

A Scheme on Reduction of NPP Liquid Effluent Activity

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Abstract

Recently each domestic NPP has achieved zero release in liquid effluent activity. However, when looking back past experiences in world nuclear power operation, it is thought that another maximum activity reduction in the released liquid effluent just prior to falling it into environment, if possible, will bring a good effect in PA viewpoint. As the intent of applying the safety concept of diversity to conducting the above activity reduction measure, a scheme passing that effluent through the Deposition Bed just before discharging it into ocean environment was devised. Both Zeolite and "the mixed "Anthracite-sand" were derived as the main activity adsorption medium used in the Deposition Bed, and the schematic drawings of this Bed were presented.

Key Words : liquid effluent, MDA, zeolite, Cs & Co, absorption medium, deposition bed

1. Introduction

1.1. Terminology or Definition of Terms

- The Off-site Dose Calculation Manual(ODCM) is a guide for calculating the off-site resident exposure dose generated by gaseous/ liquid radioactive effluent discharged from a nuclear power plant.
- The Minimum Detectable Activity(MDA) is the smallest concentration of radioactive material in a samples that will be detected with 95% probability with 5% probability of falsely concluding that a blank observation represent a real signal.. For a particular measurement system :

$$MDA(Bq/unit wt) = \frac{2.71 + 4.66 * \sigma}{T * EFF * Y * wt}$$

where

- σ is the standard deviation($\sigma = \sqrt{B}/T_b$) (B: background count or a blank sample count , T_b : counting time),
- EFF is the counting efficiency,
- T is a sample counting time
- Y is the fractional radio-chemical yield,
- wt is the weight of the sample.
 - Non-Detectable(N/D) indicates a level where a radioactive nuclide can not be detected with its concentration level below MDA.
 - CCWD is an abbreviation of the Condenser Cooling Water Duct.
 - NPP ; Nuclear Power Plant

1.2. Liquid Effluent Management at the Domestic Nuclear Power Plants

1.2.1. Off-site Resident Exposure Dose Due to Releasing Noble Gas and Tritium

(1) Radioactive nuclides, which are usually contained in the radioactive effluent discharged from NPPs, are divided into three kinds: particulates, noble gas, and tritium. Statistically, the release amount of noble gas for one year from each unit of NPP has been below 0.5 Ci even though discharged, and almost little release of noble gas has been released as coming recently. This is because, as the half-life of noble gas is usually short, longer holding time in the liquid rad-waste hold-up tank makes more natural disintegration due to radioactive decay. More than 90% of released noble gas is Xe-133(half-life: 5.25 days), followed by Xe-135(half-life: 9.1 hours), Ar-41(half-life: 1.83 hours) and Kr-87(half-life: 76 minutes) in the

order of more amount. Only Xe-133 and Xe-135 occupies over 98% of the total amount. Due to its short half-life and characteristics of no deposition in the human body, thus having nothing to do with internal exposure problems. As for Xe-133 which occupies most of the total released amount, its γ ray energy on the average is as very small as 0.03 Mev. Thus noble gas presents a very low level hazard to the human body, causing little issue due to its generation in practical.

(2) Recently, Korea's LWRs(Light Water Reactors) and PHWRs(Pressurized Heavy Water Reactors) have annually discharged an average of 350 and 1,600Ci of tritium respectively at each unit. As the biological half-life of tritium(half-life ;12.3 years) in the human body is about 10 days just like ordinary water, and tritium belongs to the lowest hazard nuclide to the human body together with noble gas due to its extremely low radiation energy(pure β emitter whose maximum energy is 18.6 kev), the

