A COST EFFECTIVE WASTE MANAGEMENT METHODOLOGY FOR POWER REACTOR WASTE STREAMS

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ABSTRACT

This paper describes a computer based methodology for the selection of the processing methods (solidification/dewatering) for various power reactor radwaste streams. The purpose of this methodology is to best select the method that provides the most cost effective solution to waste management. This method takes into account the overall cost of processing, transportation and disposal. The selection matrix on which the methodology is based is made up of over ten thousand combinations of liner, cask, process, and disposal options from which the waste manager can choose.

The measurement device for cost effective waste management, is the concurrent evaluation of total dollars spent. The common denominator is dollars per cubic foot of the input waste stream. Dollars per curie of the input waste stream provides for proper checks and balances. The result of this analysis can then be used to assess the total waste management cost. To this end, the methodology can then be employed to predict a given number of events (processes, transportation, and disposals) and project the annual cost of waste management.

For the purposes of this paper, the author's provide, examples of the application of the methodology on a typical BWR at 2, 4 and 6 years. The examples are provided in 1984 dollars. Process selection is influenced by a number of factors which must be independently evaluated for each waste stream. Final processing cost is effected by the particular process efficiency and a variety of regulatory constraints. The interface between process selection and cask selection/transportation is driven by the goal of placing the greatest amount of pre-processed waste in the package and remaining within the bounds of weight, volume, regulatory, and cask availability limitations. Disposal is the cost of burial and can be affected by disposal, but availability of burial space, and the location of the disposal site in relation to the generator.

INTRODUCTION

Historically, the general practice and effort within the radwaste industry has been directed at optimizing the process design of the waste stream input. The emphasis in this area was placed primarily on cost effective system layout and operation. When conceived, these design considerations could not foresee or account for the present industry's transportation and disposal limitations. When these limitations are taken into account, they represent a very complex picture for the waste manager. This complexity is driven simply by the attempt to decide which management option provides the least overall cost when considering processing, transportation and disposal. Within these bounds lie over 10,000 potential decisions for the waste manager to choose from. With this in mind, the computer becomes an important tool for the waste manager. The methodology to be described is an example of how this tool can be applied.

BACKGROUND

Cask Transportation

The analysis of each waste stream starts with all the cask variations. Each cask variation is then subdivided into types of process and then into liner permutations per cask. Each of these permutations is further divided into disposal site location for transportation and disposal site costs. The results is the process in a liner, transported by cask to a specific burial site that results in the lowest possible cost to the user.

It should be noted that there are about 100 Low Level Waste (LLW) casks in existance today. There are 3 types, strong tight containers, Type "A" casks and Type "B" casks. These designations depict the quantity of isotopes by type and total, that can be transported over the road. There are 3 basic types of "A" casks and 2 type "B" casks. The difference among them is their internal volume, how much Co^{60} can be shielded, and how much weight is allowed in each cask. These five casks cannot change physical features and thus become the starting point of all permutations. Phrased another way, the goal becomes the placement into the cask, as much pre-processed volume, and curies as possible. The achievement of this goal is limited by a number of factors. These limiters include:

- Total process weight, which is affected by the pre-processed waste density and the package weight. The limiting criteria in this case is the weight limit imposed by the cask Certification of Compliance and/or the transportation weight limits.

- o Internal volume, which is affected by the total process weight, size of the process package, and process efficiency (pre-processed volume -vs- final processed volume).

- o Package dose rate, which is affected by curie concentration, total curies, isotopic abundance, and pre-process and final processed waste density. These limits directly affect the shielding capability of the cask.

- o Turnaround time per shipment is affected by location of the disposal site in relation to the waste generator's site. The waste generator must have a schedule to take advantage of available burial space and cask availability. Cask availability should take into account the distance to disposal site from the waste generators site and may include such options as team driver's.

Another factor which may affect the transportation of waste by a particular generator is the loading area (laydown and overhead clearance).

