APPROACH TO CANDU SPENT RESIN MANAGEMENT

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ABSTRACT

Among the various approaches to manage spent resins from nuclear power plants, the treatment of CANDU resins by drying, followed by hot super-compaction and packaging provides a waste volume reduction of up to five for long-term storage or final disposal. The additional benefit of carbon-14 removal from some CANDU spent resins during the drying process would allow reclassification of the processed resin to "Less-than or Equal-to US Class C" low-level radioactive waste. The recovered carbon-14 would be managed as low-volume, "Greater-than-Class C" waste consisting of metal carbonates stabilized in cement, or could be further volume-reduced in a carbide waste form, if necessary. This paper presents experimental performance data for carbon-14 removal and stabilized waste-forms based on actual and simulated spent-resin samples. The paper also describes the implications of management of the volume-reduced, low-carbon-14 resin waste compared to spent resins stored without drying and compaction.

Key words: spent resin treatment carbon-14 removal, resin drying, cemented carbon-14 waste-form evaluation.

INTRODUCTION

Organic-based ion-exchange resin wastes (also referred to as spent resins or resin wastes) are generated from different liquid purification systems employed in nuclear power plants. Resin wastes represent a special type of radioactive waste because organic resins degrade gradually with time in storage through physical, chemical, radiolytic and biological effects [1]. The presence of water (freestanding and pore water within the resin matrix) has been identified to be the primary issue for gas generation and contaminant releases from resin waste during storage [1], [2]. Resin degradation during storage could result in the release of contaminants into the environment and may cause adverse environmental effects.

CANDU resin wastes, in particular those arising from the moderator purification system, contain high concentrations of carbon-14 (^{14}C). The average ^{14}C inventory in the combined resin waste can be in the range of 0.93 to 3.7 TBq/m^3 [1]. The relatively high inventory of ^{14}C in the resin waste has resulted in classifying this waste as higher than Low-Level Radioactive Waste (LLRW) or "Greater-than-Class C" LLRW waste [3], requiring environmentally stringent, costly waste storage and disposal practices.

In the absence of suitable disposal facilities for ^{14}C-bearing resin wastes, such wastes are currently stored on an interim basis, awaiting long-term storage and final disposal. It is anticipated that the ^{14}C-bearing resin waste will have a relatively long period of storage before emplacement in a disposal facility. There is a need for safe, long-term storage of the waste through appropriate treatment and packaging.

In planning the overall management of CANDU resin wastes, one of the key issues is the presence of the relatively long half-life (5730 years) isotope, ^{14}C. Carbon-14 can cause dose to humans by contact, inhalation or through the food chain via photosynthesis; it has the potential for high mobility in the geosphere and biosphere as carbonate ion or carbon dioxide gas; and it has the ability to be incorporated easily into organisms through biological carbon cycles.

Our previous assessment of the management options for the CANDU ^{14}C-bearing resin waste has revealed that such a waste could be treated by relatively simple physical methods (e.g., dewatering and drying) and containerization to produce stable waste packages for long-term storage. Complete removal of all water by drying followed by stabilization and engineered storage of the treated resin waste is an essential route to maintain security of ^{14}C during long-term management of the waste.

AECL has developed a new ^{14}C removal step during resin drying and a method to capture the released ^{14}C gases in an alkaline scrubber. AECL has integrated a sequential process for water removal followed by ^{14}C removal. These aspects have been verified through laboratory-scale tests using ^{14}C-bearing simulated and actual resin-waste samples from Gentilly 2 nuclear generating station (NGS).

The opportunity to remove all water and the majority of ^{14}C from CANDU resin wastes would result in a stable waste product and a significant reduction of ^{14}C inventory in the waste. If a final resin waste having an average ^{14}C inventory of less than 0.3 TBq/m^3 of ^{14}C can be achieved, that waste would qualify for “Less-Than Class C” Low-Level Radioactive Waste instead of the current higher than LLRW classification.

This paper presents the results of drying tests with simulated and actual ^{14}C-bearing resin-waste samples to evaluate the behaviour of ^{14}C during resin drying. The paper examines the characteristics of resin samples after dewatering and drying, and also evaluates a soda lime-cement waste form for recovered ^{14}C from resin drying.

CANDU RESIN-WASTE CHARACTERISTICS

The quantity of resin-waste generation varies widely among different nuclear power plants. Similarly, the contaminant inventories (radionuclides and non-radioactive chemicals) vary among the plants, depending on normal and non-routine operations. The CANDU 6 plants generate spent resins in the range of 5 to 10 m^3/a/reactor.