Table 1. Near-by Resident Dose Per NPP Site by Liquid Effluent Discharge

		KoRi	Wolsong	YeongGwang	Ulchin
1995	Off-site resident dose(mrem)	7.84E-04	1.80E-03	2.20E-03	4.62E-02
	H-3 ratio(%)	44.9	92.3	79.3	83
1996	Off-site resident dose(mrem)	7.65E-04	2.08E-02	3.14E-02	2.16E-02
	H-3 ratio(%)	100	100	86.9	91
1997	Off-site resident dose(mrem)	5.90E-04	4.52E-03	3.54E-02	1.91E-02
	H-3 ratio(%)	100	100	99.4	100
1998	Off-site resident dose(mrem)	4.41E-04	4.77E-03	3.03E-02	3.51E-02
	H-3 ratio(%)	100	100	100	100
1999	Off-site resident dose(mrem)	2.01E-04	1.12E-02	2.17E-02	3.09E-04
	H-3 ratio(%)	100	100	100	100
Average H-3 ratio(%)		89	98.5	93.1	94.8
Total resident dose(mrem)		2.78E-03	4.31E-02	1.21E-01	1.22E-01
Unit-Year Total		20	11	19	13
Annual resident dose per unit(mrem)		1.39E-04	3.92E-03	6.37E-03	9.41E-03
Ratio of annual resident dose per unit to the annual 3 mrem criteria(%)		0.005	0.131	0.212	0.314

legally permissible discharge value of tritium is very large.

However, as the actual tritium discharge amount has accounted for over 99.9% of the total radioactivity amount in the liquid effluent, the tritium portion of nearby resident dose due to the released radioactivity of liquid effluent, as shown in Table 1 has become about 92% with LWRs and more than 98% with PHWRs respectively.

(3) The legal effective dose limit for off-site resident in the NPP exclusion area is 3 mrem/unit-year. The results on liquid effluent activity discharge over the period from 1995~99, was merely less than 0.4% of the legal dose limit even in case of largest discharged NPP unit. This implies that the liquid effluent has been managed to a very safe level.

(4) It is very difficult to remove tritium once it is contained in the released liquid effluent, hence the best way to control is to reduce the leakage of reactor coolant or moderator. When saying zero release of liquid effluent activity in any country, it means the values except for tritium.

1.2.2. Particulate Type Radioactivity

Therefore in the ALARA aspect, this paper focused on reducing particulate type nuclides, which have a relatively higher level hazard to the human body, and which are somewhat controllable in the aspect of activity release reduction, though having the much less activity than tritium in liquid effluent discharge. The various particulate nuclides exist in liquid effluent, and its activity concentrations are distributed to the level $0 \sim 10^{-3} \mu\text{Ci}/\text{cc}$. Of the entire particulates nuclides, the activities of Co-58, Co-60, Cs-137, Cs-134, & I-131 in the order of release quantity, occupy 0~99% of the total discharged activities, thus this paper especially sought to put emphasis on the way to eliminate Co and Cs isotopic

nuclides, excluding I-131 which has a short half-life.

This is considered as the management of operation, maintenance, and liquid effluent control at each NPP has been improved in overall.

Nevertheless, it was intended to devise any emphasis which should not be overlooked or new measure in treating liquid rad-waste in viewpoint of ALARA concept.

2. Improvement Scheme After the Liquid Effluent Discharge

2.1. Consideration

The level of hazard of gaseous and liquid effluent discharged from NPP to the nearby resident is expressed as off-site resident dose, which is estimated by ODCM. The off-site resident dose resulted on liquid effluent activity discharge over the period from 1995~99, was merely less than 0.4% of the legal dose limit even in case of largest discharged NPP unit. Moreover, in recent years, domestic NPPs have increasingly achieved "zero release of β - γ activity except for tritium". However, retrospectively the past experiences of each NPP in the world on effluent activity release, this paper sought the measure of reducing liquid effluent activity at the stage just before releasing into the final environment with low expenses in the ALARA aspect, being regardless of a successful records on effluent activity release of domestic NPPs and regulatory requirements.

The liquid rad-waste treatment system of NPP collects and processes liquid effluent which is continuously generated during either normal operation or maintenance outage. While the collecting and processing capacity of the above said system is limited, the case of sudden and large generation of highly contaminated liquid effluent, depending on some NPP conditions, does not

allow enough decontaminating time. Such a case causes inevitable discharging a very small amount of activity to environment.

