Characterization of In-Drum Drying Products

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ABSTRACT

A few years ago Krsko NPP decided to introduce In-Drum Drying technology for treatment and conditioning of evaporator concentrates and spent ion resins. The main reason to employ this technology was the need for waste volume reduction and experience with vermiculite-cement solidification that proved inadequate for Krsko NPP. Use of In-Drum Drying technology was encouraged by good experience in the field at some German and Spanish NPP's.

In the paper, solidification techniques in vermiculite-cement matrix and In-Drum Drying System are described briefly. The resulting waste forms (so called solidification and dryer products) and containers that are used for interim storage of these wastes are described as well. A comparison of the drying versus solidification technology is performed and advantages as well as disadvantages are underlined. Experience gained during seven years of system operation has shown that drying technology resulted in volume reduction by factor of 20 for evaporator concentrates, and by factor of 5 for spent ion resin.

Special consideration is paid to the characterization of dryer products. For evaporator concentrates the resulting waste form is a solid salt block with up to 5% bound water. It is packaged in stainless steel drums (net volume of 200 l) with bolted lids and lifting rings. The fluidized spent ion resins (primary and blow-down) are sluiced into the spent resin drying tank. The resin is dewatered and dried by electrical jacket heaters. The resulting waste (i.e. fine granulates) is directly discharged into a shielded stainless steel drum with bolted lid and lifting rings.

Characterization of both waste forms has been performed in accordance with recommendations given in Characterization of Radioactive Waste Forms and Packages issued by International Atomic Energy Agency, 1997. This means that radiological, chemical, physical, mechanical, biological and thermal properties of the waste form has been taken into consideration. In the paper, the main results of the analysis are presented. The results show that satisfying the waste

acceptance criteria for waste disposal will probably require additional conditioning due to the fine granulates.

It is concluded that installation and usage of an In-Drum Drying System resulted in a significant reduction of waste volume. This has solved the interim storage capacity problem at the site temporarily. On the other hand, the problem of satisfying waste acceptance criteria for disposal is raised. This problem is taken into consideration in the paper, and few possible options are discussed.

INTRODUCTION

Conditioning means those technologies and operations that are used to produce waste packages suitable for handling, transportation, storage and/or disposal. Conditioning may include the conversion of the waste to a solid waste form (solidification), enclosure of the waste in drums (containers), and, if necessary, providing an overpack [1].

The liquid radioactive wastes, (i.e. evaporator concentrates and spent ion resin) were conditioned at Krsko NPP by solidification in vermiculite-cement matrix from the start of commercial operation (1982). In 1998 a new technology, In-Drum Drying System, was put into operation. The decision to introduce the new technology was driven by waste volume reduction requirements, the insufficient capacity of the on-site storage facility and encouraged by good experience in the field at several German and Spanish NPP’s.

In 1995 a supercompaction campaign was conducted for packages containing evaporator concentrates solidified in vermiculite-cement matrix. That project was motivated by the same storage capacity concerns mentioned above.

According to the Krsko NPP predictions given in [2], and taking into consideration all waste volume reduction improvements that have already been applied as well as the improvements that will be implemented in forthcoming years, the available capacity of the storage facility at the site will be 95% full of waste packages in 2010. On the other hand, the radioactive waste disposal facility is still in the planning phase. The expectation is that it will start to operate in 2013 [3]. Responsibility for constructing the disposal facility lies with the Radioactive Waste Management Agency in the Republic of Slovenia (ARAO).

Providing storage capacity for the 3 year time gap is the main challenge for plant management. From a pragmatic point of view obtaining storage capacity has a greater priority than producing packages suitable for disposal. This seems clear when specific acceptance criteria for the disposal facility are not developed.

But, the issue is a little bit different. Namely, if acceptance criteria for disposal are not developed, the operator is supposed to anticipate them and implement conditioning technologies that are able to satisfy anticipated criteria. This is a common recommendation in a number of related documents and guides. Even if Krsko NPP bridges the gap successfully, and if disposal facility starts to operate when expected, the Krsko NPP will still not be in position to transfer waste packages to the disposal facility because they will not satisfy the acceptance criteria for disposal. It seems pretty clear that now is the right time to consider extension of the on-site storage capacity or construction of a treatment and conditioning facility to reduce waste generation. The possibility of waste conditioning abroad could be an option as well. In addition to that, the use of high integrity containers that will guarantee waste isolation for 300 years should be analyzed. Finally, an extensive cost-benefit analysis would provide the basis for decision-making. Beside financial aspects, significantly different level of public acceptance of the options described above might have an impact.