Resin wastes generated from nuclear power plants contain a variety of contaminants including radionuclides, toxic metals and chemicals. The principal radionuclides in CANDU spent resins include ^{3}H, ^{14}C, ^{55}Fe, ^{60}Co, ^{90}Sr, ^{134}Cs, and ^{137}Cs. Generally, depending on the age of the resin waste, the total radioactivity can vary from a few tenths of a TBq/m^{3} to several TBq/m^{3}. Non-radioactive metal cations and anions are also commonly present in the resin wastes. The types and concentrations of these species vary from tens of parts-per-million (ppm) to hundreds of ppm, depending on the source of the resin waste. The commonly found cations come from metals including Al, B, Ca, Cr, Fe, Li, Gd, Mn, Ni, Cu, U, W and Zn. The anionic species are chloride, nitrate, sulphate, carbonate and bicarbonate. Other chemicals used in various plant operations may also pass through ion-exchange resin purification columns. Examples include hydrogen peroxide, hydrazine, morpholine (tetrahydro-1, 4 oxazine) and ammonium hydroxide. In addition, plant laboratories use small quantities of chemicals, which end up in some purification systems such as the radwaste treatment resins. Resin wastes from decontamination operations are expected to have varying amounts of complexing agents such as oxalic acid, citric acid, and EDTA [1].

Resin sampling studies have revealed varying levels of ^{14}C in the CANDU resin wastes. The ^{14}C inventories in the moderator purification resins are in the range of 0.03 – 11.0 TBq/m^{3}, and 26 – 259 GBq/m^{3} for the primary coolant resin wastes [1]. The wide range of ^{14}C inventories can be attributed to differences in power plant operations, and methods of resin sampling and analysis. The ^{14}C inventory in the combined moderator and primary coolant resin waste in CANDU plants operated by Ontario Power Generation (OPG) is estimated to be approximately 1 TBq/m^{3} [4]. This value is about four times greater than the maximum ^{14}C inventory of 0.3 TBq/m^{3} (8 Ci/m^{3}) that the U.S. Nuclear Regulatory Commission (US NRC) uses as a cut-off value for “Class C” LLRW classification [3].

RESIN-WASTE MANAGEMENT PRACTICES

Different resin-waste management practices are currently used in Canadian CANDU reactors. For example, the Pickering Nuclear Generating Stations operated by Ontario Power Generation (OPG) and Bruce Power (BP) store the spent resins from various purification systems in storage tanks without segregation. The resins are transferred periodically from the storage tanks to resin containers, and the containers are shipped to the OPG Western Waste Management Facility (WWMF) for storage. Darlington NGS stores the moderator resin, which contains relatively high levels of ^{14}C, separately from the other resins. Other CANDU reactors, Gentilly-2 (G-2) and Point Lepreau Generating Station (PLGS) store the fuel contacted resin and non-fuel contacted resin separately. However, this practice has been changed at G-2 in early 2002 because of unexpected localized resin “humps” in one of the resin storage tanks, which limits the addition of new resin-waste until such time this “hump” issue has been resolved. In Canada, resin wastes are stored on an interim-basis as resin-water slurries in spent resin storage tanks, or as dewatered resins in containers, typically 3 m^{3} in volume, and stored in below ground storage structures. The expectation is that the resin wastes will be disposed of eventually in suitable disposal facilities with or without processing and stabilization through an applicable regulatory process yet to be determined.

The Light Water Reactors (LWRs) in various countries appear to have employed different approaches for managing resin wastes [1]. Some of the approaches include: incineration;

stabilization in different binders such as bitumen, Portland cement, high-performance cement, or polymer cement; and physical treatment to achieve volume reduction and stability by a combination of steps such as dewatering, drying and compaction, and packaging for storage and/or disposal. Disposal containers include containers made of carbon steel, stainless steel, metal or polymeric High Integrity Containers (HIC).

In general, the resin-waste management practices can be classified as:

- Interim storage as resin-water slurry in spent resin storage tanks
- Storage/disposal of resin waste in containers after dewatering to remove the bulk of freestanding water
- Storage/disposal of resin waste in containers after physical treatment such as dewatering, drying, compaction, etc., and stabilization in various binders such as cement, bitumen and polymers
- Storage/disposal of the residue in containers after thermal treatment of resin waste (e.g., incineration or steam reforming)

Depending on the contaminant inventories in the resin waste, some of these approaches produce waste packages that are suitable for long-term storage or disposal. Other approaches are only suitable for interim storage. Additional treatment and packaging of the resin wastes will be required prior to preparing the wastes for long-term storage or disposal.

With the exception of physical processes such as dewatering, drying and compaction, most other considerations for LWRs, involving more severe resin-waste treatment steps (e.g., steam reforming, wet-oxidation, incineration) are considered unproven for CANDU resin wastes, primarily because of the complexities associated with ^{14}C. It should be noted that the concentration of ^{14}C in LWR operational resin-wastes is one to two orders of magnitude lower than that in CANDU resin wastes [1].

