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The Comparison on Treatment Method of Liquid Radioactive Waste in Yonggwang #3&4 and #5&6

영광 3&4와 5&6호기에서 액체 방사성폐기물 처리방법의 비교

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Abstract

Most of the low-level liquid radioactive wastes generated from PWR plants are classified into high or low total suspended solid(HTDS or LTDS), and into radiochemical and radioactive laundry waste. Although the evaporation process has a high decontami- nation ability, it has several problems such as corrosion, foam, and congestion. A new liquid waste disposal process using the ion-exchange demineralizer(IED), instead of the current evaporation process, has been introduced into the Yonggwang NPP #5 and 6. These two methods have been compared to understand the differences in this study. Aspects compared here were the released radioactivity amount of the liquid radioactive wastes, the dose of off-site residents, the decontamination factor, and the amount of the solid radioactive wastes.

The IED system is designed to discharge higher radioactivity about 20% than the evaporating system, and the actual radioactivity released from the evaporating and IED system were 0.473mCi and 1.098mCi, respectively. The radioactivity released from the IED was 2.32 times higher than that of the evaporating system. The dose of off-site residents was 2.97×10^{-6}mSv for the evaporating system, and 6.47×10^{-6}mSv for IED.

The decontamination factor(DF) of the evaporator is, in most cases, far lower than the lower limits of detection(LLD) with the Ge-Li detector. Due to the low concentration of the liquid wastes collected from the liquid waste system, the decontamination factor of IED is very low. Since there is not enough data on the amount of solid radioactive wastes generated by the evaporation system, the comparison on these two systems has been conducted on the basis of the design, and the comparison result was that the evaporating system generated more wastes about 40% than IED.

Key Words :ion-exchange demineralizer(IED), evaporator, liquid radioactive waste, dose of off-site residents, decontamination factor, Treatment

I. Introduction

Low-level liquid radioactive wastes are generated at PWR plants through equipment drain, floor drain, contaminated wastes etc. For the disposal of these wastes, the evaporation method has been used at most of plants around the world, including Korea. Despite the superiority of this system, there have been noticed problems such as corrosion by residues, chemical congestion, foam, and crystallization quality of Boric-acid[1][2]. Because of these problems, waste enrichments have been restricted[6][8], and the treatment of liquid wastes depending only on the evaporator may not be expected to be very effective. Although radioactive disposals using the ion-exchange process have many merits such as comparatively simple but excellent decontamination, easy maintenance and repair, the existing IED is not suitable for the treatment of radioactive liquid wastes with general ions as the life of ion-exchange resin is short, and also as the existing IED gets rid of both radioactive and non-radioactive ions. So the evaporation system has been adopted at Yonggwang #5&6[9].

In this paper, the amount of radioactive liquid wastes released, dose of off-site residents, decontamination factor(DF) and the amount of solid radioactive wastes are respectively compared and reviewed to grasp the differences between the ion-exchange demineralizer(IED) and the evaporator.

II. Treatment of Radioactive Liquid Waste.

1. The Disposal in Korea and Overseas

The evaporator has been used mainly for liquid waste treatment, but due to erupting problems mentioned above, most plants in the U. S. are adopting the ion-exchange process. <Table 1> shows liquid wastes collection and treatment methods of all the PWR plants in Korea[11].

The PWR plants of Korea has been using the evaporator ranging from Kori #1 to Yonggwang #4 constructed in 1995. But recently Yonggwang #5&6 have introduced the IED to simplify the operation process and to minimize personal dose.

2. Characteristics

As most of the liquid wastes are generated from system, equipment drain, floor drain rather than chemical liquid and laundry wastes. The characteristics of the wastes which are generated from the evaporation and ion-exchange methods have been compared in this study.

As shown on <Table 2>, Yonggwang #5&6 have been operated only for one and a half years, and the

Table 1. Methods of Collection and Treatment of Liquid Radioactive Wastes

Plant Name	Operation	NSSS Supply	Liquid Waste		
			Collection Method	Treatment Method	Main Equipment
Kori 1	78	W	mixing	mixing	evaporator
Kori 2	83	W	mixing	mixing	evaporator
Kori 3	85	W	mixing	mixing	evaporator
Kori 4	85	W	mixing	mixing	evaporator
Yonggwang 1	86	W	mixing	mixing	evaporator
Yonggwang 2	86	W	mixing	mixing	evaporator
Yonggwang 3	94	CE	mixing	mixing	evaporator
Yonggwang 4	95	CE	mixing	mixing	evaporator
Yonggwang 5	02	CE	mixing	mixing	IED
Yonggwang 6	03	CE	mixing	mixing	IED
Ulchin 1	88	F	mixing	mixing	evaporator
Ulchin 2	89	F	mixing	mixing	evaporator
Ulchin 3	97	CE	mixing	mixing	evaporator
Ulchin 4	98	CE	mixing	mixing	evaporator
Ulchin 5*	04	CE	mixing	mixing	IED
Ulchin 6*	05	CE	mixing	mixing	IED

* under construction

conductivity of it is 29~63μ mho/cm. Also the total floating density of the water is 0.019~0.024ppm, and the gloss activity concentration (1.882×10^{-2} ~ 1.744Bq/cc) in the liquid wastes appeared to be low, and no nuclide were detected in the liquid wastes.