Even the case that the activity level is measured to be very low or N/D which does not need decontamination in the liquid effluent also needs quite a lot of time to process liquid effluent in basic. As an example for this, let us look into the minimum time taken to discharge a full waste monitor tank without decontaminating treatment.

Let us suppose that this tank has a capacity of 30,000gal and the auxiliary tank pump has a flow rate of 280gpm.

- ① Tank contents recycling time
= twice the tank capacity/recycled flow rate
= $2 \times 30000\text{gal} / 280\text{gpm} = 214$ minutes
- ② Tank liquid grab sampling & analysing request ... 30 minutes
- ③ Liquid sample radioactivity measurement(50 minutes) and "chemical analysis to check if the general environmental requirements have been met"(60 minutes)" ... 110 minutes
- ④ Issuance of a liquid effluent discharge permit based on ③, report to the operating section, preparation work for discharge operation ... 30 minutes
- ⑤ Tank effluent discharge operation = $30000\text{gal} / 280\text{gpm} = 107$ minutes (*The tank cannot receive additional liquid effluent during discharge operation.)

$$\text{①} + \text{②} + \text{③} + \text{④} + \text{⑤} = 8 \text{ hours and } 11 \text{ minutes}$$

If the tank contents have to be decontaminated due to high-level activity, it would additionally require at least several hours. As the liquid effluent treatment process normally requires a lot of time, the time to measure activity of liquid effluent sample is limited to an average of 40 minutes, not allowing tens of thousands seconds as for measuring environmental samples. Thus a measurement time is to be set, below the MDA value(= $5.6 \times 10^{-7} \mu\text{Ci/cc}$) of all unidentified γ nuclides contained in liquid effluent, to an average of 40 minutes within the range of 1000~3000 seconds, though it more or less varies depending upon NPPs due to the difference of detector efficiency.

Accordingly, the MDA of liquid effluent sample can not become as low as that of environmental radioactivity sample, though the difference is a very little. The terminology N/D being used in sample activity measurement is not concept meaning equal to 'zero', while means the value existing somewhere between 0 to MDA, and in some cases, the value may come very close to the MDA. However, the MDA value itself is extremely small and N/D is practically zero, so the fact that liquid effluent with N/D value has been released in tens of times(20~100m³ per each release) does not mean that a meaningful amount of radioactivity have been released.

Table 2. Liquid Effluent Release Per 2 NPP Units Over the Last 3 Years(unit; m³)

	1995	1996	1997	Total
KoRi Unit 1,2	2,766	2,723	2,169	7,658
KoRi Unit 3,4	9,184	9,379	10,427	28,990
Wolsong Unit 1,2	22,536	17,557	20,747	60,840
YeongGwang Unit 1,2	12,062	15,588	14,000	41,650
YeongGwang Unit 3,4	12,289	14,912	15,678	42,879
Ulchin Unit 1,2	9,518	8,633	7,834	25,985
Total	68,355	68,792	70,855	208,002

In <Table 2> below, the average annual release amount per two units is calculated as $208,002 \div 13.5 = 15,406\text{m}^3$. Here why using 2 NPP units is that two units usually shares one discharge outfall. '13.5' indicates 13.5 times 2 NPP units.

If N/D value radioactivity which has been released at a 2 NPP units over 10 years is accumulated up, then will it amount to a radioactivity enough to affect on the sea environment around the NPP? Among the various nuclides contained in liquid effluent, the shorter half-life ones would be remained less as disappearing sooner. In this regard, let us assume more or less simply that only 3 nuclides of Co-60, Cs-137, and Cs-134 are released as follows:

- The N/D cases whose nuclides are not detected although some nuclides exists infinitesimally in each effluent release is 90%.
- MDA of those nuclides is $8 \times 10^{-8} \mu\text{Ci}/\text{cc}$ though it varies through NPPs.
- In case of N/D, the actual activity level is 70% of MDA.

