MANAGEMENT OF LIQUID AND SOLID RADIOACTIVE WASTE FROM NUCLEAR POWER PLANTS IN THE FEDERAL REPUBLIC OF GERMANY

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ABSTRACT

For treatment of liquid waste, the main process methods used in German nuclear power plants are evaporation and mechanical filtration. An improved method, instead of a mechanical filter, is the use of centrifuges. The centrifuge system offers at least the same decontamination factor but generates 10 times less waste. For treatment of liquid concentrates and solid waste, several methods are available. An improved method for cementation is the use of a continuous mixer instead of an in-drum mixer. This continuous process offers, due to the small dimensions and the good homogeneity of the product, a number of advantages.

INTRODUCTION

Methods for the treatment of liquid effluents have largely become established in German nuclear power plants and the relating systems are designed for a maximum decontamination efficiency and highest possible availability. A number of liquid concentrates and solid waste.

The following contains a selection of processes most frequently used or available for use in German light water reactor plants for treatment of different types of radwaste.

The various wastes can be classified according to their physical conditions as shown in Table I.

TABLE I

Radioactive Waste from PWR and BWR Power Plants

Condition	Waste Type	Origin
Gaseous	Off-gas Inert gas mixture (N2,O2,H2) with radio-nuclides (Xe,Kr,N,J)	Primary systems feed water storage systems, etc.
	Exhaust ventilation air Possibly with radio-nuclides (iodine, aerosols)	Safety containment, reactor buildg., auxiliary buildg., turbine buildg.
Liquid	Waste water with radio-nuclides (fission + activ. products)	Primary systems, auxiliary systems, sumps, laboratories, laundries etc.
	Concentrated waste Filter slurries, spent resins, evaporator bottoms with radio-nuclides (fission + activ. products)	Water treatment systems within the controlled area of the power plant
Solid	Solid waste Contaminated metal parts, Paper, textiles etc.	Plants, machines and all rooms of the controlled area of the power plant

RADIOLOGICAL BACKGROUND

Two requirements regarding the degree of decontamination govern the design for the treatment of liquid radwaste in Germany:

- The maximum permissible release rates as shown in Table II for a 1300 MW light water reactor plant and
- The additional requirement of the Radiation Protection Ordinance (Atomic Energy Act) that the radiation exposure of plant personnel and of population be kept "as low as possible".

This last requirement demands the use of the most efficient treatment processes to minimize the activity release with liquid as well as highest degree of operational safety and reliability and easy maintenance.

TABLE II

Permissible Release Rates for Radionuclides for a 1300 MW PWR

Exhaust Air and Off-Gas	Noble Gases	30000,0	50000,0	Ci/a
	Iodine - 131	0,4	0,5	Ci/a
	Aerosols	0,5	1,0	Ci/a
Waste Water	Radium Free Mixture without Tritium	1,0	1,5	Ci/a
	Tritium	1000,0	1500,0	Ci/a

LIQUID WASTE TREATMENT

Table III shows the main sources of liquid waste in a 1300 MW PWR plant indicates the maximum quantities and activities expected.

The flow diagram for the liquid waste treatment system for a modern 1300 MW PWR is shown in Fig. 1.

According to this concept, the different types of waste are divided into three groups and collected in separate tanks. The first group is the more radioactive waste without detergents. The second group is mainly represented by lower radioactive water including detergents containing washing water. The third group comprises the noramlly inactive regeneration and flushing water from the steam generator blow down system.

TABLE III

Sources, Quantities and Activities of Liquid Waste in a 1300 MW PWR

Origin	Annual Average [m³/d]	Activity Concentration [Ci/m³]	Collecting Tank
Sump Water Equipment Rooms	6	1 – 10 [illegible]	Waste Water Collector 1 and 2
Laboratory and Decontam. Water	2	10 [illegible] – 10 [illegible]	
Sump Water Operating Rooms	8	10 [illegible] – 10 [illegible]	Waste Water Collector 3 and 4
Laundry Water	10	10 [illegible] – 10 [illegible]	
Waste Water Showers and Sinks	9	10 [illegible] – 10 [illegible]	
Distillate Coolant Treatment System	8	10 [illegible] – 10 [illegible]	
Chem. Waste from Steam Generator Blowdown Demin. System	9	Normal: inactive Steam Generator Leak: 10 [illegible] – 10 [illegible]	Waste Water Collector 5
Backwash Water E-Magn. Filter	2	Normal: inactive Steam Generator Leak: 10 [illegible] – 10 [illegible]	