Table 2. Analysis data of Liquid Radioactivity Waster in Each Treatment

Section	Evaporator Method	Ion-Exchange Method
pH	6.81~7.2	6.4~6.8
conductivity (μmho/cm)	209~515	29~63
TSS(ppm)	6.78~13.71	0.019~0.024
activity concentration (Bq/cc)	3.70×10^{-1}~3.70×10^{2}	1.882×10^{-2}~1.744
detect nuclide	Cr-51, Mn-54, Co-58, Fe-59, Co-60, Zn-65, Co-57, Zr-95, Cs-137, I-131, etc	Cr-51, Mn-54, Co-58, Fe-59, Co-60, Zn-65, Co-57, Zr-95, etc

* Evaporator disposal method : Yonggwang #3&4
* Ion-exchange method : Yonggwang #5&6

Table 3. Components and Capacity of Evaporator

name	amount	capacity
HTDS Tank	2	1800gallon
LTDS Tank	2	1800gallon
Chemical Waste Drain Tank	2	4500gallon
Chemical Waste Tank	2	8400gallon
EVAP Feed Tank	2	8800gallon
Demineralizer Feed Tank	2	18000gallon
Monitor Tank	2	18000gallon
Recycle Tank	1	27000gallon
Release Tank	1	27000gallon
HTDS Filter	2	6μ
LTDS Filter	2	6μ
Chemical Waste Filter	2	6μ
Demineralizer Filter	2	20μ
Chemical Waste Demineralizer Filter	2	20μ
Radwaste Demineralizer	2	50ft^3
Chemical Waste Demineralizer	2	50ft^3
Polishing Demineralizer	2	50ft^3
Oil Adsorber	2	50ft^3
Oil Coaleser	2	150gpm
LRS EVAP PKG	2	30gpm

* Demineralizer facility : Radwaste Demineralizer, Chemical Waste Demineralizer, Polishing Demineralizer

These trends are similar to the those of evaporator in operation for the same period of time.

3. Treatment Methods of Liquid Wastes

<Table 3> shows components and capacity of evaporator used in Yonggwang #3&4, and <Table 4> presents components and capacity of IED used in Yonggwang #5&6.

3.1. Generation of Liquid Wastes

As shown on <Table 5>, the amount of the chemical and laundry liquid wastes at each plant is 900 gallon/day which amounts to 34% of all the water flowing into the liquid waste system, and the rest, 66%(1700 gallon/day) is the water used for other general purposes.

3.2. Treatment Method[7]

The liquid wastes generated at PWR plants can be divided into system liquid wastes (highly-dissolved solid liquid waste, low- dissolved solid liquid waste) and chemical or laundry liquid

Table 4. Components and Capacity of IED

name	amount	capacity
HTDS Tank	2	1800gallon
LTDS Tank	2	1800gallon
Chemical Waste Drain Tank	2	4500gallon
Chemical Waste Tank	2	9000gallon
EVAP Feed Tank	2	18000gallon
Monitor Tank	2	27000gallon
Decanter	2	60gpm
Separator	1	60gpm
Metering Pump	1	65gpm
Slurry Pump	2	2.2~17.6gpm
Slurry Tank	2	665gallon
Organic material Adsorber	4	60gpm
Selective ion-exchange	2	60gpm
Cation Demineralizer	2	60gpm
Anion Demineralizer	2	60gpm
purification ion Demineralizer	2	60gpm

* Centrifuge facility : Decanter, Separator, Metering and, Slurry Pump
* Ion-exchange facility : Organic material Adsorber, Selective ion-exchange, Cation and Anion Demineralizer, purification ion Demineralizer

Table 5. The Inflow of Liquid Wastes in Each Treatment Method

Sources	Expected Amount (GPD/plant)		note
	Evaporator disposal method	Ion-exchange method	
Highly-dissolved/ Low-dissolved Solid Liquid Waste			66%
-Containment	530	540	
-Aux. building	486	480	
-Fuel building	700	700	
Chemical liquid waste			34 %
-Chemical Lab. drainage	50	50	
-Equipment decontamination	350	350	
-Laundry liquid waste	300	300	
-Personnel shower liquid waste	200	200	
Liquid wastes from Condensate Demineralizer due to Secondary System Contamination			Generally released to sea. Sent to liquid waste system if over limit.
-Highly-dissolved solid liquid waste	18,000	20000	
-Low-dissolved solid liquid waste	54,000	20000	
-Chemical liquid waste	18,000	10000	

* Evaporator disposal method : Yonggwang #3&4

* Ion-exchange method : Yonggwang #5&6

waste. System liquid wastes (SLW) are generated by system water drain, equipment drain, floor drain, and it flows into the general collector and are treated in the liquid waste system[10].

- Treatment of low-dissolved solid liquid wastes(LDSLW) : LDSLW from equipment detours or drains the evaporator, and are treated in the demineralizer. But if LDSLW contains too many impurities, it is treated in the evaporator or IED.
- Treatment of highly-dissolved solid liquid wastes(HDSLW) : HDSLW is accumulated from the fuel building or the auxiliary building, and when having many impurities, it is treated by the evaporator or IED. The evaporator removes floating materials by prefilter, separates oil by oil separator, purifies through the evaporator, removes ions by demineralizer and resin by after- filter, collects samples from the monitor tank, and discharges into the environment after analysis.

