Cost Benefit Analysis of Liquid Radioactive Waste Treatment Methods

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1. Background and Introduction

Liquid radioactive waste treatment can be done in various ways, such as by evaporation and ion exchange. Ion exchange is the treatment of liquid radioactive waste by exchanging the cations or anions in the waste. From the two methods of liquid radioactive waste treatment, it is necessary to carry out a cost-benefit analysis in order to achieve efficient and cost-effective liquid radioactive waste treatment. Cost-benefit analysis can determine an optimum method by combining aspects of safety and sustainability. In the aspect of safety, the potential dangers of the two methods of treating liquid radioactive waste Whereas in the aspect of sustainability, the energy requirements required from both liquid radioactive waste processing methods.

2. Methods of Radioactive Waste Treatment

2.1. Evaporation Treatment Method

Evaporation is the treatment of liquid radioactive waste by evaporation using steam. The treatment of liquid radioactive waste by the evaporation method uses the principle of evaporation using hot steam with a temperature of less than 146 ^{0}C to separate the liquid radioactive waste into concentrate and distillate. Liquid radioactive waste is collected in a storage tank and then flowed into the evaporator column using a pump to separate the vapor phase from the liquid phase with steam flow. The vapor phase is flowed into the separator column with the addition of mineral-free water to prevent the carryover of radionuclides carried by the vapor phase to the condenser and reduce the temperature of the vapor phase to distillate. While the liquid phase as concentrate is accommodated in the concentrate tank for the next process, namely cementation.

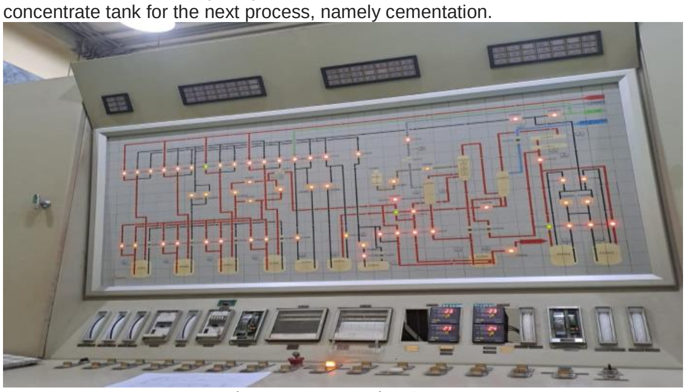

Figure 1. Evaporation System

2.2. Ion Exchange Treatment Method

Ion exchange is the treatment of liquid radioactive waste by exchanging the cations or anions in the waste. The ion exchange method is one way of treating liquid radioactive waste besides the evaporation method. Ion exchange can be carried out on low- and medium-activity liquid radioactive waste originating from the GA Siwabessy Multipurpose Reactor, which contains the dominant nuclides, namely Cs-137 and Co-60. Liquid radioactive waste is accommodated in a storage tank and then flowed into the column containing cation resin using a pump. In the resin column, the cation resin process captures liquid radioactive waste nuclides, resulting in a decrease in activity from before the ion exchange process. The cation resin that has been used and is saturated is accommodated in the concrete shell for the next process, namely cementation.

Figure 2. Ion Exchange System

3. Result

3.1. Data of Cost Benefit Analysis

The limitation of cost-benefit analysis is that it only calculates the main needs of each method show the table 1. comparison time and cost treatment methods.

NO	PARAMETER	ION EXCHANGE	EVAPORATION	INFORMATION
1	Time Operation	336 hour	134 hour	The evaporation process has not taken into account the cost incurred by the operation of supporting system such as demin water, softeners, cooling towers, etc.
2	Main Need Cost			
	Resin Amberlite	10 zak (250 lt)		
		10 x Rp 1.500.000		
		= Rp 15.000.000 (A)		
	Solar		134 hour x 175 lt	
			23.450 lt x Rp 18.610	
			= Rp 436.404.500 (A)	
3	Concrete Shell	1 pcs	8 pcs	
		1 x Rp 20.000.000	8 x Rp 20.000.000,-	
		= Rp 20.000.000 (B)	= Rp 160.000.000,- (B)	
	Total (A+B)	**Rp.35.000.000,-**	**Rp 596.404.500,-**	

Table 1. Comparison Time and Cost Treatment Methods with 100 m^{3} Liquid Radioactive Waste

The table above describes the method for treating liquid radioactive waste by evaporation and ion exchange using the same volume of 100 m^{3} of liquid radioactive waste. The main requirement for the ion exchange method is 10 sacks of cation resin and 250 liters of cation resin per 100 m^{3} of radioactive waste. Meanwhile, the evaporation method requires 23,450 liters of diesel fuel as the main requirement for 100 m^{3} of radioactive waste. The diesel fuel is used for the operation of boilers that produce hot steam so that they can separate liquid radioactive waste into concentrate and distillate. The evaporation method for treating waste per 100 m^{3} requires around 600 million rupiah, while the ion exchange method requires 35 million rupiah. The ion exchange method saves operational costs for liquid radioactive waste management by a significant 94% compared to the evaporation method.

3.2. Aspect of Safety Radioactive Waste Treatment Methods

The two methods of treating liquid radioactive waste have different potential hazards from a safety perspective. The evaporator unit has potential electrical hazards such as electrical short circuits in components that support a very complex evaporation process. Meanwhile, the ion exchange unit has simpler supporting components compared to the evaporator unit. The ion exchange unit has potential hazards such as contamination if waste is spilled; therefore, workers must wear complete personal protective equipment. The evaporator unit has a potential hazard to a steam-producing boiler if high pressure occurs that exceeds normal operating pressure, which can cause an explosion. Normal evaporation operation requires steam with a steam pressure of 5 bar and a steam temperature of 151 ^{0}C, while normal operation of the ion exchanger uses a pump with a pressure of 2 bar and temperature of liquid radioactive waste is 27 ^{0}C. Then the evaporation unit has a potential chemical hazard because it uses nitric acid and soda, but ion exchange just uses resin for treatment. So that the ion exchange method has a lower potential hazard than the evaporation method from the parameters of chemical, pressure, and temperature when normal operation is carried out.

Parameter	Evaporation	Ion Exchange
Pressure		
Steam	**5 bar**	**-**
Pump	**5 bar**	**2 bar**
Cooling water	**3 - 4 bar**	**-**
Service water	**5 – 6 bar**	**-**
Demineralized water	**3 – 4 bar**	**-**
Temperature		
Steam	**151 ^{0}C**	**-**
Liquid radioactive waste	**100 ^{0}C**	**27 ^{0}C**
Chemical	**HNO_3 and NaOH**	**Resin**

Table 2. Comparison parameter operation normal condition of evaporation and ion exchange

3.3. Aspect of Sustainability Goals

The sustainability aspect regarding the energy requirements required from the liquid radioactive waste processing method is in accordance with one of the seventeen sustainability goals, namely clean and affordable energy. The energy used must be efficient, affordable, and not dependent on non-renewable fossil fuels, which is the goal of sustainability. The evaporation method requires 23,450 liters of diesel fuel as the main requirement to process 100 m^{3} of radioactive waste for 134 hours. This shows that the amount of diesel fuel needed is very large, while diesel is a non-renewable fuel whose amount will be depleted for the foreseeable future. Meanwhile, the ion exchange method does not require diesel fuel as the main requirement during operation. So that in the aspect of sustainability, ion exchange can fulfill one of the sustainability goals, namely affordable and clean energy.

4. Conclusions

- From the cost benefit analysis, ion exchange can be determined as an optimal method by combining safety and sustainability aspects.

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