Σ approx. 55m³/d approx. 20000 m³/a

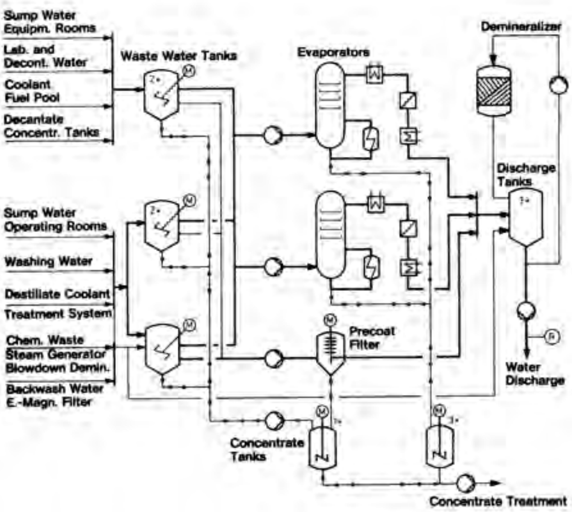

Fig 1. Liquid Waste Treatment System PWR.

Improved Method Using Centrifuges

The various processes available as e.g., evaporation and filtration are well known and described in numerous publications. Developments in this field concentrate more on trying to improve the reliability and efficiency of the system and on providing simpler and less expensive treatment equipment.

The removal of solids from waste water has to date, usually been performed using precoat filters. The precoat material was also added during operation. The amount of waste produced during operation in the form of filter aides was up to ten times greater than the amount of solids removed from the water.

The centrifuge system described in the following offers at least the same decontamination factor, but generates 10 times less waste which is a considerable advantage regarding the final disposal.

KWU's centrifuge combination not only permits considerable volume reduction but also results in a dry product which can be further reduced by incineration.

Extensive investigations have shown that the optimum decontamination, volume reduction and drying of the waste can be achieved by using a decanter and separator combination as shown in Fig. 2.

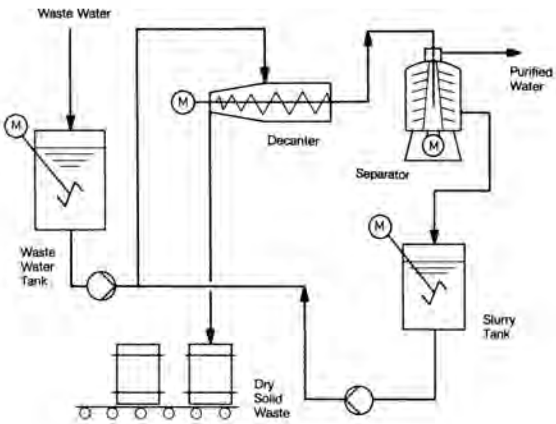

Fig. 2. Liquid Waste Purification with Centrifuges.

During initial treatment, most of the solids are removed by using a decanter. Afterwards, the liquid is routed to the separator where the fine solids are separated.

The sludge arising in the decanter is dewatered and dried before discharge. The quality of the dry product is such that it can be stored as it is and will not ferment or decompose, or it can be immobilized in a solidification agent either immediately or at a later date.

The fine particles removed and concentrated in the separator are returned as slurry to the decanter where the remaining water is removed. The dry product is then discharged.

Drains from washing machines, washing basins and showers which contain detergents can be treated using centrifuges. These drains with a high solid content and often very low activity which means that mechanical cleaning process is usually sufficient.

Further possibilities for the use of decanters and separators either individually or in combination are as follows:

- Mechanical cleaning of liquid waste before evaporation.
- Mechanical cleaning of ion exchange resin regenerants, filter backwash water and sump water.

- Concentration and drying of filter sludges e.g., powder resin suspensions.

Table IV compares the data for the amount of waste generated annually when treating 5000 m^3 of washing water in a decanter/separator system with the data obtained when using a precoat filter.

This shows that centrifugation generates less than one tenth waste instead when using precoat filters.