The ion-exchange method gets rid of floating particles of more than 0.1 micron[·Ï] by the centrifuge before sending wastes to the IED, separates oil by the adsorption dimineralizer, removes radioactive nuclides through the cesium, cation, anion dimineralizer and the polishing deminera- lizer, collects samples from the monitor tank, and discharges into the environment after analysis.

- Treatment of chemical liquid wastes : after liquid wastes from chemistry labs. and decontamination water reach the general chemical liquid waste tank, sampling and analysis are conducted. And then the wastes are sent to the evaporator or IED to add acid, alkali or other chemicals before collected in the monitor tank.
- Treatment of laundry liquid wastes : if the radioactivity concentration existing within the waste water after laundry is above the limit, the waste water is treated with the evaporator, and if the radioactivity concentration of it is below the limit, it is sent to the monitor tank. In the treatment using the ion exchange method, if the radioactivity concentration of the water is above the limit, the water is collected into the chemical wastes tank, the floating particles and radioactivity are lowered by the centrifuge and IED before discharged into the environment, but if the radioactivity concentration of the water is lower than the limit, it is discharged without any special treatments.

4. Comparison and Analysis on the Effectiveness of Liquid Waste Treatments

4.1 The Analysis on the Effectiveness of Waste Treatments

Discharge of Radioactive Materials to Off-Site

As shown on <Table 6>, the designed amount of radioactive nuclides discharged through the liquid waste system is ten times more in the IED than in the evaporator, which seems to result from the differences in the design concept for the evaporator and IED. Namely, the IED is designed to discharge about 20% more nuclide than the evaporator[4][5].

As shown on <Table 7>, based on the designed emission quantity, the activity concentration of liquid wastes released from Yonggwang #3&4 was compared with that of the liquid wastes discharged from Yonggwang #5&6.

Because the evaporator of the Yonggwang #3&4 has been used for 8 years, the activity concentration of liquid wastes generated through it would be higher than that discharged through IED of the Yonggwang #5&6 which is in its second year operation. But as shown in <Table 7>, the level of radioactivity released from Yonggwang #5&6 was 2.2 times higher than that discharged from Younggwang #3&4.

Dose to Off-site Residents

During normal operation, as seen in the <Table 8>, the designed maximum individual dose for whole body to off-site residents by liquid wastes treated through IED was higher(2.10×10^{-4}mSv) than dose by those through the evaporator(4.66×10^{-5}mSv). And the difference was even greater in the maximum organ dose; that is, IED showed 1.33×10^{-2}mSv/year, on the other hand, the evaporator showed 1.01×10^{-3}mSv/year. The difference also exists in the designs; that is, the evaporator is designed to be ten times more capable than IED in treating liquid wastes.

Based on data on the liquid wastes discharged into the environment through the evaporator and the IED, the dose to residents was estimated. The analysis code used to calculate the dose generated from liquid wastes was LIQDOS. Important exposure pathways considered here are internal exposures by the ingestion of aquatic products,

Table 6. The expectation amount of nuclide discharged in liquid emission materials (per plant, Ci)

Methods	Boron Recovery	Liquid Radioactive Waste System	Secondary System	Turbine Building	Total	Calibrated Emission Quantity (Ci/yr)
evaporator method	3.04 $\times 10^{-3}$	1.98 $\times 10^{-2}$	2.51 $\times 10^{-1}$	9.10 $\times 10^{-1}$	2.75 $\times 10^{-1}$	4.35 $\times 10^{-1}$
ion-exchange method	2.73 $\times 10^{-3}$	1.15 $\times 10^{-1}$	2.44 $\times 10^{-1}$	8.99 $\times 10^{-1}$	3.64 $\times 10^{-1}$	5.23 $\times 10^{-1}$

Table 7. Comparison on the amount of radioactive concentration emission and released liquid(2002yr)

Month	Evaporator Method		Ion-Exchange Method	
	Radioactive Concentration (Bq)	Liquid Quantity (m^3)	Radioactive Concentration (Bq)	Liquid Quantity (m^3)
1	1.326×10^6	430	1.66×10^5	24,121
2	under LLD	419	3.89×10^5	1,316
3	1.190×10^6	1223	3.13×10^4	21,380
4	3.005×10^5	594	3.52×10^6	12,288
5	2.739×10^5	836	$3.00 \times$ E+07	22,802
6	3.491×10^6	1020	8.90×10^5	8,926
7	3.056×10^5	1661	1.83×10^6	25,913
8	5.521×10^6	2189	1.26×10^6	30,859
9	5.366×10^5	1338	1.26×10^6	122,545
10	4.585×10^6	1400	1.28×10^6	4,769
total	1.75×10^7 (0.473 mCi)	11,110	4.06×10^7 (1.098 mCi)	274,919

Table 8. The Maximum Individual Dose to Off-site Residents by Liquid Wastes During Normal Operation.

	Evaporator Method	Ion-Exchange Method	10 CFR 50	note (Evaporator : Ion-Exchange)
Whole Body (mSv/yr)	4.66×10^{-5}	2.10×10^{-4}	3.0×10^{-2}	1 : 4.51
Maximum Organs Dose (mSv/hr)	1.01×10^{-3}	1.33×10^{-2}	1.0×10^{-1}	1 : 13.2

external exposures by accumulated radioactive materials on the seashore, and external exposures by leisure activities at the nearby ocean.