Studies (e.g., [1], [2]) suggest that the presence of water in the resin waste is the primary contributing source for gas generation, corrosion of the container, and biological activities. Thus, complete removal of water (freestanding and pore water) from the resin waste should minimize gas generation and corrosion of the container.

EXPERIMENTAL

Resin-Waste Test Samples

The simulated resin-waste sample was prepared with fresh Purolite NRW-37LC mixed-bed resin. The resin was loaded with carbonate and ^{14}C by mixing with 1 mol/L of Na_2CO_3 solution and an ampoule of ^{14}C source (each contained 50 microgram of $NaH^{14}CO_3$ in 1 mL of sterile water at pH 9.5, with a specific activity of 0.31 TBq/mole). The loaded resin was separated from the carbonate solution by vacuum filtration. The resin was then washed with de-ionized water until the wash-water pH became neutral and the conductivity of the wash water was relatively low (< 0.1 mS/cm). The Total Inorganic Carbon (TIC) and ^{14}C in the filtrate and wash-water samples were analyzed to determine the amounts of carbonate and ^{14}C being loaded on the resin on the basis of material balance calculations.

For actual resin-waste sample, a batch of spent-resin was obtained from Gentilly-2 NGS in 2001. The batch included eight resin-water slurry samples taken from different locations (e.g., middle and top) in the non-fuel contacted spent-resin storage tank (79140-TK1) at Gentilly-2 NGS. The samples were dewatered by vacuum filtration prior to the drying tests.

Apparatus

Figure 1 shows the schematic diagram of the apparatus used for the continuous resin-drying tests with simulated and actual resin-waste samples. The basic system consists of a 7.5-cm diameter stainless-steel drying vessel to house the resin, a constant temperature chamber (Model TB/2C from Standard Environmental System, Inc.) for temperature-control, a carrier gas (nitrogen) supply cylinder, a mass flow controller (Model 840L and 902C from Sierra Instruments, Inc.) to control the carrier gas flow rate, a cold trap in an ice bath to collect condensable species, an acid trap to capture tritium as HTO, two caustic bubblers to capture all CO_2, including $^{14}CO_2$, released from the resin sample during drying, a vacuum pump to evacuate the system, and associated valves and piping.

The resin-drying vessel was loaded with approximately 200 to 300 g of simulated or actual resin-waste sample and placed inside the temperature chamber for drying. The air inside the system was evacuated using the vacuum pump prior to the test. During resin drying at a predetermined constant temperature, dry nitrogen gas was passed through the drying system at a pre-set flow rate (e.g., 0.5 L/min) as a purge gas. The off-gas from the vessel was passed through the cold trap to capture the condensable materials, a bubbler containing 100 mL of 0.5 mol/L HCl to capture tritium as HTO, and then through two bubblers, each containing approximately 125 mL of 4 mol/L NaOH, in series to capture carbon dioxide. The chamber, resin-bed and vessel temperatures, and the system pressure were recorded during the test. After the pre-determined drying time, samples taken from the cold trap and bubblers were analyzed for ^{14}C by liquid scintillation counting. For each drying test with the actual resin sample, two untreated resin-waste sub-samples and three treated (i.e., dried) resin-waste sub-samples were taken for ^{14}C analysis by acid leaching and total combustion procedures. Analysis errors were estimated to be within 5%.