Then, $15,408\text{m}^3/2 \text{ unit-year} \times 10 \text{ Years} \times 0.9 \times 8 \times 10^{-8}\text{Ci}/\text{m}^3 \times 0.7 \times 3(\text{number of nuclides}) = 2.33 \times 10^{-2}\text{Ci} = 23.3\text{mCi}$

In order to simply calculate the activity released for 10 years under N/D condition, it is assumed that those three nuclides have been released at once by 10mCi, 10mCi, and 3.3mCi respectively, and that each half-life of Co-60 and Cs-134 is 5 years and 2 years respectively. Then, total released activity comes to 10.6 mCi as follows.

- Co-60 : $10\text{mCi} \times (1/2)^2 = 2.5\text{mCi}$
- Cs-137 : $10\text{mCi} \times (1/2)^1 = 5\text{mCi}$
- Cs-134 : $3.3\text{mCi} \times (1/2)^5 = 0.1\text{mCi}$

In similar way, the N/D activity could be approximately calculated after an elapse of 15, 20, or 30 years. If N/D activity and/or "detection-recorded activity" in liquid effluent discharged from a NPP into the oceanic environment over a long period of time, most of those activity

becomes diffused or diluted along with ocean currents and tides, part of them becomes deposited on sediment or benthos at the bottom ground of sea around the discharge outfall. Although the amount of effluent activity released from NPP is of course entirely far away from the level affecting the near-by resident's health as presented in Section I-A-(2) of this paper, the activity level of sediment or benthos around the discharge outfall may be measured to be higher than the natural level, being resulted from the above mentioned long period release.

In this case, it may give a negative effect to PA(Public Acceptance) though its practical effect is negligible. Therefore this paper has attempted to seek the measure to eliminate most of released effluent activity in advance before this activity is deposited onto the environment around the discharge outfall. It was also attempted in the diversity viewpoint on nuclear safety to apply the effluent decontamination measure which is different from what is currently being applied in NPPs.

Accordingly, it was thought desirable to make released effluent passed through "the non-powered, artificially made absorption bed" just before this effluent reaches the discharge outfall. The activity absorption media used in the above absorption bed become replaced with a new media when its absorption capability approaches to saturation, and the spent absorption media become disposed depending on its condition and according to the relevant waste disposal regulations.

2.2. Selection of the Absorption Medium

2.2.1. Properties of Zeolite Used in Water Treatment

It is in the form of natural ore that zeolite is

Table 3. Ion Exchange Capability and Selectivity of Members of the Zeolite Family

Member	Cation exchange capability(meq ⁺ /g) (Anhydrous)	Ion exchange selectivity
Analcite	4. 95	Complicated by ion-sieving
Chabazite	4. 95	Tl>Cs>K>Ag>Rb>NH ₄ >Pb>Na = Ba>Sr>Ca>Li
Clinoptilolite	2. 64	Cs>K>NH ₄ >Na>Sr>Ca>Mg
Erionite	3. 86	Cs>Sr>K>Na
Mordenite	2. 64	Cs>K>NH ₄ >Ba>Sr>Ca>Mg
Synthetic(A-51)		Ag>Zn>Sr>Ba>Ca>Co>K>Cs

* is the unit of ion exchange capability. 1eq means the ability to exchange a 6.023 E+23. ion of 1 valence(+ or -). 1meq is equal to 1/1000eq.

produced and processed. It is often compounded in an artificial manner. Its product forms include ① powder(100-400 mesh), ② particle(20-50 mesh), and ③ pellet(1/16-1/32 inches in diameter and 1-5mm in length). Zeolite is a gigantic molecule composed of AlO₂/SiO₂ unit crystal. AlO₂/SiO₂, the minimum unit of zeolite, has a tetrahedron structure. O₂, interconnecting molecules, forms a reticular tetrahedron structure as shown on the left figure of Attachment 1. The spatial shape of the crystal structure of mordenite, a member of zeolite family, is shown on the right figure of Attachment 1.