Disposal

Disposal site cost is defined as the total cost of burial. The controlling factors that affect disposal is the amount of avaiable burial space to the waste generator and the disposal site cost. Specific items on which the waste manager must base his decisions are:

- o Amount of available burial space

- o Disposal site cost are breakdown by:

  - o packagage volume
  - o package dose rate
  - o package curie content
  - o handling fees
  - o package weight
  - o surcharges
  - o taxes

The Liner/Process selections is controlled by several factors. These factors include:

- o Processing efficiency, is defined as the ratio of the amount of pre-processed waste delivered to the processing unit versus the usable volume of the container used for processing.

- o Waste stream requirements, which affect the solidification chemistry, limit the process efficiency.

- o Disposal efficiency, defined as the final process volume versus the disposal volume.

- o Casks that house the liner

- o Title 10 and 49 regulations

- o Total process and liner weight for cask C of C.

- o Disposal Site License and Criteria

  - o oil
  - o chelating agents
  - o organics
  - o TRU
  - o Etc

- o Disposal site Cost

The result of this analysis can then be used to assess the total waste management cost. To this end, the methodology can then be employed to predict a given number of events (processes, transportation, and disposals) and project the annual cost of waste management.

This paper assumes the use of a large liner inplant/or vendor supplied service solidification system with dewatering capabilities. The transportation is assumed to be vendor supplied services. For simplicity this paper does not assume capital expenditures, and assumes that the systems are inplace.

METHODOLOGY DESCRIPTION

This section describes the major inputs to selecting the most cost effective method for processing a specific waste stream and provides a discussion of the "Cost Effective Waste Management Flow Diagram;" (See Fig. 1). Further discussion also contains results from the application of the model for a generic model 1100 M(e) BWR.

- o Waste Input Stream Data

  This is the initial information required to start the analysis. The base information that is required is the volume of waste input, curie concentration (Co^{60} percent abundance), waste classification, and preprocessed density. The example is a 1100 MW(e) model BWR. The example is based on normalized data from four (4) operating BWR's (See Graph I and Table I). The example data is depicted from years 2, 4, and 6. It should be noted that this methodology does provide a better solution if it is used in real time, with actual known conditions.

  NOTE: Graph I and Table I do not represent a specific BWR. The reduction in volume of waste based on plant life represents the internal pressure to improve operational and maintenance practices to meet ALARA concern and reduce operational cost.

- o Process Method

  There are generally two (2) process methods in practice today. They are solidification and dewatering. This methodology does not assume one over the other. The methodology does determine though, the most economical method of processing based on transportation and disposal. This is accomplished by calculating through the entire matrix of all cask and liner permutations possible for dewatering and solidification and then provides a comparison of results.

- <u>Cask and Liner Selections</u>

  The cask liner selection is represented by all of the possible cask and liner combinations.

- <u>Physical Limit Per Liner and Cask</u>

  This section is used to set the limits on all the possible cask and liner permutations, based on the waste input stream data. (See Table II for Limits and Assumptions). The other limits are set by Title 10 and 49.

- <u>Optimized Performance Per Cask and Liner</u>

  This section readjusts the performance of each of the cask and liner permutations. This will dictate the final volume of preprocessed waste, and total curies per liner.

- <u>Disposal Criteria</u>

  The disposal criteria sets the limts for the disposal site and calculates the disposal fees, for each casks and liner combination.

- <u>Disposal Site Location</u>

  This section represents the cost per foot cubed at each disposal site broken down into three areas. The three areas are; Process cost; Transportation Cost; and Disposal Cost. Again this is performed for each liner and cask combination.

- <u>Process Cost Per Cubic Foot</u>

  Is the final corrected cost per foot cubed of input waste based on disposal site criteria, for each liner and cask permulation.

- <u>Transportation Cost Per Cubic Foot</u>

  Is the final corrected cost per foot cubed based on the disposal site location, for each liner and cask permutation.