WASTE CHARACTERIZATION

In 2005 Krsko NPP started a Waste Characterization Project. From the formal point of view, the project was initiated in order to review and achieve a higher level of compliance with the IAEA safety standards documents [4]. Namely, the member states are encouraged and supposed to follow IAEA safety standards requirements.

Waste properties and parameters must be evaluated for further treatment and conditioning to transfer waste to ARAO for disposal. Characterization process is being conducted in accordance with recommendations given in document [5]. It means that radiological, chemical, physical, mechanical, biological and thermal properties of the raw wastes, waste forms and waste packages have been taken into consideration. The scheme of the applied waste characterization process is given in Fig. 1. All together some 35 parameters associated with waste properties have been systematically evaluated. Data obtained during waste characterization has the potential to be inputs for conducting required safety analyses and determining acceptance criteria for the disposal facility [6].

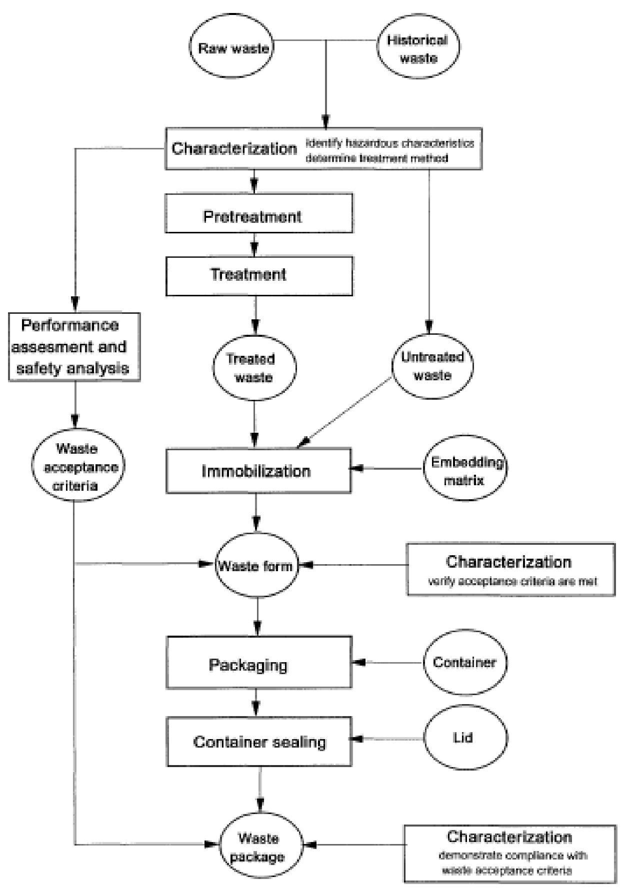

Fig. 1. Waste characterization process diagram [7]

The project activities are still under way. Expectation is the project will finish in the first half of 2006. Nevertheless, some of the main results relevant for the issue are discussed below.

SOLIDIFICATION TECHNOLOGIES

Solidification in Vermiculite-cement Matrix

Solidification in vermiculite-cement matrix was used for conditioning of evaporator concentrates and spent ion resins in standard 0,2 m^3 carbon steel drums. Drum thickness is 1 mm. Interior of drums is smeared by corrosion protective paint. Vermiculite acts as the absorbent and the cement as the binder.

Evaporator Concentrates Solidification

Solidification of 12% boric acid evaporator concentrates (Fig. 2) adversely affects the cement settings, and the vermiculite-cement monolith has low compressive strength. Since the presence of some freestanding water in the product cannot be excluded, the product is preliminary assessed as corrosively aggressive. Voids are also a potential problem for this waste form.