Taking into account that Al has a valence of 3 and oxygen has a valence of -2, it can be said that each tetrahedron containing Al has an electrical charge of -1 on the whole. Cations, such as Na, K, Ca, Mg, and Sr, are present within the crystal, thus maintaining the electrical charge neutrality. They are so free in movement that they dominate the cation exchange of zeolite. As seen in the Figure mentioned above, zeolite has a great number of pores, most of which are filled with water. The kind and property of zeolite depend on the formation ratio of alumina(AlO₂) with silica(SiO₂). Properties such as acidity, thermal stability, ion exchange and ion selectivity are different according to the kind. In addition, the ratio of water molecule to cation and the sizes of

internal pores and finite pathways also affect the property of ion exchange. In case that alumina content is lower than silica content, selectivity becomes strong for 1 valence ions such as Cs, K, Ag, and NH₄. In case that alumina content is higher than silica content, selectivity becomes strong for 2 valence ions such as Sr, Ca, Co, and Ni. Zeolite is known to contain over 30 kinds of ores, such as chabazite, mordenite, erionite, phillipsite, clinoptilolite, and analcite. They are distributed in many countries, such as U.S.A., France, Germany, Italy, Bulgaria, Mexico, and Japan. Particularly, Ca-clinoptilolite and mordenite, known to have a great absorption capability, are distributed along the South-east Coast of Korean Peninsula, especially in the Young-il area. The table below shows the ion exchange capability and the selectivity of the natural zeolite family.

There have been numerous researches on the utilization of natural zeolite for liquid effluent treatment. The No.3 paper listed in the References finds that, the smaller the zeolite particle is, the greater the radioactivity absorption capability is. An experiment which used domestic natural zeolite with an average size of 0.9mm was made to treat simulated liquid rad-waste with Cs-137 concentration being 0.9μCi/cc and Co-60 concentration being 0.35μCi/cc, which had been

generated by adding radioactive isotopes into a typical liquid effluent tank water at Wolsong Unit 1. As a result of that, it was found that the zeolite column didn't reach the Cs-137 breakthrough even at CV of 250 while Cs-137 and Co-60 achieved a decontamination factor (DF) of 49 and 4.7 respectively. Based on this, it was estimated that a decontamination factor (DF) of over 10 could be achieved if 200 l of zeolite was used to treat 50 tons of liquid effluent. In addition, the above No. 3 paper presents other cases of reaching the breakthrough at 300CV and 800CV as the result of test to treat the liquid containing Cs, Co, and Sr with zeolite. According to the No.9 paper listed in the References, the Krsko NPP conducted the pre-treatment of its liquid effluent by using zeolite through a pH-10 column test and then it conducted the post-treatment of it by using $\text{Fe}(\text{OH})_3$ cohesive agents. As the result of this pre-treatment, most of Cs isotopes, 5% of Co isotopes and 85% of Mn-54 were decontaminated. Undecontaminated Co isotopes in colloidal form and other types of activity were removed during the post-treatment. As the result of the post-treatment, over 99.9% of Cs and Co isotopes, 99.95% of Mn-54, and 90% of Co-60/58 were decontaminated. This paper also presented that solidified zeolite with cement has a much higher strength and volume reduction ratio than solidified organic ion exchange resin. Zeolite has an excellent absorption property for cations such as Cs and K. It is also inexpensive and has a strong capability to selectively absorb a specific nuclide such as Cs and Sr under poor water quality conditions: e.g, a high level contamination concentration. It has been reported that zeolite, due to its selectivity for radioactive nuclides, raises the efficiency of ion exchange process, greatly reduces the amount of waste resin, and lasts 5-10 times the life of ion exchange resin.