- <u>Disposal Cost Per Cubic Foot</u>

  Is the final corrected cost per foot cubed based on the disposal site fees, for each liner and cask permutation.

- <u>Total Cost Per Cubic Foot</u>

  Is the total for the Process, Transportation and Disposal cost, for each liner and cask permutation.

- <u>Best Option Based on Cost and Allocation</u>

  This is represented by the most cost effective selection between Site A and Site B options. This is achieved by comparing all the results from the total cost of each of the cask and liner permutations. The results for years 2, 4, and 6 are shown in Tables III, IV, and V respectively.

- <u>Final Selection of Process Liner, Cask and Disposal Location</u>

  This section provides the final comparison of Dewatering vs Solidification options.

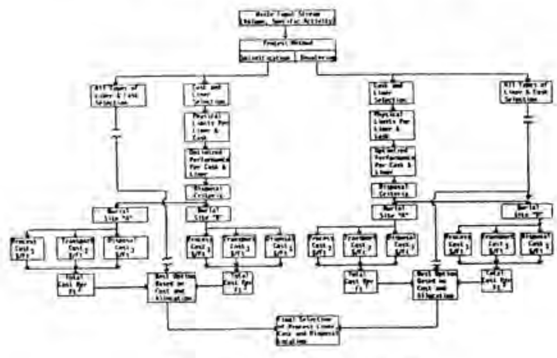

Fig. 1 [illegible]

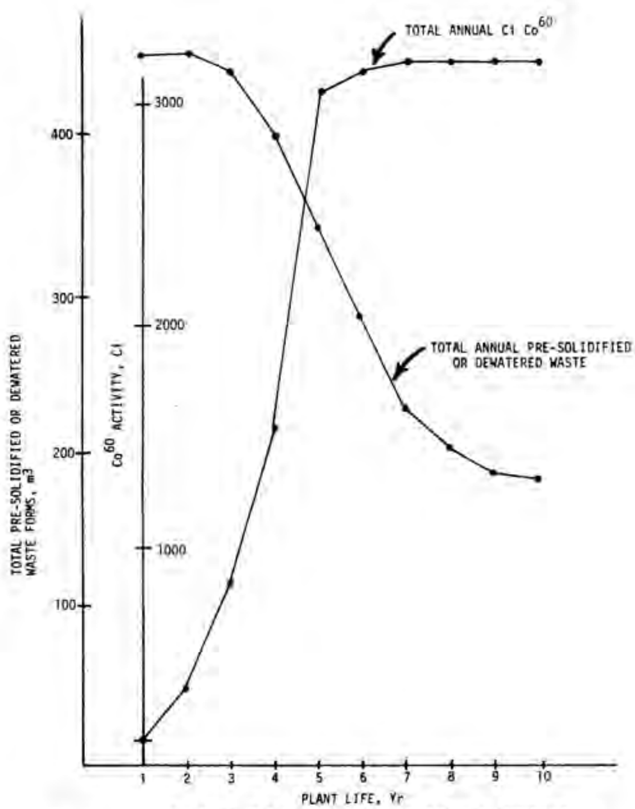

Fig. 1a Total Annual Generation of Pre-Solidified or Dewatered Waste and total Co^{60} generation, for a Model 1100 MW(e) BWR.