Accumulated doses and Maximum individual doses to the residents living within a radius of 80 km from the plants were evaluated, and the results follows below.

As shown on <Table 9> and <Fig 1>, maximum Organ Dose for the residents near the plant with IED was 2.19×10^{-5}mSv, and which indicates that the doses to the residents near the plant with an IED system were higher than those near it with an evaporator.

But with the IED in operation for a relatively short period of time compared to the evaporator and with insufficient operational data, these results cannot be enough evidence to find out the differences of the two systems. Therefore, further study should be followed in the future.

4.2 Decontamination Factor

Ion Exchange Method

As shown on <Fig 2>, through an analysis on samples gathered at 7 spots (the entrance and the exit of the ion exchange equipment, between each of the absorbers and the demineralizers), nuclides detected include no fissile nuclides but only radioactive corrosion products such as Cr^{51}, Mn^{54}, Co^{58}, Fe^{59}, Co^{60}, Zn^{65}, Co^{57}, Zr^{95}, existing in nuclear reactor coolant.

<Table 10> shows decontamination factors of selective ion-exchange equipment which is the analysis results on liquid waste concentration during the whole treatment process. The decontamination factors varied from 3 to 230, and <Table 11> shows those of U.S[11].

As shown on <Table 11>, decontamination factors in U.S. plants are presented from 100 to

Table 9. Calculation Result of organ dose to off-site residents by Liquid Release Materials (2002)[3][12]

year / Dose	1/4		2/4	
	Evaporator	Ion-Exchange	Evaporator	Ion-Exchange
Effective (mSv/yr,man)	1.178×10^{-6}	1.350×10^{-8}	1.356×10^{-6}	6.280×10^{-6}
Thyroid (mSv/yr,man)	1.136×10^{-6}	1.330×10^{-8}	1.312×10^{-6}	2.880×10^{-6}
Maximum Organ (mSv/yr,man)	1.414×10^{-6}	1.470×10^{-8}	1.592×10^{-6}	2.130×10^{-5}
year / Dose	3/4		Total	
	Evaporator	Ion-Exchange	Evaporator	Ion-Exchange
Effective (mSv/yr,man)	$4,360 \times 10^{-7}$	1.740×10^{-6}	2.97×10^{-6}	6.470×10^{-6}
Thyroid (mSv/yr,man)	$3,080 \times 10^{-7}$	9.180×10^{-8}	2.756×10^{-6}	2.990×10^{-6}
Maximum Organ (mSv/yr,man)	1.710×10^{-6}	5.390×10^{-7}	4.716×10^{-6}	2.190×10^{-5}

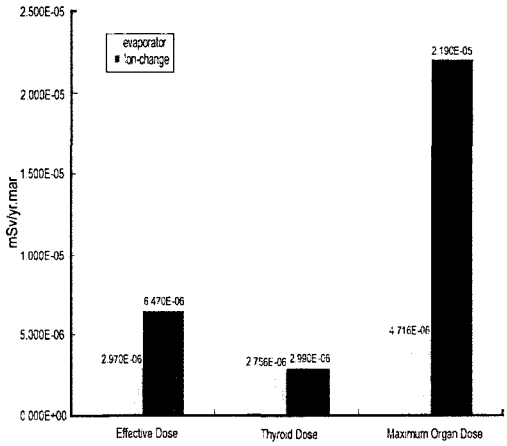


Fig 1. Level of organ dose to off-site residents(2002)

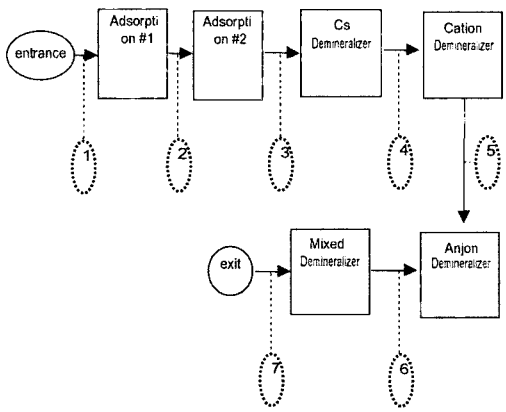


Fig 2. Sampling locations of selective ion-exchange equipment

1507 according to each plant. This result can be caused by various factors such as operation condition, operation period, sampling point etc, and also this wide difference can happen at even plants using the same method according to various factors mentioned above.

The analysis results as to the decontami- nation factors shows that radioactivity of the nuclides gets remarkably weaker as those go through the two absorption demineralizers. The adsorption demineralizers which were made of charcoal is to prevent oil from wrapping resins which causes a severe deterioration of the ion exchanging capacity. It showed an excellent radioactivity removing ability. The radioactivity level of the nuclides in liquid wastes after adsorption got much low during the cesium demineralizing process. This is because the radioactivity reached below the designed level, and it showed no difference after the cesium demineralizing process. <Fig 3> through <Fig 8> show the removing effect of each demineralizer.