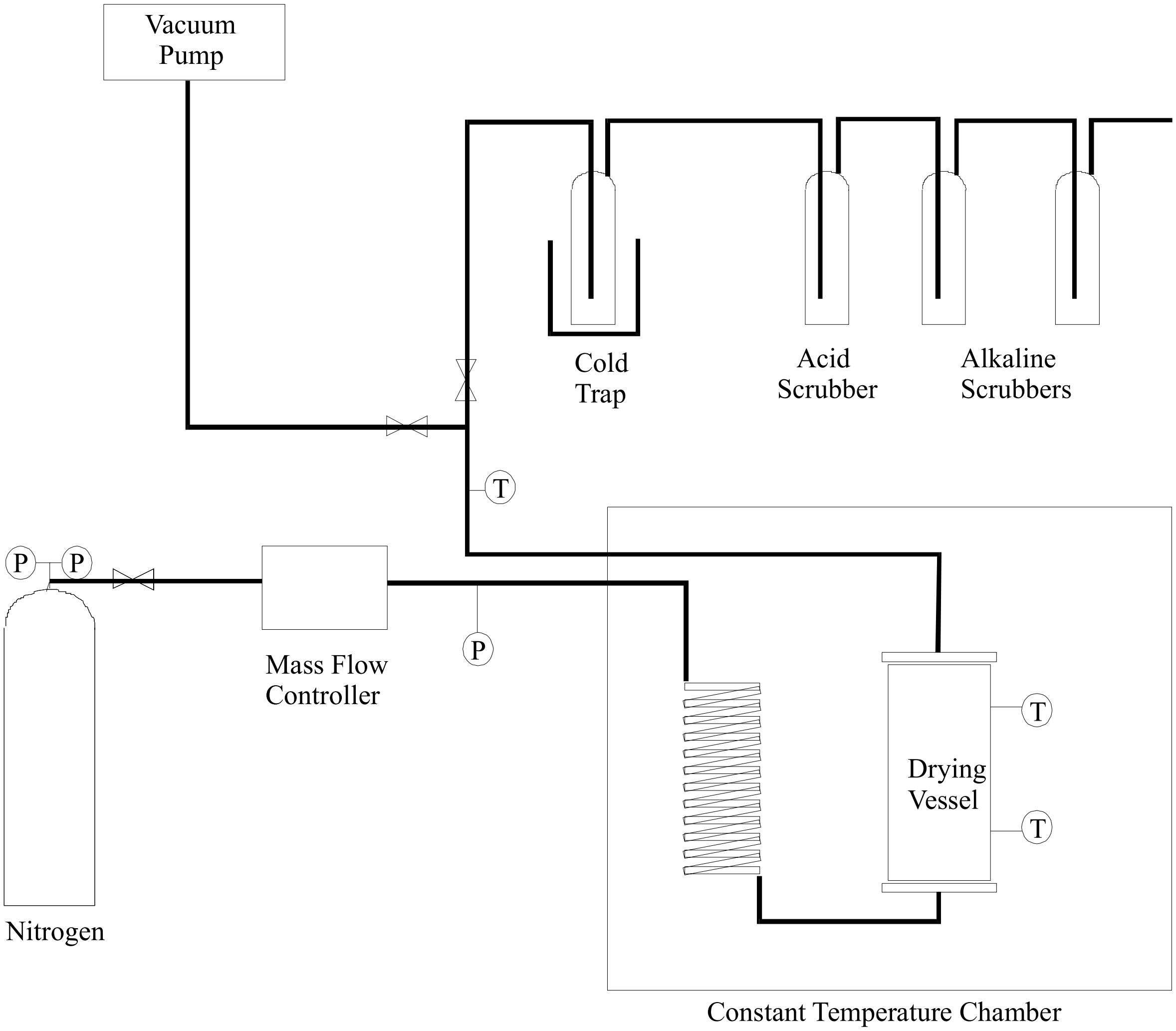

Figure 1: Schematic Diagram of Laboratory Resin Drying Apparatus
(P = pressure, T= temperature)

RESULTS AND DISCUSSION

In general, ^{14}C is held on the anion-exchange resin as bicarbonate and/or carbonate anions. It has been recognized that the anion-exchange resin is easily decomposed by heat [5], [6]. Thus, the fate of ^{14}C was studied during drying of the resin at various temperatures.

It should be noted that the actual temperatures and drying times are not included in the results (Figure 2, 3 and 4) because of a patent application being filed presently by AECL. The figures show only scaled temperature and time units to illustrate trends for the removal of water and ^{14}C.

Figure 2 shows that the resin-drying profile can be arbitrarily divided into three regions. The first region involves pore-water removal. In this region, approximately 95% of pore water was removed from the resin and the resin-bed temperatures were always lower than the normal water boiling point (i.e., 100°C), as well as the set drying temperature. The majority of the heat input was consumed by evaporating the pore water in the resin instead of heating the resin. As a result, a relatively small amount of ^{14}C was released in this region due to minimal thermal degradation of the anion-exchange resin including the quaternary ammonium functional groups.

The second region is a transition zone. In this region, the residual pore-water (i.e., the last 5% of the water) was removed and as a consequence the resin-bed temperature increased rapidly and reached the drying temperature. Decomposition of the anion-exchange resin was expected at this temperature as reflected in higher measured TIC and ^{14}C values in the off-gas (Figure 3).

The last region represents the steady drying-temperature region. The resin-bed temperature was steady and close to the drying temperature in this region. The ^{14}C release rate reached a maximum and then reduced gradually until the ^{14}C inventory had been exhausted (Figure 3). The results suggest that thermal decomposition of the resin functional groups (i.e., quaternary ammonium group) was the primary factor for high ^{14}C releases. High TIC and TOC levels (mainly from the degradation products such as methanol and trimethylamine) measured in the off-gas samples also support thermal decomposition of anion-exchange resin.