TABLE I

Waste Stream Generation for the 10 Years of a Model 1100 MW(e) BWR

Pre Solidified or Dewatered Waste	Plant Life in Years: 1	2	3	4	5	6	7	8	9	10
TYPE OF WASTE FORM										
1. Concentrates										
Waste Generation (ft^3)	9,250	9,250	9,000	7,800	6,100	4,600	3,100	2,800	2,600	2,500
Co^{60} Curie Generation (Ci)	75	100	250	520	1,100	1,100	1,100	1,100	1,100	1,100
2. Demineralizers										
Waste Generation (ft^3)	3,150	3,150	3,100	3,100	3,000	2,700	2,400	2,100	1,800	1,500
Co^{60} Curie Generation (Ci)	8	25	65	120	200	220	220	220	220	220
3. Filter Sludge										
Waste Generation (ft^3)	2,500	2,500	2,500	2,200	2,000	1,800	1,600	1,400	1,200	1,000
Co^{60} Curie Generation (Ci)	4	10	35	60	100	120	130	130	130	130
4. RWCU										
Waste Generation (ft^3)	900	900	900	900	900	900	900	900	900	900
Co^{60} Curie Generation (Ci)	40	160	450	800	1,700	1,700	1,700	1,700	1,700	1,700
TOTAL										
Waste Generation (ft^3)	15,800	15,800	15,500	14,000	12,000	10,000	8,000	7,200	6,500	5,900
Co^{60} Curie Generation (Ci)	75	295	800	1,500	3,100	3,140	3,150	3,150	3,150	3,150

TABLE II

Assumed Data

	*Number of Process Ft^3 Per Shipment: Solidification	Dewatering	Disposal Cost Per Trip: Disposal Volume	Disposal Site "A"	Disposal Site "B"	Total Ci Co Per Cask: Solidification	Dewatering
1. "A" Type Cask							
A. Light	165	--	240	$ 4,000.	$15,000.	8	7.5
B. Medium	120	145	180	$ 6,000.	$15,000.	13	7
C. Heavy	130	160	200	$ 5,000.	$15,000.	27	13
2. "B" Type Cask							
A. Medium	80	95	126	$13,000.	$35,000.	700	350
B. Heavy	50	60	85	$ 8,000.	$27,000.	1800	700
3. FLATBED Shipment	240	300	400	$ 4,000.	$ 8,000.	.7	.18

4. Average cost of Solidifying or Dewatering the waste form is about $100 per ft^3 this includes Operations, Maintenance and Materials.

5. Average internal plant cost per shipment is about $5,000 per shipment.

6. Assumed that plant has 17,000 ft^3 of allotment at Barnwell per year.

7. Plant is located in the Northeast.

* Note that due to container size that there can be an infinite number of container cask permutations. These changes can be made for Regulation Compliance as well as cost benefits.

o DISCUSSION OF RESULTS

o Optimized Economics Over Plant Life

The methodology can pick the optimum process method at any point in plant life. As an example, Tables III, IV, and V depict the results of the cost effective waste management methodology flow diagram (Fig. 1). The results are shown by waste stream and then totalized. The major points of interest show that the total cubic foot disposed decrease with plant age. The individual waste streams processing cost changes with plant age. The evaporator concentrates total process cost decreases primarily due to the decreased amount of preprocessed waste. The RWCU total cost increases which is attributed primarily to increased curie concentration. Both the cost of demineralizer and filter sludge wastes remain roughly constant. This is due an increase in curie generation, even though volume decreases. In summary, with an optimize approach the total preprocessed waste volume decreases with plant age, the curies disposed of increase and the total net cost does decrease.

The results in the example show that the total optimized waste management cost can decrease throughout the plant life. If improper waste management cost control tools are used, the cost could double or triple i.e., if waste management cost control methods from year 6 is use for year 2, then the results would exorbitant.

To achieve an optimum cost effective waste management system, the user should use the methodology on short term planning as well as long term planning. As can be seen in the "Summary of Optimized Economics" (Table VI), cask needs change over plant life. As do the cask, transportation, liner, and disposal requirements, needs change with waste stream's day to day changes. The best information for the paper's methodology is simply the latest information, and be prepared for change.

