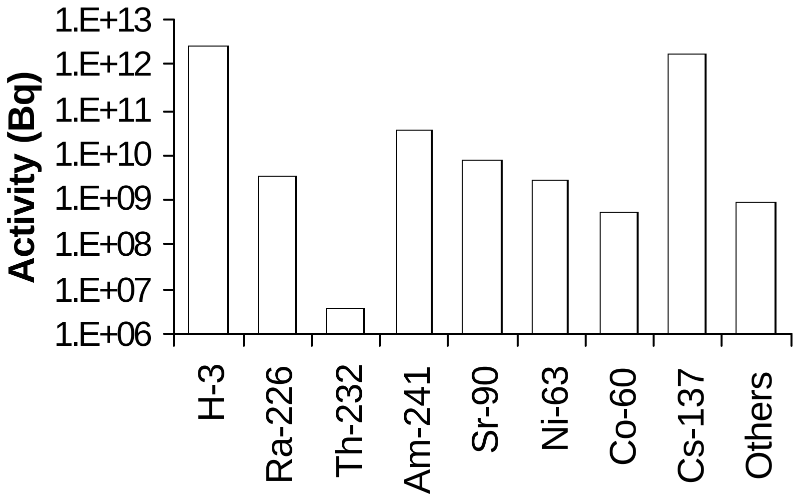

Figure 5 - Inventory of Radioactive Waste Disposed

VIII. SUMMARY

Radiological decommissioning is one step in the environmental qualification of surplus DND facilities. Over the past five years of radiological decommissioning activities, a great number of sites, buildings, rooms and compartments have been reviewed and surveyed. Radioactive waste materials were characterized, packaged and disposed to the Chalk River Waste Management Facility.

The procedures developed for the Master Plan were compared to the Multi-Agency Radiation Survey and Site investigation Manual (MARSSIM) document [Reference 1], when published. It was found that the MARSSIM document was very similar in form and protocol to the procedures developed independently by SAIC Canada. This allowed for an added degree of validation of the procedures.

ACKNOWLEDGMENTS

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REFERENCES

1. Master Plan for Radiological Decommissioning, SAIC Canada, Version 6, 2000.

2. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), US Nuclear Regulatory Commission, NUREG-1575, 1997.