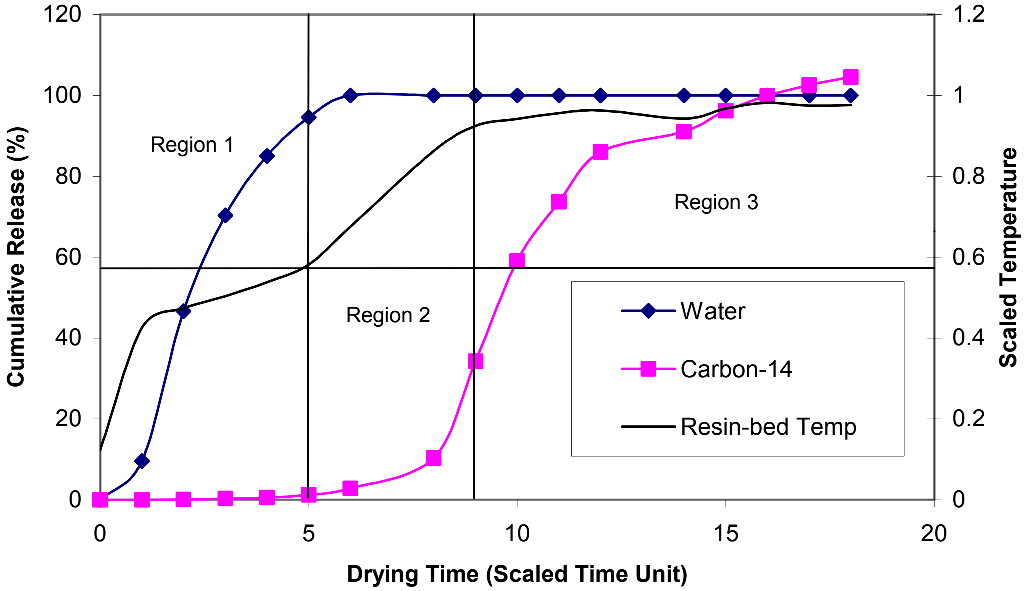

Figure 2: Water and Carbon-14 Releases During Resin Drying

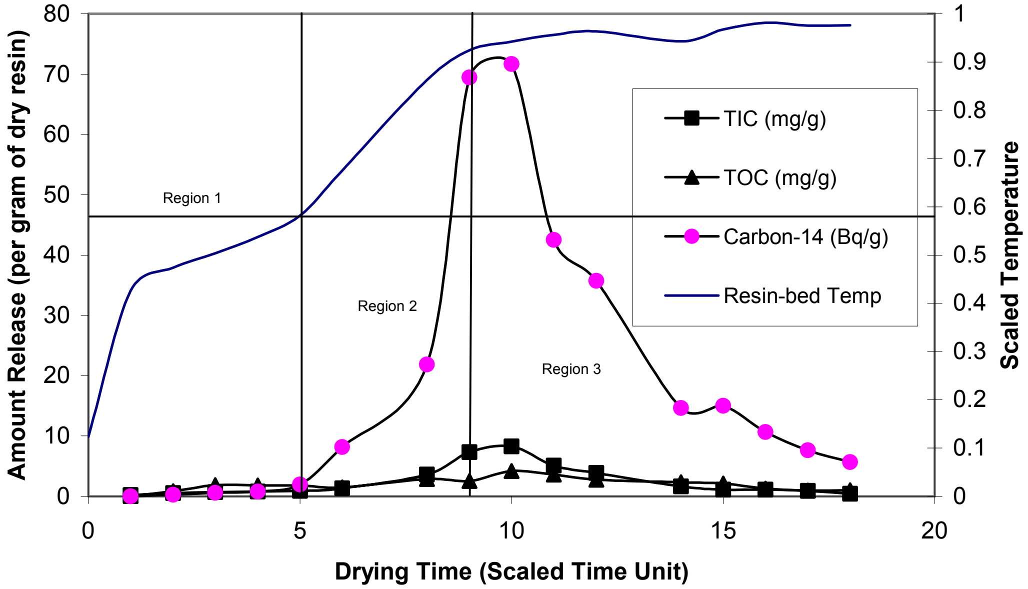

Figure 3: Release of TIC, TOC and Carbon-14 during Resin Drying

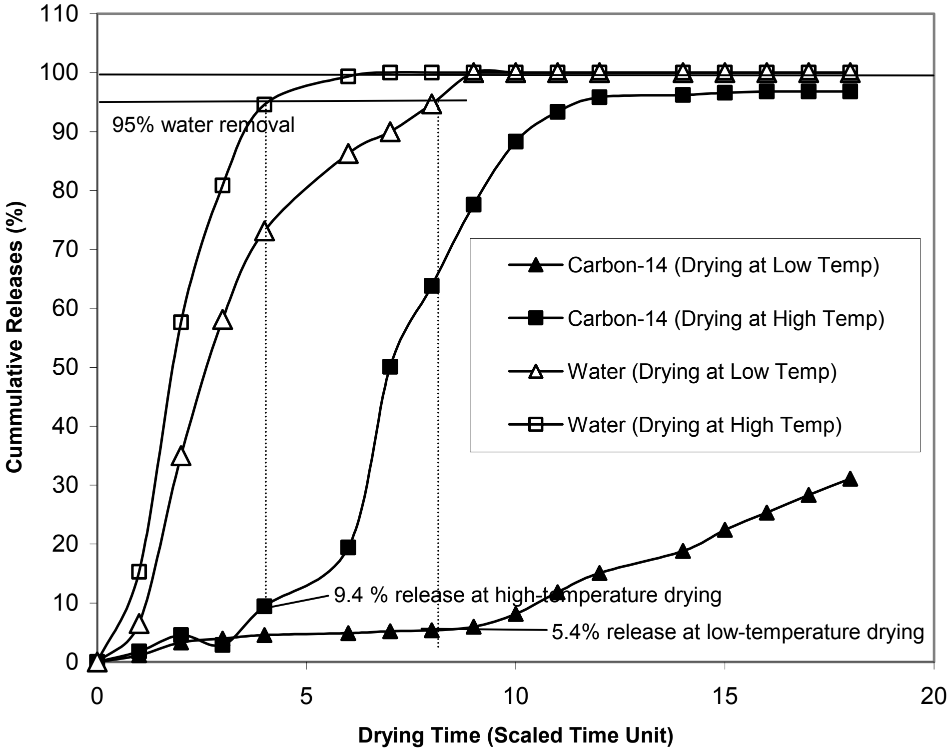

Figure 4: Comparison of Release Rates of Water and Carbon-14 from Resin Sample Dried at Different Temperatures

Figure 4 compares the ^{14}C release behaviour during resin drying at different temperatures. The data show that the ^{14}C release rate is much lower at lower-temperature drying, especially in the transient region. Thus, there is a benefit in carrying out resin-waste drying at higher temperatures for ^{14}C removal.

Table 1 shows the resin-drying results with the G-2 resin-waste samples. The final ^{14}C activities in the resin-waste samples after drying were all less than the target level of 0.3 TBq/m^3.

Table 1: Results of Resin Drying Tests with Actual Resin-Waste Samples Obtained from Gentilly-2 Spent-Resin Storage Tank

Sample Description	**Initial ^{14}C Activity[a] (Bq/m^3)**	**Final ^{14}C Activity after Drying at 170°C[b] (Bq/m^3)**
Sample taken from the top of tank	$1.16 \pm 0.19 \times 10^{12}$ (31.28 Ci/m^3)	$4.92 \pm 1.1 \times 10^{10}$ (1.33 Ci/m^3)
Sample taken from near the top of tank	$1.04 \pm 0.01 \times 10^{11}$ (2.81 Ci/m^3)	$2.51 \pm 0.53 \times 10^{10}$ (0.68 Ci/m^3)

Note: [a]: average of two measurements.
[b]: average of three measurements.

The drying tests also show that the majority of the ^{14}C could be removed from the resin after all the pore water was removed. This provides an opportunity to reduce the ^{14}C inventory to less than 0.3 TBq/m^3 (8 Ci/m^3) in the resin, and would allow the reclassification and management of the treated resin-waste as low-level radioactive waste. The expectation is that the volume of ^{14}C-containing secondary-waste would be significantly lower than the original resin waste-volume.

On the basis of experience from Siemens' LWRs in Phillipsburg, Germany [7], LWR resin processing experience at Hitachi (Japan) Ltd. [8] and our assessment, the combined volume reduction factor of the resin drying and hot-compaction process is approximately 5. It should be also noted that resin drying alone provides a volume reduction of approximately 2.

STABILITY OF CARBON-14 IN DRIED RESIN-WASTE

The major factors that contribute to resin-waste stability during storage include biological, chemical, radiological and thermal effects. The key pathways for contaminant migration out of storage as a result of resin degradation are gaseous releases and leaching caused by water ingress into the waste packages during storage.

To compare the stability of ^{14}C in different waste forms without binder addition for interim storage, the following assumptions were made in performing the experimental design and evaluation of test results:

- The treated resin waste is stored in containers that are not airtight, which allows air-exchange (i.e., the air inside the container can exchange with the surrounding air).
- The air-exchange rate is not known and the rate is dependent on the variations in atmospheric pressure, temperature, wind speed at the storage facility location;
- The amount of ^{14}C released in an air-exchange volume equivalent to 500 resin-bed volumes is used to compare the waste form performance.
- The surrounding air is saturated with water.