TABLE III

Optimized Economics
Plant Life Year 2

TYPE OF WASTE STREAMS	Concentrates	Demineralizer	Filter Sludge	RWCU	TOTAL
1. Best Cask	Type "A" Light	Type "A" Heavy	Type "A" Heavy	Type "A" Heavy	
2. Best Process	Solidification	Dewatering	Dewatering	Solidification	
3. Number Shipments	56	70	16	11	103
4. Total Volume of Waste Disposed (ft^3)	13,500	3,900	3,100	1,400	21,900
5. Cost per ft^3 Waste Processed					
A. Disposal Site "A"					
Process	$ 100.	$ 100.	$ 100.	$ 100. (3)	
Transportation	$ 30.	$ 32.	$ 31.	$ 41.	
Disposal	$ 54.	$ 54.	$ 47.	$ 105.	
Total	$ 184.	$ 186.	$ 178.	$ 246.	
B. Disposal Site "B"					
Process	$ 100. (1)	$ 100. (2)	$ 100.	$ 100.	
Transportation	$ 91.	$ 91.	$ 94.	$ 189.	
Disposal	$ 40.	$ 41.	$ 76.	$ 55.	
Total	$ 231.	$ 232.	$ 270.	$ 344.	
6. Difference between Disposal Site "B" and Disposal Site "A" $/$ft^3$	$ 37.	$ 46.	$ 47.	$ 71.	
7. Number of Shipment to					
A. Disposal Site "A"	15	70	16	11	
B. Disposal Site "B"	41				
8. Subtotal ($)					
A. Process	$ 875,000.	$315,000.	$250,000.	$ 90,000.	$1,530,000.
B. Transportation	$ 689,300.	$100,800.	$ 77,500.	$ 56,700.	$ 924,300.
C. Disposal	$ 430,000.	$170,100.	$117,500.	$ 49,500.	$ 767,100.
D. Plant	$ 280,000.	$100,000.	$ 80,000.	$ 55,000.	$ 515,000.
Total ($)	$2,274,300.	$685,900.	$525,000.	$251,200.	$3,736,400.

(1) Best cask is Type "A" Heavy Solidified Waste Form.
(2) Best cask is Type "A" Heavy Dewatered Non HIC Form.
(3) Type "A" Heavy cask using a Type B Medium Liner.

TABLE IV

Optimized Economics
Plant Life Year 4

TYPE OF WASTE STREAM	Concentrates	Demineralizer	Filter Sludge	RWCU	TOTAL
1. Best Cask	Type "A" Medium	Type "A" Heavy	Type "A" Heavy	Type "B" Medium	
2. Best Process	Solidification	Dewatering	Dewatering	Dewatering	
3. Number Shipments	66	20	14	9	108
4. Total Volume of Waste Disposed (ft^3)	11,900	3,900	2,700	1,100	19,800
5. Cost per ft^3 Waste Processed					
A. Disposal Site "A"					
Process	$ 100.	$ 100.	$ 100.	$ 102	
Transportation	$ 42.	$ 32.	$ 11.	$ 134.	
Disposal	$ 79.	$ 62.	$ 69.	$ 164.	
Total	$ 221.	$ 194.	$ 180.	$ 398.	
B. Disposal Site "B"					
Process	$ 100.	$ 100. (1)	$ 100. (2)	$ 100 (3)	
Transportation	$ 185.	$ 125.	$ 94.	$ 438	
Disposal	$ 87.	$ 43.	$ 31.	$ 63	
Total	$ 272.	$ 268.	$ 225.	$ 601.	
6. Difference between Disposal Site "B" and Disposal Site "A" $/$ft^3$	$ 51.	$ 74.	$ 35.	$ 203	
7. Number of Shipment to					
A. Disposal Site "A"	23	20	14	9	
B. Disposal Site "B"	43				
8. Subtotal ($)					
A. Process	$ 780,000.	$310,000.	$220,000.	$ 95,000.	$1,400,000.
B. Transportation	$ 750,900.	$ 99,200.	$ 68,200.	$170,600.	$1,038,900.
C. Disposal	$ 213,300.	$197,200.	$129,800.	$147,400.	$ 687,900.
D. Plant	$ 330,000.	$100,000.	$ 70,000.	$ 45,000.	$ 545,000.
Total ($)	$2,074,700.	$701,400.	$480,000.	$473,700	$3,668,800.