TABLE IV

Treatment of Laundry and Washing Water with Decanter/Separator or Precoat Filter

Process and Volume Reduction Data		Decanter/ Separator	Precoat Filter
Quantity of Water	m3/a	5.000	5.000
Suspended Solids before Treatment	ppm	150	150
Decontamination Factor		5-15	5-10
Dry Solids Separated	kg/a	750	750
Dry Filter Aid Material	kg/a	-	6.000
Quantity of Dry Solid Waste	kg/a	750	6.750
Quantity of Waste Slurry	m3/a	-	35
Number of Drums of Cemented Dry Waste	200 l	10	110
Number of Drums of Cemented Waste Slurry	200 l	-	350
Number of Drums of Cemented Ash after Incineration of Dry Solid Waste	200 l	3	-

TREATMENT OF CONCENTRATES AND SOLID WASTE

The situation regarding the treatment of concentrated liquid waste and solid waste is, however, different compared with the liquid waste treatment. The problems associated with the final disposal of these types of radwaste continually require new approaches involving the development of new systems or the modification of existing systems.

A variety of technologies is available for the treatment of liquid concentrates and solid waste. Two different alternatives are used for the treatment of the concentrates. The first way is direct solidification by mixing with a solidification agent in a one-step operation. The other possibility is a two-step operation. The first step gives rise to an intermediate product, which in the second step can then be immobilized using a solidification agent or by packing in a safety container.

The most important objectives of the concentrate and solid waste treatment are:

- Reduction of the waste to the smallest volume, unless activity concentration is the limiting factor, and
- Protection against migration of the concentrated radioactive substances after final disposal.

For the realization of these objectives, some examples of the technology combinations are demonstrated in Fig. 3.

Important parameters for the selection and design of concentrate and solid waste treatment processes and waste type, quantity, activity, means for immobilization and the achievable volume reduction factors. In this connection, Table V presents a summary of data as a guide to the low-level and intermediate-level radwaste from PWR plants.

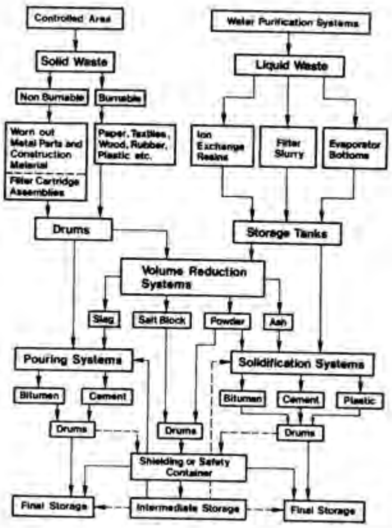

Fig. 3. Treatment of Solid and Concentrated Liquid Waste in PWR and BWR.

TABLE V

Summary of Typical Data for Liquid and Solid Waste 1300 MW PWR

	Type of Waste	Quantity m^3/a	Activity Concentration Ci/m^3	Volume Reduction Process	Embedding	Volume Red. Factor	200l-Drums/a
LAW	Evaporator Bottoms 20% b.w. (incl. Filter Slurry + Decont. Solution)	60	0.1 5	no no Borate Solidification Drum Dryer " " In-Drum Dryer	Bitumen Cement no no Bitumen Cement no	2,5 0,6 5,0 3,6 3,0 1.7 7,5	120 500 60 83 100 176 40
LAW	Burnable and Compactable Waste	190	0.001 0.15	Compactor 16 to Compactor 16 to + Shredder Compactor 300 to Compactor 800 to Incineration Incineration Incineration incl. Second. Waste	no no no no no Cement Cement	2,0 2,5 3,0 5,0 60 45 35	475 380 315 190 15 20 30
LAW	Unsorted Burnable and Non-Burnable Waste Ratio 80:20	250	0,001..0.5	Incineration and Remaining Waste Compaction 800 to	Cement	30	40
LAW	Non-Burnable but Compactable Waste	60	0.01....0,5	Compactor 800 to	no	3	100
LAW	Non-Burnable and Non-Compactable Waste	2	0.01... 5	no	no	1	10
LAW/MAW	Ion Exchange Resins 90% b.w.	2	200....400	Drying " "	no Bitumen Cement	2 0,3 0.14	5 33 71
LAW/MAW	Filter Cartridge Assemblies	15 Assemblies/a	1.... 50/ Assembly	no Drying	Cement Bitumen	1 1	15 15

Improved Method Using a Continuous Mixer for Solidification of Liquid and Dry Products in Cement

Along with bitumen and plastic, cement is one of the solidification agents most often used.