The test procedure for the waste-form evaluation was similar to that of the resin-drying test. Service air (containing approximately 350 ppm_v of CO_2) saturated with water (by passing through a water bubbler) was used as the purge gas. The purge gas with a flow rate of 0.5 L/min was passed through the resin bed (approximately 155 mL), which provided an air exchange rate equivalent to about 3.2 resin-bed volumes per minute. The off-gas from the vessel was passed through two bubblers, each containing 125 mL of 4 mol/L NaOH solution, to capture ^{14}C as $^{14}CO_2$. Two waste forms, without binder-induced stabilization, were studied. They were: dewatered resin waste (bench-mark case involving only removal of freestanding water by vacuum filtration) and dried resin waste after removing 95% of the pore water by heating. The test results were normalized to an air-exchange volume equivalent of 500 resin-bed volumes (i.e., 160 minutes of purging). The results obtained for the amounts of ^{14}C released are compared in Table 2.

Table 2: Comparison of Behaviour of Dewatered and Dried Resin Samples

Waste From	**Carrier Gas**	**^{14}C Released in an Air-Exchange Volume Equivalent to 500 Resin-Bed Volumes (Bq/g of dry resin)**	**Percent of ^{14}C inventory Released (%)**
Dewatered resin (Bench-Mark)	Water saturated air	1.8 (Initial ^{14}C loading: 159.0 Bq/g of dry resin)	1.1
Dried resin (95% of pore water was removed)	Water saturated air	0.18 (Initial ^{14}C loading: 167.9 Bq/g of dry resin)	0.1

The results in Table 2 show that the amount of ^{14}C released from the dried resin waste was approximately one-order-of-magnitude lower than that from the dewatered resin (bench-mark case) using water-saturated air as the purge gas. Since the dewatered resin contains approximately 50 wt.% of pore water, it appears that the pore water acts as a medium for ^{14}C transfer and release. The anticipated mechanisms for ^{14}C transfer and release from the resin is:

Step 1: The inactive $^{12}CO_2$ (g) in air dissolves in the pore water

$$CO_2(g) \rightarrow CO_2(aq)$$

Step 2: The dissolved $CO_2(aq)$ exchanges with ^{14}C (held as inorganic carbonates) in the resin waste

$$^{12}CO_2(aq) + {}^{14}C \text{ (as carbonates)} \rightarrow {}^{14}CO_2(aq) + {}^{12}C \text{ (as carbonates)}$$

Step 3: The $^{14}CO_2(aq)$ in the pore water transfers to the purge gas in a manner governed by the gas-liquid equilibrium conditions.

$$^{14}CO_2(aq) \rightarrow {}^{14}CO_2(g)$$

REMOVAL OF CARBON-14 FROM OFF-GAS

Previous ^{14}C scrubber studies indicated commercially available alkaline absorbents including soda lime could remove $^{14}CO_2$ effectively. The expectation is that any potential environmental ^{14}C releases from the resin during drying can be easily captured by a bed of soda lime placed either within the drying vessel or outside the drying vessel.

A series of tests was performed to investigate the effectiveness of a thin layer of soda lime over the resin-bed. The experimental procedure for these tests was similar to that of the normal resin-drying test, but included a layer of soda lime (1 or 2 cm thick) placed on the top of the mixed-bed resin. The soda lime was obtained from Alphachem Ltd., Mississauga, Ontario. The particle sizes ranged from 0.06-2.36 mm (8-28 mesh). The composition of soda lime was about 80% by weight of $Ca(OH)_2$, 2% NaOH, 3% KOH and 15% water. The test results are summarized in Table 3.

Table 3: Summary of Drying Test Results with a Layer of Soda Lime Over the Resin Bed

Test	A-1	A-2	B-1	B-2
Soda Lime Thickness (cm)	1.0	1.0	2.0	2.0
Weight of Soda Lime (g)	45.8	45.2	90.5	90.3
Carbon-14 loaded on resin (Bq/g of dry resin)	268.6	268.6	170.5	170.53
Weight of Resin (g)	198.4	202.3	202.2	202.0
Total ^{14}C released (Bq/g of dry resin)	0.48	0.18	0.06	0.29
Percent ^{14}C released (%)	0.29	0.11	0.03	0.17

In general, the soda lime captured the majority of ^{14}C released from the resin and very low concentrations of ^{14}C were detected in the off gas. The results show that 1-cm thick soda lime layer was sufficient for this test configuration; doubling the thickness of the soda-lime bed did not have any significant benefits.

The removal of $^{14}CO_2$ by soda lime is achieved mainly by the following chemical reaction:

$$^{14}CO_2 + Ca(OH)_2 \rightarrow Ca^{14}CO_3 + H_2O$$

The spent absorbent (i.e., soda lime) contains mainly calcium hydroxide and oxide (residue of the reactant) and calcium carbonate (product). It is expected that the alkalinity and high calcium content of cement should make the waste product stable for long-term storage.