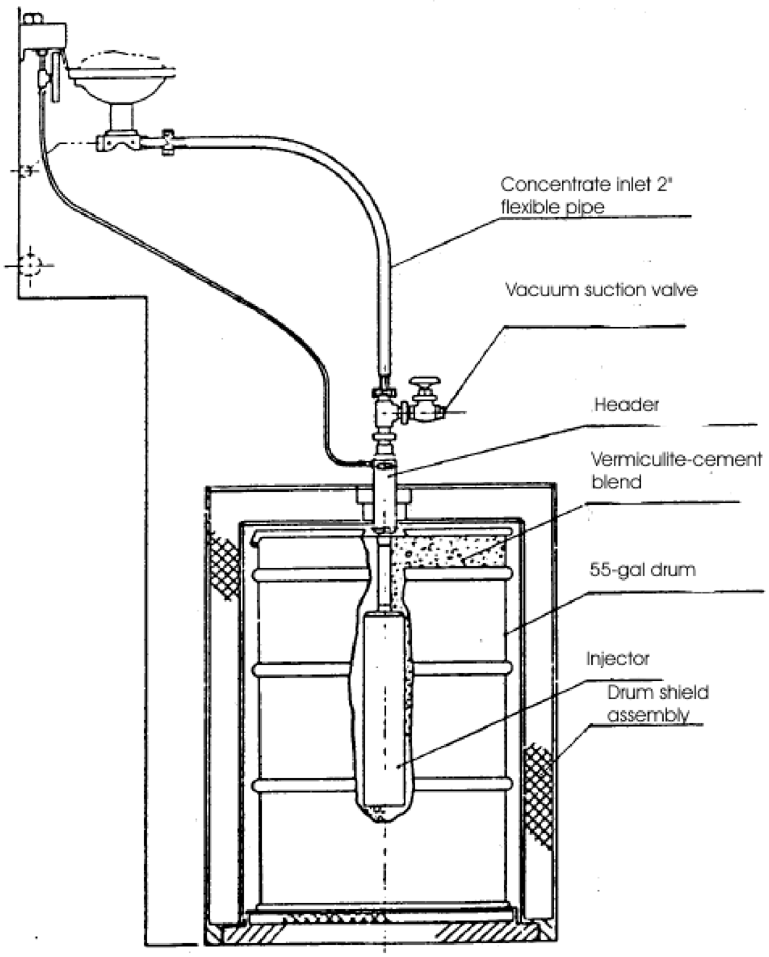

Fig. 2. Prepared drum installed and ready to receive evaporator concentrates [8]

Useful volume of the drum is 0,11 m^3 and matrix occupies the rest. The weight of a drum with injector and vermiculite-cement matrix is 180 kg while the weight of waste packages produced ranged from 300 to 540 kg.

Over the 16 year period of system operation 7,423 packages of evaporator concentrates were produced or approximately 464 packages per year. The gross volume of the packages produced is about 1,500 m^3 containing some 820 m^3 of concentrates.

The solidification waste forms have a wide span of radiological properties. The range of specific β/γ activity is $8.92x10^0$ to $9.11x\cdot10^6$ Bq/g and specific α activity is ranged between $1.88x10^{-6}$ and $7.14x10^1$ Bq/g. Dose rates on the surface of the packages range from 50 to 30,000 μSv/h.

Waste characterization has shown the packages are suitable for storage but probably will not satisfy acceptance criteria for disposal. Furthermore, technology has proven to consume the storage capacity at Krsko NPP.

Spent ion resin solidification

The drums used for solidification of spent ion resin are shielded with 45 mm of concrete. The useful volume of a drum is 80 l. The space between metal cage and shield is filled with cement and vermiculite mixture. Fluidized resin pressurized by nitrogen is loaded into drums under vacuum. The wet resin is not solidified in the best possible way within the metal cage because of the variable water-resin ratio meaning that certain void fraction is present. The presence of freestanding water cannot be excluded. The weight of an empty drum is 190 kg while the weights of waste packages produced range from 400 to 600 kg.

Up to 1998 some 1,005 packages of this type were produced (approximately 63 drums per year). The gross volume of the packages produced is some 200 m^3 containing about 80 m^3 of spent resins.

The waste forms have a wide span of radiological properties as well. The range of specific β/γ activity is 6.49×10^0 to 1.43×10^6 Bq/g and specific α activity range is between 5.66×10^{-4} and 6.40×10^2 Bq/g. Dose rate on the surface of the packages range between 1 and 250,000 μSv/h.

Waste characterization has shown the packages are suitable for storage. In order to assess their suitability for disposal it has been recommended further laboratory investigations of the waste properties that include radiological, chemical and structural stability of the packages produced. This technology has proven to be inefficient in waste packaging volume.