Because most of the chromium ions were removed by the adsorption demineralizers, no difference was made in the number of chromium ions by the cesium, cation, anion, and mixed demineralizers. The relatively higher level of radioactivity concentration of Sample 8 dropped significantly after adsorption 1 and 2, but remained almost same after then.

The ability of the selective ion-exchange equipment to remove Mn^{54}, Co^{58} and Co^{60} was very excellent. As shown on <Fig 5> and <Fig 6>, Mn^{54} and Co^{58} were most removed at the process of absorption 2 - Cs demineralizer regardless of initial concentration. Also these nuclides were removed nearly up to below lower limits of detection(LLD) after going through Cs demineralizer. And in case of Co^{60} shown on <Fig 7>, radioactivity concentration was removed nearly up to below LLD after going through Cesium demineralizer.

As for Fe^{59}, as shown on <Fig 8>, there is no resin that is particularly effective in removing it. The processes of adsorption 1 and 2 remove a little of Fe^{59}, but resins seem to have no ability removing it. As Fe^{59} is found in all the samples, further study should be followed to find resins which are effective in removing Fe^{59} from the IED.

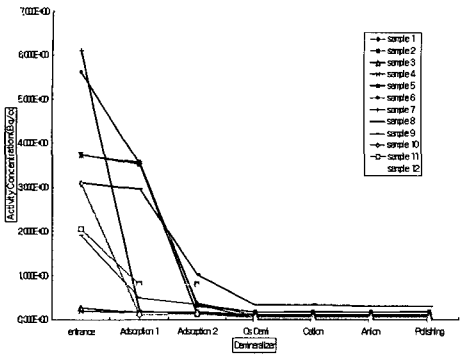
In case of plants in operation for a long period

Table 10. Decontamination Factor of selective ion-exchange equipment

	Activity Concentration of Liquid Wastes(Bq/cc)		Decontaminat ion Factor	note
	before treated	after treated		
sample 1	3.737	1.692×10^{-2}	221	
sample 2	3.737	1.868×10^{-1}	20	
sample 3	2.782×10^{-1}	9.764×10^{-2}	3	
sample 4	9.981×10^{-1}	8.596×10^{-2}	12	
sample 5	3.737	6.755×10^{-2}	55	
sample 6	3.402×10^{-1}	1.709×10^{-2}	20	
sample 7	5.612	9.066×10^{-2}	62	
sample 8	6.094	2.649×10^{-2}	230	
sample 9	3.106	3.018×10^{-1}	10	
sample 10	7.583×10^{-1}	9.415×10^{-3}	81	
sample 11	1.896	3.190×10^{-2}	59	
sample 12	3.090	4.889×10^{-2}	63	
sample 13	2.046	9.415×10^{-3}	217	

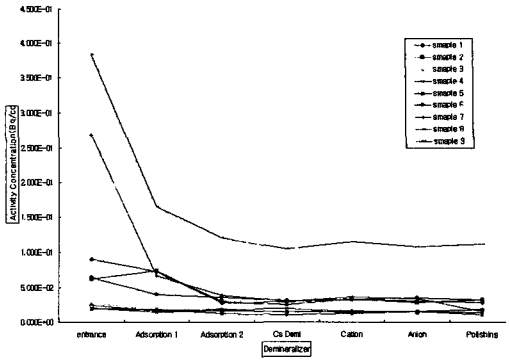
Table 11. Operation Result of Selective Ion-Exchange Equipment in U.S Plants

Plant	Treatment of Liquid Wastes per year (Gallon)	Activity Concentration of Liquid Wastes (Bq/cc)		Decontamination Factor
		before	after	
Comanche Peak	4,200,000	5.6×10^{-3}	6.0×10^{-6}	933
Fort Calhoun	3,900,000	1.0×10^{-3}	9.3×10^{-6}	107
Haddam Neck	1,364,000	9.8×10^{-4}	6.5×10^{-7}	1507
Seabrook	1,500,000	3.6×10^{-4}	2.6×10^{-6}	138
McGuire	750,000	1.0×10^{-3}	1.0×10^{-5}	100



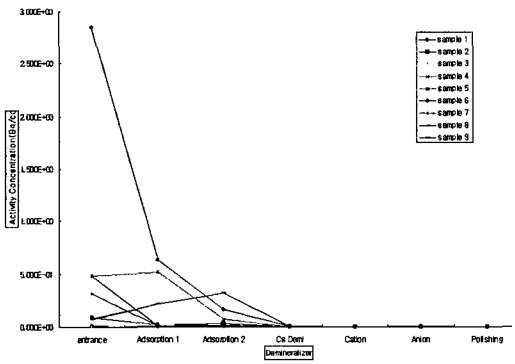
sample	entranc	Adsor. #1	Adsor. #2	Cs Demi	Cation	Anion	Polishing
1	3.7E+00	3.5E+00	3.4E-01	1.7E-01	1.7E-01	1.7E-01	1.7E-01
2	3.7E+00	3.6E+00	3.0E-01	1.7E-01	1.7E-01	1.6E-01	1.9E-01
3	2.8E-01	1.5E-01	1.5E-01	1.0E-01	9.6E-02	9.1E-02	9.8E-02
4	2.0E-01	1.5E-01	1.7E-01	9.0E-02	9.1E-02	8.8E-02	8.6E-02
5	3.7E+00	3.5E+00	1.2E-01	6.3E-02	6.6E-02	6.9E-02	6.8E-02
6	5.6E+00	3.5E+00	3.6E-01	8.9E-02	9.1E-02	9.7E-02	9.1E-02
7	6.1E+00	1.9E-01	1.2E-01	8.6E-02	7.3E-02	5.8E-02	2.6E-02
8	3.1E+00	2.9E+00	1.0E+00	3.4E-01	3.5E-01	3.0E-01	3.0E-01
9	1.9E+00	4.9E-01	3.4E-01	2.8E-02	3.2E-02	3.1E-02	3.2E-02
10	3.1E+00	8.8E-02	1.2E-01	5.0E-02	5.0E-02	4.6E-02	4.9E-02
11	2.0E+00	7.8E-01	7.8E-01	1.6E-02	1.8E-02	1.9E-02	9.4E-03
12	7.6E-01	7.8E-01	7.8E-01	1.6E-02	1.8E-02	1.9E-02	9.4E-03