Relatively little work has been conducted to assess the optimal waste loading of the cement matrix. Because ^{14}C is a weak beta emitter, the effects of long-term radiation, gas evolution from radiolysis, and heat generation on the stability of the cement matrix are expected to be minimal. Bush et al. [9] suggest a cement loading of 30 wt.% for $CaCO_3$.

The cemented waste forms of ^{14}C-bearing soda lime were evaluated following the US NRC guidelines [10] and the procedure (Test ANSI 16.1-1986) recommended by the American Nuclear Society [11]. The ^{14}C bearing soda lime was mixed with Portland cement and water with a mass ratio of 1:2:1. The mixtures were cast into cylindrical moulds of 0.03-m in diameter by 0.07-m long. The waste-cement mixtures were cured at room temperature in a sealed water-saturated container for at least 28 days. The solidified wastes were then removed from the moulds, weighed, and prepared for the leach test. The leachability indices for the leach tests are summarized in Table 4. The measured leachability indices were generally high (about 11) and greater than the target US NRC guideline value of 6.0 [10] within the 99% confidence interval. The test results showed that ^{14}C is stable in the cemented waste form because of the high pH environment in the cement matrix.

Table 4: Summary of Waste-Form Leaching Results for Cemented ^{14}C-Bearing Soda Lime

Sample No	Description	Leachability Index	Uncertainty (2-Sigma Statistics)
DSA-1	Resin Drying Test A	10.1	±0.2
DSA-2		11.3	±2.1
DSA-3		11.5	±2.0
DSB-1	Resin Drying Test B	10.4	±1.7
DSB-2		11.1	±2.7
DSB-3		10.6	±0.5

PROPOSED RESIN-WASTE MANAGEMENT APPROACH

On the basis of our test work and assessment, the following steps provide an effective management of CANDU resin-wastes containing ^{14}C:

1. Removal of freestanding water from the resin (dewatering);
2. Removal of pore water from the resin (drying);
3. Removal of long-lived carbon-14 from the resin waste to re-classify the waste as LLRW (drying at higher temperatures);

4. Provision of additional volume reduction of the treated resin-waste (super-compaction) by a factor of approximately 5;
5. Packaging of the compacted (with an optional waste stabilization, if needed) resin-waste in appropriate container configuration for storage; and
6. Stabilization of the recovered ^{14}C secondary waste in an intrinsically stable, highly volume-reduced carbonate-cement matrix for storage (which could be further converted to a significantly volume-reduced ceramic waste form such as Si-Al carbide at a future date).

Currently, AECL has pooled various expertise and inputs to develop a process for the CANDU ^{14}C resin-waste treatment by exploiting the principles of an already proven drying process in use at some LWRs in Germany and Japan.

The proposed resin-waste treatment system referred to as AECL's Candu CArbon-14 Resin Management System (CCARMS) has several attractive features for CANDU resin-waste management. They include:

- Opens up several other cost-effective and environmentally responsible options for storage and/or disposal of the volume reduced, treated resin waste as LLRW.
- Eliminates nuisance issues associated with possible, uncontrolled emissions related to ^{14}C during long-term storage and unnecessary monitoring and repackaging of the waste.
- Provides security of ^{14}C in the recovered ^{14}C secondary waste during long-term storage.
- Offers potential cost savings through reducing costs associated with monitoring, handling, storage and final disposal.

CONCLUSIONS

The following conclusions have been drawn from this study:

- The resin-drying tests showed that when the resin-bed temperature was maintained for prolonged periods at a desired temperature, the majority of the ^{14}C present in the resin could be removed. This provides the opportunity to reduce the ^{14}C inventory in the waste to less than the 0.3 TBq/m^3 (8 Ci/m^3) target for low-level radioactive waste classification. The potential to remove and capture ^{14}C from the resin waste into a small-volume waste for long-term storage would allow the treated resin waste to be reclassified and managed as low-level radioactive waste.
- Carbon-14 inventory reduction from the resin waste was found to be attractive because only a small volume of waste would have to be managed as higher than low-level radioactive waste, and the majority of ^{14}C will be converted to a more stable inorganic waste form (e.g., spent alkaline sorbent stabilized in proper inorganic binder) instead of managing the less stable organic-based resin as higher than low-level radioactive waste.
- The cemented waste form for the soda lime containing recovered ^{14}C provided desirable high leachability index, suggesting further consideration of its suitability for long-term storage and disposal.

- Dried resin-waste is more stable than the dewatered resin with only the freestanding water removed. The amount of ^{14}C released from the dried resin waste is about ten-fold lower than that from resin dewatered via air-exchange.
- Resin-waste treatment based on drying and compaction with appropriate packaging is the most promising option for the management of CANDU resin wastes.

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