In-Drum Drying System

The In-Drum Drying System (IDDS) consists of several process units: two sets of in-drum drying stations, heating jackets, spent resin drying tank, common system for condensate and steam cleaning as well as drum handling and manipulation system with remote control drum closure[9]. It is a fully automated and remotely controlled system (Fig. 3).

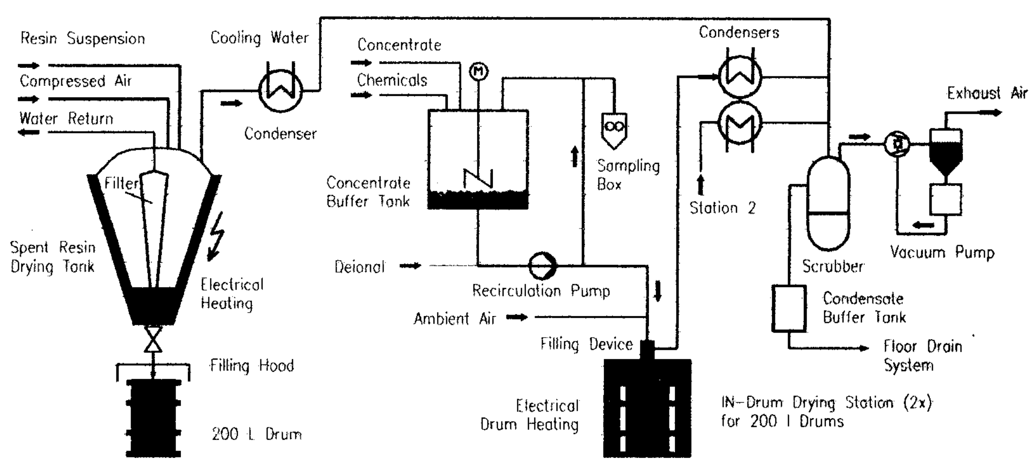

Fig. 3. In-drum drying system scheme

Evaporator Concentrates Drying

The evaporator concentrates drying product is a solid salt block with up to 5% residual moisture content and no freestanding water. However, the product is assessed as hygroscopic and soluble. The product is conditioned in stainless steel 200-liter drums with bolts and lifting ring in absence of any stabilization material. Drum thickness is 1,5 mm. The weight of an empty drum is 65 kg while the weights of waste packages produced range from 250 to 350 kg.

Over 7 years of system operation some 102 packages of this type have been produced (approximately 15 packages per year). The gross volume of the packages produced is some 21 m^3 containing a slightly smaller volume of waste. Compared with solidification in vermiculite-cement the volume reduction factor of 30 has been achieved, taking into the consideration NPP operational improvements, which reduced the annual amount of waste boric acid to be processed the net effect of deployment of the new technology is reduction factor of 20 (comparing volume of waste boric acid per drum of the product).

The waste forms have a bit more uniform radiological properties compared with the vermiculite-cement waste form. The range of specific β/γ activity is $5.58x10^2$ to $3.56x10^4$ Bq/g and the specific α activity ranged is between $4.09x10^{-2}$ and $4.16x10^0$ Bq/g. However, the surface dose rate on the packages range between 450 and 250,000 μSv/h and is still wide. Waste characterization has shown the packages are suitable for storage but because of the absence of stabilization material they will not satisfy acceptance criteria for disposal.

Drying of Spent Ion Resins

IDDS has been used for solidification of concentrated fluids in some German and Spanish NPP’s. The Krsko NPP management decided to extend the technology for drying spent ion resin as well. The drying is performed in a batch-wise mode with annual capacity of approximately 23 batches, or some 6 m^3 of wet resin. The fluidized spent ion resins (primary and blow-down) from spent resins storage tanks are loaded into IDDS spent resin drying tank, dewatered and dried by electrical jacket heaters. The primary dry resin is directly discharged into a stainless steal 200-liter shielded (30 mm thick) drum while 200-liter drums without internal shielding are used for blow-down resins. In both cases it has been performed in the absence of any stabilization material.

The waste volume per drum is 150 and 200 l respectively. Resulting product is a free flowing bead resin with no freestanding water and with moisture content of less than 30%. The weight of an empty shielded drum is 450 kg while the weight of waste packages produced in this case range from 510 up to 630 kg.

Up to now some 211 packages of this type (99 containing primary and 112 containing blow-down resins) have been produced (approximately 15 per year). The gross volume of the packages produced is some 42 m^3 containing some 37 m^3 of waste. Compared with vermiculite-cement solidification, a reduction factor of about 5 has been achieved.