Fig 3. Radioactivity Removal Process



sample	entranc	Adsor. #1	Adsor. #2	Cs Demi	Cation	Anion	Polishing
1	8.9E-02	7.3E-02	2.8E-02	2.9E-02	3.3E-02	3.1E-02	2.8E-02
2	6.2E-02	7.4E-02	3.0E-02	2.5E-02	3.3E-02	2.8E-02	3.2E-02
3	2.8E-02	1.8E-02	2.1E-02	1.4E-02	1.7E-02	1.4E-02	1.8E-02
4	2.0E-02	1.5E-02	1.7E-02	1.6E-02	1.5E-02	1.6E-02	1.3E-02
5	1.9E-02	1.8E-02	1.3E-02	1.1E-02	1.3E-02	1.5E-02	1.1E-02
6	6.5E-02	4.0E-02	3.6E-02	3.1E-02	3.2E-02	3.5E-02	3.3E-02
7	2.7E-01	6.7E-02	3.9E-02	3.0E-02	3.6E-02	3.4E-02	1.5E-02
8	3.8E-01	1.7E-01	1.2E-01	1.0E-01	1.1E-01	1.1E-01	1.1E-01
9	2.5E-02	1.7E-02	1.8E-02	1.9E-02	1.6E-02	1.6E-02	1.9E-02

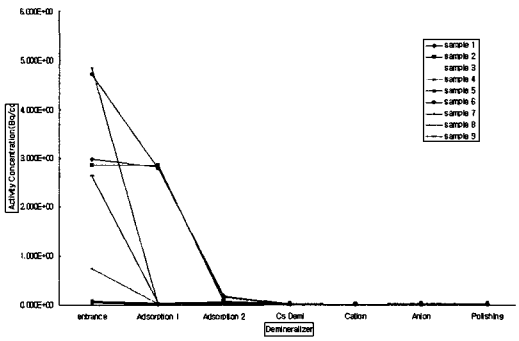
Fig 4. Process of Reducing Radioactivity Concentration (Cr^{51})



sample	entranc	Adsor. #1	Adsor. #2	Cs Demi	Cation	Anion	Polishing
1	1.1E-02	7.5E-03	2.2E-02	3.0E-03	0.0E+00	0.0E+00	0.0E+00
2	8.9E-02	2.1E-02	3.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
3	5.3E-03	1.7E-02	1.7E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
4	4.9E-01	5.1E-01	7.2E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5	4.8E-01	5.9E-03	3.4E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00
6	2.8E+00	6.3E-01	1.6E-01	4.1E-03	2.7E-03	5.2E-03	2.2E-03
7	3.1E-01	4.7E-03	1.5E-02	8.8E-04	5.9E-04	5.2E-04	5.5E-04
8	7.3E-02	2.1E-01	3.2E-01	4.7E-03	0.0E+00	0.0E+00	0.0E+00
9	7.9E-02	2.1E-01	3.2E-01	4.7E-03	0.0E+00	0.0E+00	0.0E+00

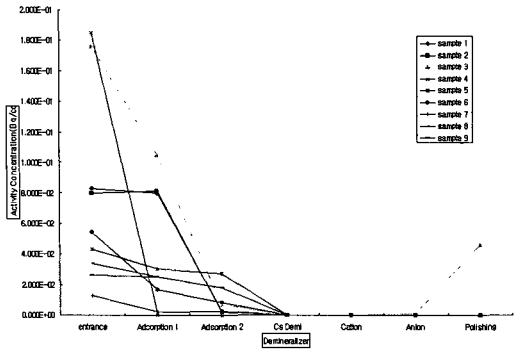
* 0.0E+00 is less than LLD(5.30E-04 Bq/ cc)