In the Federal Republic of Germany, the waste/cement product has to date generally been obtained using an in-drum mixing process. This is, however, a batch process which limits the amount of waste which can be treated. In comparison, the DMA cementation process described in the following is an advanced treatment method. It is a continuous process enabling the treatment of larger amounts of waste and features excellent product homogeneity. The equipment is simple in design and can be used for solidification of the following types of waste:

- Evaporator concentrates
- Filter concentrates
- Resin suspensions (ion exchangers)
- Suspension containing charcoal, ash, etc.
- Decontamination solutions containing chemicals (if compatible with the cement)
- Spent oils
- Dry, granulated or powdered wastes
- Encapsulation of bulky waste

The main component of the cementation system is the continuous mixer, Fig. 4. It comprises a pipe containing a mixing element and an integral product pump. The main features of this mixer are its small dimensions and its simple design.

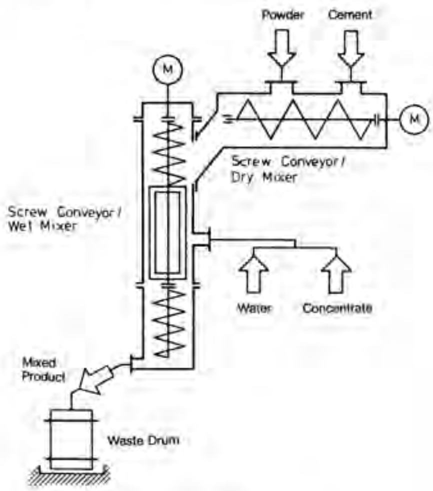

Fig. 4. Waste Cementation Unit DMA.

Only ca. 2 liters of the cement/waste product are in the mixer when treating liquid concentrates or resin suspensions which allows access to the equipment and enables the treatment of wastes having higher specific activities. Solidification of a concentrate with an activity of 10 Ci/m^3 (50% Co, 50% Cs), for example, would only result in a dose rate of approximately 5 mrem/h at a distance of 1 m from the mixer without shielding. The continuous mixer is the main component of the waste cementation system shown in Fig. 5.

For liquid waste solidification, the wastes are first collected in a mixing tank where they are prepared for cementation if necessary with additives to improve the final product. The pre-mixed waste is routed to the mixer where the dry cement is added and thoroughly mixed with the waste.

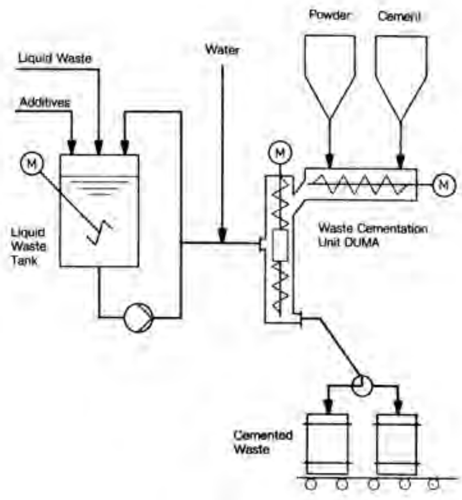

Fig. 5. Waste Cementation System.

For the solidification of powdered or granulated waste, the wastes are first mixed with dry cement and any additives in a dry pre-mixer. Fresh water or liquid waste such as evaporator concentrates are then added to the continuous mixer to produce the cemented product. The mixer can be used for granular wastes with a grain size of up to approximately 5 mm in the mixture of cement and liquid.

The product is discharged from the continuous mixer by an integral pump and can be filled into almost all types of containers and also routed to other rooms. This equipment can also be used to prepare cement for filling drums containing bulky waste.

The system is provided with its own control and proportioning equipment allowing the mixing ratios to be set as necessary for the solidification of the different types of waste, so that an optimum final product is obtained. Product quality depends on the:

- Composition of the waste
- Amount of waste in the final product
- Type of cement and
- Water/cement ratio.

The water/cement ratio mainly determines the compression strength of the final product which is also a measure of other important properties such as its resistance to leaching, to chemicals and its porosity. The water/cement ratio, therefore, has to be selected such that an optimum is achieved as regards to the compression strength and the amount of waste for ultimate disposal. Experience has shown that, depending on the type of waste and cement, this usually requires water/cement ratios between 0.3 and 0.4; the formation of freestanding water imposes an upper limit on the mixing ratio.

Bibliography

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