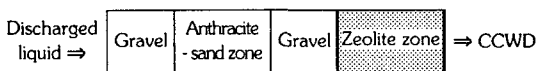
2.2.2. Pre-absorption of Suspended Solids

The above section presents the various properties of zeolite. As noted in Section II-2-a, the absorption medium should be selected so as to absorb Cs and Co isotopic nuclides. As zeolite has a strong selectivity for Cs isotopes, its capability for the absorption of Cs isotopic nuclides was verified through the mobile liquid rad-waste decontamination equipment performed at the Wolsong NPP. Currently in Korea, zeolite is being produced in great quantities at a price of 1,000 won per liter, which is available at a lower price than organic ion exchange resin. Zeolite is suitable as an absorption medium for removing Cs isotopic nuclides, though not having a great ion selectivity for Co isotopes. Meanwhile, eliminating suspended solids in liquid effluent to the utmost helps enhancing zeolite's cation absorption capability. More than 50% of all Co isotopes contained in liquid effluent can be treated using a $0.45\mu\text{m}$ filter while the others are present as dissolved in it. In most cases, dissolved Co exists in 2-valence cation state. Under certain conditions, however, it may have a valence of 3, 4, or 1. It also exists as anion at a pH of 11 or above. $\text{Co}(\text{OH})_2$ precipitations are generated in the aqueous solution at a pH of 8~9 and are present in the form of particle or colloid. Most troublesome thing is that they may combine with organic compounds contained in liquid effluent to form a complex, thus making the ion exchange difficult. Considering the complicated chemical properties of Co isotopic nuclides, it is recommended to use cohesive agents in eliminating Co and other organic suspended solids contained in liquid effluent. Contrary to the principles of equipment convenience and economy, however, this involves many complicated processes such as agitation for dissolution of cohesive agents, pH adjustment, and

floc removal. For the purpose of processing liquid effluent before its inflow into zeolite, it is desirable to use "a medium consisting of anthracite and sand compounded in the ratio of 1:1", which is also usable in the general water treatment. Anthracite, black-colored and porous, has a specific gravity of 1.35-1.7. Its composition includes 90-95% carbon, 2-4.5% hydrogen, and 3-5.5% nitrogen. Anthracite, with similar function to charcoal, is utilized as a filter for eliminating organic suspended solids including water impurities, colloid substance, and bacteria. Its price is around 450 won per litter.

2.2.3. Selection and Arrangement of the Absorption Medium

With the intention to reduce the movement of the 'anthracite-sand' compound layer mentioned in Section B, adjust the flow of liquid effluent, and conduct filtering before and after the inflow of liquid effluent into the medium, a shortish gravel zone is placed in front of and at the rear of the medium. Below is the conceptual diagram of the absorption medium through which the discharged liquid effluent passes in the deposition bed.



2.3. Guidelines for the Design of Deposition Bed

2.3.1. General

- The installation and operation of this facility shall have no adverse effect on the to manage and operate existing indoor liquid effluent treatment facility, and on the its performance.
- In case this facility is not operable for some reasons, the existing facility shall be used and operated as done in the past.

- When designing this facility, the convenience in installation, operation and maintenance shall be considered.

2.3.2. Connection to the Existing Pipeline

- The deposition bed inlet pipeline shall be installed by extending the pipeline which is connected, via the final release valve, to Condenser Cooling Water Duct(CCWD). The deposition bed outlet pipeline shall be connected to the near CCWD.
- The new pipeline shall have the same material properties and sizes as the existing pipeline.

2.3.3. Location & Unit of Installation

- A set for two NPP units shall be installed below the outdoor ground level near the liquid effluent discharge monitor.

2.3.4. Material Properties of the Absorption Medium

- It shall be less expensive and longer-lived than organic ion exchange resin.
- It shall maintain the average decontamination factor of over 5 for Cs and Co isotopes in the liquid effluent treatment process.

2.3.5. Liquid Effluent Flowing Through the Absorption Medium

- Liquid effluent shall flow in gravitational and at a very slow speed.
- Liquid effluent shall flow through the absorption medium.