Fig 5. Process of Reducing Radioactivity Concentration (Mn^{54})



sample	entranc	Adsor. #1	Adsor. #2	Cs Demi	Cation	Anion	Polishing
1	3.0E+00	2.8E+00	1.6E-01	1.9E-02	1.8E-02	2.1E-02	1.1E-03
2	2.9E+00	2.9E+00	7.5E-02	1.9E-02	1.8E-02	2.0E-02	2.8E-02
3	1.2E-01	3.0E-02	3.5E-02	1.8E-02	1.2E-02	1.0E-02	9.4E-03
4	7.4E-01	2.5E-02	5.1E-02	8.3E-03	9.3E-03	8.0E-03	7.8E-03
5	5.0E-02	1.8E-02	3.4E-02	5.7E-03	5.8E-03	5.8E-03	5.4E-03
6	4.7E+00	2.8E+00	2.0E-01	1.4E-02	1.5E-02	2.0E-02	1.2E-02
7	4.9E+00	0.0E+00	1.5E-02	8.8E-04	5.9E-04	5.2E-04	5.5E-04
8	7.3E-02	4.0E-02	2.5E-02	1.3E-03	6.9E-03	4.0E-03	8.9E-04
9	2.6E+00	3.9E-02	6.1E-02	1.2E-02	1.3E-02	1.3E-02	1.1E-02

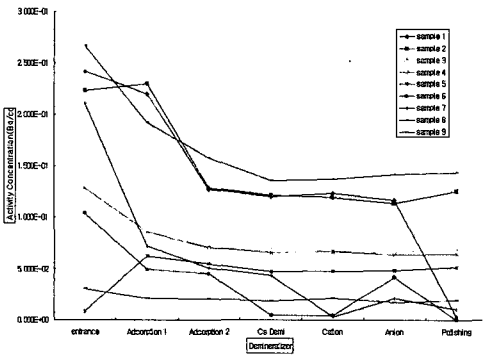
Fig 6. Process of Reducing Radioactivity Concentration (Co^{58})



sample	entranc	Adsor. #1	Adsor. #2	Cs Demi	Cation	Anion	Polishing
1	8.3E-02	8.0E-02	2.7E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00
2	8.0E-02	8.1E-02	2.2E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00
3	1.8E-01	1.0E-01	6.7E-03	0.0E+00	0.0E+00	1.1E-03	4.6E-02
4	1.8E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5	4.3E-02	3.0E-02	2.7E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
6	5.4E-02	1.7E-02	8.4E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00
7	1.3E-02	2.0E-03	2.4E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00
8	3.4E-02	2.5E-02	1.8E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
9	2.6E-02	2.5E-02	1.8E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00

* 0.0E+00 is less than LLD(2.77E-04 Bq/cc)

Fig 7. Process of Reducing Radioactivity Concentration Co^{60})



sample	entranc	Adsor. #1	Adsor. #2	Cs Demi	Cation	Anion	Polishing
1	2.4E-01	2.2E-01	1.3E-01	1.2E-01	1.2E-01	1.2E-01	3.4E-03
2	2.2E-01	2.3E-01	1.3E-01	1.2E-01	1.2E-01	1.1E-01	1.2E-01
3	1.1E-01	9.1E-02	7.1E-02	6.9E-02	6.7E-02	6.7E-02	7.0E-02
4	1.3E-01	8.7E-02	7.1E-02	6.6E-02	6.7E-02	6.4E-02	6.5E-02
5	8.5E-03	6.2E-02	5.5E-02	4.7E-02	4.7E-02	4.8E-02	5.1E-02
6	1.0E-01	4.9E-02	4.4E-02	4.4E-03	4.4E-03	4.1E-02	0.0E+00
7	2.1E-01	7.2E-02	5.0E-02	4.3E-02	3.0E-03	2.1E-02	1.0E-02
8	2.7E-01	1.9E-01	1.6E-01	1.4E-01	1.4E-01	1.4E-01	1.4E-01
9	3.0E-02	2.0E-02	2.0E-02	1.8E-02	2.1E-02	1.7E-02	1.9E-02

* 0.0E+00 is less than LLD(1.16E-03 Bq/cc)

Fig 8. Process of Reducing Radioactivity Concentration (Fe^{59})

of time, the radioactive levels of wastes will be high. Therefore, in case that the radioactive concentration at the entrance maintains similar concentration in contrast to design value, many studies to find out the effect of the resins in reducing the concentration level of radioactive corrosion products and fission products should be followed.

Evaporator Treatment Method

Samples collected at the beginning of the evaporation process in the form of liquid, and at the end of the process in the form of steam were analyzed. Nuclides detected through analysis were ranged from corrosion products such as Cr^{51}, Mn^{54}, Co^{58}, Fe^{59}, Co^{60}, Zn^{65}, Co^{57}, Zr^{95}, to fissile products such as, Cs^{137}, I^{131}, Also, according to the increasement of operation period, many nuclides of fissile products not detected through the IED method were found.

As shown on <Table 12>, the concentration of wastes before treatment was relatively high with a range from 1×10^{0}Bq/cc to 1×10^{3}Bq/cc, but analysis results were reduced to LLD at the end of the evaporation process. Most of decontamination factors were lower than LLD, which means that the evaporator is very effective in removing the radioactive materials in the liquid wastes.

In comparison with the decontamination capability of the selective IED, despite some possible errors because of the different concentration levels of the liquid wastes, of the equipment used, of the researcher, the evaporation process appeared to be much better in the treatment of liquid wastes.

4.3 The Amount of Liquid Wastes[4][5].

It appear significant differences in the amount of wastes from a PWRs in the U.S. that has

replaced its evaporation waste treatment system with the IED for equipment improvement.

<Table 13> shows the differences in the amount of wastes before and after the replacement. The same reduction in the waste amounts is expected to result in Korea after some years of operation.