(1) Solidified waste shipped to Hanford, the best cask would be Type "A" Medium.
(2) Best cask Type "A" Heavy Dewatered Non HIC
(3) Best cask Type "B" Medium, Solidified, 11 Shipments, 1400 ft^3 disposed.

TABLE V

Optimized Economics
Plant Life Year 6

TYPE OF WASTE STREAM	Concentrates	Demineralizer	Filter Sludge	RWCU	TOTAL
1. Best Cask	Type "A" Heavy	Type "A" Heavy	Type "A" Heavy	Type "B" Heavy	
2. Best Process	Solidification	Dewatering	Dewatering	Dewatering	
3. Number Shipments	58	17	11	15	101
4. Total Volume of Waste Disposed (ft^3)	7,300	3,300	2,100	1,300	14,000
5. Cost per ft^3 Waste Processed					
A. Disposal Site "A"					
Process	$ 100. (1)	$ 100.	$ 100.	$ 100.	
Transportation	$ 63.	$ 32.	$ 31.	$ 133.	
Disposal	$ 109.	$ 75.	$ 73.	$ 235.	
Total	$ 272.	$ 207.	$ 204.	$ 468.	
B. Disposal Site "B"					
Process	$ 100.	$ 100. (2)	$ 100.	$ 100. (3)	
Transportation	$ 188.	$ 125.	$ 125.	$ 449.	
Disposal	$ 55.	$ 46.	$ 46.	$ 88.	
Total	$ 343.	$ 271.	$ 271.	$ 637.	
6. Difference between Disposal Site "B" and Disposal Site "A" $/$ft^3$	$ 71.	$ 64.	$ 67.	$ 169.	
7. Number of Shipment to					
A. Disposal Site "A"	48	17	11	15	
B. Disposal Site "B"	10				
8. Subtotal ($)					
A. Process	$ 460,000.	$270,000.	$180,000.	$ 90,000.	$1,000,000.
B. Transportation	$ 389,800.	$ 86,400.	$ 55,800.	$119,700.	$ 651,700.
C. Disposal	$ 458,200.	$202,500.	$131,400.	$211,500.	$1,003,600.
D. Plant	$ 290,000.	$ 65,000.	$ 55,000.	$ 75,000.	$ 505,000.
Total ($)	$1,598,000.	$643,900.	$422,200.	$496,200.	$3,160,300.

(1) Use in conjunction with Type "B" Medium Cask Liner.
(2) Solidified waste shipped to Hanford, the best cask would be Type "A" Medium.
(3) Type "B" Heavy, solidified, 18 shipments, 1500 ft^3 disposed. (Type B Medium would be a special request, greater than 100 R).

TABLE VI

Summary of Optimized Economics for Conclusion and Summary

- Cask Usage Per Transportation

	Number of Transportations
Year 2	
Type "A" Light	56
Type "A" Heavy	47
TOTAL	103
Year 4	
Type "A" Medium	66
Type "A" Heavy	34
Type "B" Medium	9
TOTAL	109
Year 6	
Type "A" Heavy	86
Type "B" Heavy	15
TOTAL	101

NOTE: Transportations remain about the same, but use varying cask.

- Total Average Cost Per Pre-Solidified or Dewatered Volume (ft^3)

Year 2 - $240./$ft^3$
Year 4 - $262./$ft^3$
Year 6 - $316./$ft^3$

NOTE: As plant life increases so does the cost per ft^3.

- Total Average Cost Per Curie of Co^{60} (Ci)

Year 2 - $12,800./Ci
Year 4 - $ 2,400./Ci
Year 6 - $ 1,000./Ci

NOTE: As plant life increases the cost per curie of Co^{60} decreases.

- Total Cost

Year 2 - $3,786,400.
Year 4 - $3,666,800.
Year 6 - $3,160,300.

NOTE: As plant life increases total cost decreases less than 20%.