The resin waste forms have wide span of radiological properties. The range of specific β/γ activity is $2.38x10^1$ to $6.64x10^6$ Bq/g and the specific α activity range is between $1.43x10^{-3}$ and $2.72x10^{-3}$ Bq/g. Surface dose rate on the packages range from 2 – 250,000 μSv/h. This is mostly because the difference between primary and blow-down resins has not been taken into consideration in the paper. Waste characterization has shown the packages are suitable for storage but because of the absence of stabilization material they will not satisfy acceptance criteria for disposal.

SUPERCOMPACTION

In order to reduce existing volume occupied by the packages containing evaporator concentrates supercompaction campaign was conducted in 1995. For solidified waste drums, tests have shown that a volume reduction factor of 2 can be achieved by eliminating the voids in the solidified monolith. Some 7,135 drums of this type were supercompacted and resulted in the same number of pucks.

The pucks were placed into 1,417 specially designed tube type carbon steel containers (5 pucks per container in average) in absence of any stabilization material. In some packages a drying agent (desiccants) have been added due to possible moisture. Thus the void fraction within the packages produced is above 10% of the container volume. The packages have wide span of radiological properties as well. Waste characterization has shown the packages are suitable for storage but absence of stabilization will not satisfy acceptance criteria for disposal.

The dimensions of the tube type containers (inner diameter 660 mm, overall height 2,700 mm, tube thickness 2 mm, volume 860 l, weight 117 kg) have been optimised to provide maximum volumetric utilization of the storage facility. An epoxy resin liner is sprayed into the interior of the container to provide protection from internal corrosion [10].

The supercompaction campaign recovered needed storage capacity of some 600 m^3. Half of this was from waste reduction (overall reduction factor is 1.17) and half from tube type container placement in storage facility. Namely, the tube type containers are positioned vertically in the storage facility.. When the ground level is filled, shelves are installed and tube type containers are stored on the upper level in the same fashion.

CONCLUSION

Three different technologies have been used at Krsko NPP for conditioning of evaporator concentrates and spent ion resins. These are: solidification in vermiculite-cement matrix (for both waste types), In-Drum Drying (for both waste types as well) and supercompaction (for waste packages containing evaporator concentrates solidified in vermiculite-cement matrix). The main results of the analysis given in previous pages are summarized in the following table (Table I).

Table I. Comparison of the Results Reached

Waste Type	Solidification in vermiculite-cement matrix	In-Drum Drying	Supercompaction
Evaporator concentrates	• Volume consumption technology • Block is insufficiently stiff • Presence of freestanding water • Presence of voids • Corrosiveness of waste form • Wide span of radiological properties • Suitable for storage • Anticipated acceptance criteria for disposal are not satisfied	• Volume saving technology • Waste form is hygroscopic and soluble • Absence of stabilization material • High surface dose rate • Almost uniform radiological properties • Suitable for storage • Anticipated acceptance criteria for disposal are not satisfied	• Volume saving technology • Absence of stabilization material • Presence of voids • Wide span of radiological properties • Suitable for storage • Anticipated acceptance criteria for disposal are not satisfied
Spent ion resins	• Not effective technology • Presence of freestanding water • Presence of voids • Wide span of radiological properties • Suitable for storage • Suitability for disposal should be investigated	• Volume saving technology • Waste form is hygroscopic and soluble • Absence of stabilization material • High surface dose rate • Wide span of radiological properties • Suitable for storage • Anticipated acceptance criteria for disposal are not satisfied	

The main conclusion is that all waste packages considered in the paper are suitable for storage, but none of them are likely to be suitable for disposal. As a matter of fact, spent resin solidified in vermiculite-cement matrix should be investigated in detail as unsuitable for disposal.

Waste storage capacity at the Krsko NPP is essential for operation. Maintaining storage capacity was the main reason the volume reduction technology was implemented. This has solved the interim storage capacity problem temporarily. On the other hand, the problem of satisfying (currently non existing) waste acceptance criteria for disposal might arise. In respect to this problem, introduction of high integrity containers maybe a solution. Several options to disposal are: extension of the storage capacity at the site, construction of additional treatment and conditioning facility and the possibility of waste conditioning abroad are some of them. Added cost is a common characteristic for all mentioned solutions. The cost-benefit analysis and public acceptance should provide the basis for decisions in the field.

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