Enriched liquid wastes are one eventual outcome of evaporating liquid wastes and sludge is the counterpart of IED, and spent resins and filters are generated from both the treatments. <Table 14> shows the amount of these wastes generated from the two treatments(The amount for IED given here is the designed amount as the plant is on its early stage of operation.).

The total amount of spent resins, sludges, and spent filters generated from the IED is 33.866m^3 (163 drums), and the amount of spent resins, of waste liquid enriched, and of spent filters generated from the evaporator is 48.30m^3 (232 drums). From above result, it can be known that the evaporating method in comparision with the IED one generates much waste water about 40%.

III. Conclusion

Table 12. Analysis Results on Decontamination Capacity in the Evaporator Treatment Method

	Activity Concentration of Liquid Wastes(Bq/cc)		Decontamination Factor	note
	before treated	after treated		
sample 1	1.57×10^{1}	under LLD	-	
sample 2	4.62×10^{1}	under LLD	-	
sample 3	3.31×10^{1}	$8.62^{\circ} \times 10^{-2}$	384	
sample 4	$2.35^{\circ} \times 10^{1}$	$3.45^{\circ} \times 10^{-2}$	681	
sample 5	2.09×10^{2}	$2.49^{\circ} \times 10^{-3}$	83936	
sample 6	2.26×10^{2}	under LLD	-	
sample 7	2.35×10^{2}	under LLD	-	
sample 8	7.77	under LLD	-	
sample 9	1.291×10^{3}	$5.674^{\circ} \times 10^{-2}$	22753	
sample 10	8.019×10^{1}	under LLD	-	

This study reviewed effect on the amount of radioactive materials discharged to off-site after treated by the evaporator and the IED, on dose to residents, on decontamination factors in each treatment method, and on the amount of radioactive wastes generated during the two processes.

The amount yearly emitted by radioactive nuclides was designed to 0.435 Ci in case of the evaporation treatment, and to 0.523 Ci in case of the IED. The IED is designed to generate more nuclides up to about 20% than the evaporator. However the actual amount of radioactive wastes generated from the IED was 2.32 times more than that generated from the evaporator.

Effective doses to residents were higher by the liquid wastes from the IED(6.47×10^{-6}mSv) than by those from the evaporator(2.97×10^{-6}mSv),

Table 13. The Amount of Wastes at U.S. Plants Before and After Adopting the Selective IED

Plant	The Amount of Wet Solid Wastes (㎥)		note
	before IED	after IED	
Callaway	24.78	15.6	
Millstone 2	85	15.28	
Salem 1&2	360	5.84	
Sequoyah 1&2	89.3	19.8	

Table 14. The Amount of Solid Radioactive Wastes from Each Liquid Waste Treatment

Treatment	Spent Resin(㎥)	Enriched Liquid Waste(㎥)	Sludge (㎥)	Spent Filter(㎥)	Total (㎥)
ion-exchange	5.096	-	8.49	20.28(note 1)	33.866
evaporator	11.10	12.5(note 2)	-	24.70	48.30

Note 1) As IED has no filters in treating liquid wastes, out of the total spent filters generated from the evaporator, 82% of them were assumed to have been used in the primary system(Yonggwang #5&6 FSAR).

Note 2) Enriched liquid wastes was calculated from the actual data of CE type plants[12].

which is similar to the designed doses.

Decontamination factors ranged from 3 to 230 in the IED and were less than LLD(lower limits of detection), which indicates that the evaporator is superior to the IED in decontamination. But the low radioactivity concentration levels at an early stage of plant operation calls for further studies on the decontamination capabilities of these two waste treatment methods at a later stage when the actual concentration level of liquid wastes is close to the designed level.

By the analysis result based on small amounts of wastes discharged to off-site, the evaporating method in comparision with the IED one showed superiority in treating liquid wastes, and presented low doses to residents, and had high decontamination factors. Also, it generated more wastes (48.30m^3 or 232drums) about 40% than the IED(33.866m^3 or 163drums), which means that the IED method is superior to the evaporating method in terms of the amount of wastes generated.

<Table 15> shows in order the result summarized. The amount of waste for IED and evaporator given here is only the designed amount as the Yonggwang #5&6 is on its early stage of operation.

Table 15. Summation of result

		Evaporation Method	Ion Exchange Method	Ratio	Note
Amount Released	Design	0.435 Ci/year	0.523 Ci/year	1 : 1.2	
	Result	0.473 mCi/total of ten months	1.098 mCi/total of ten months	1 : 2.32	
Doses to Residents (Whole body)	Design	4.66E-05 mSv/yr	2.10E-04 mSv/yr	1 : 4.5	
	Result	2.97E-06 mSv/yr	6.47E-06 mSv/yr	1 : 2.3	Effective Doses
Decontamination factors		384 ~ 84000	3 ~ 230	128 ~ 365 : 1	
Amount of Wastes Generated		48.30m^3 (232 drums)	33.866m^3 (163 drums)	1.4 : 1	

And as this study is based only on a comparison between the actual data and designed data on the evaporator, and on the IED, it cannot be said that the difference between the two methods shown in this study will be the same as the difference occurring during the actual waste treatment process.

Therefore, additionally many studies on this should be followed when plants have been operated long enough to generate sufficient actual data needed for more accurate comparison.

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