2.3.6. Structure and Capacity

- It shall have a thin, flat structure and its floor

shall have a gentle slope.

- It shall have a high level of durability and incombustibility and shall be corrosion-resistant. Its surface shall be smooth, fine and impermeable. Also, it shall allow no radioactive permeation and shall facilitate decontamination.
- Liquid effluent shall not be flooded to outside of this structure except the outlet pipeline.
- The volume of the absorption medium shall be around 40 % of the working capacity of the largest liquid effluent discharge tank.
- It shall have a structure allowing easy loading and change of absorption medium.
- It shall be structured to facilitate medium efficiency & performance inspection activities, such as absorption medium sampling or visual examination.
- It shall not allow any incoming of precipitation including rain to be mixed with liquid effluent.

2.4. Design Concept for the Deposition Bed

2.4.1. Structure Material

- It shall be built of the same reinforced concrete as the floor of the NPP reactor building or auxiliary building.
- Painting shall be done in the same specifications as the floor of the NPP reactor building or auxiliary building.

2.4.2. Absorption Medium

- As stated above, the absorption medium shall consist of an anthracite-sand medium, gravels(5 ~25mm in diameter) and zeolite.
- Zeolite shall be of the same kind as that used for the selective ion exchange facility, which is scheduled to be installed at the KoRi and Ulchin NPPs.
- Anthracite and sand shall be of the same kind as

those used for water treatment at the general power plants.

- Thin and strong wire mesh shall be placed over both the entering and exiting sides of the zeolite zone so as to prevent the movement of the medium.
- In order to increase the contact between the medium and the liquid effluent, the upper surface of the absorption medium shall be wave-like.
- The average depth of the absorption medium is shown in the Figure of Attachment 3.

2.4.3. Connection to the Existing Pipeline

- The deposition bed inlet pipeline shall be installed by extending the pipeline which is connected to, via the final release valve, to Condenser Cooling Water Duct(CCWD). The extended pipeline shall have the same material properties and sizes as the existing pipeline.
- The deposition bed outlet pipeline shall be connected to the near CCWD.
- A conceptional diagram of the connection to the existing pipeline is shown in Attachment 2.

2.4.4. Outline Drawing of Structure

- Based on the discharged liquid effluent tank capacity of 100 m³ (Non-scale)
- For contents, see the drawings in Attachment 2 and 3.

3. Conclusion

3.1. Discharge Management of Liquid Effluent Activity

The legal effective dose limit for off-site resident in the NPP exclusion area is 3 mrem/unit-year. The results on liquid effluent activity discharge

over the period from 1995~99, was merely less than 0.4% of the legal dose limit even in case of largest discharged NPP unit. This implies that the liquid effluent has been managed to a very safe level. Noble gas became little problem when dividing liquid effluent activity into 3 parts, that is, noble gas, tritium, and particulates. Tritium occupies more than 99.9% of total liquid effluent activity, and the resident dose portion by tritium become 92% in case of LWRs and more than 98% in case of PHWRs respectively. But there is no way to remove tritium once it is contained in the released liquid effluent, hence the only way to control is to reduce the leakage of reactor coolant or moderator.

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Nevertheless, it was intended to devise any emphasis which should not be overlooked or new measure in treating liquid rad-waste in viewpoint of ALARA concept. Therefore this paper focused on reducing particulate type nuclides, which have a relatively higher level hazard to the human body, and are somewhat controllable in the aspect of activity release reduction, though having the less activity than tritium in liquid effluent discharge. Of the various particulate nuclides existed in liquid effluent, this paper especially put emphasis on the way to eliminate Co and Cs isotopic nuclides, which are discharged much and have long half-life.

3.2. Installation and Operation of the Deposition Bed

So far, some management and attention on the released liquid effluent have been paid and

conducted in each aspect of both environment monitoring and PA(Public Acceptance) improvement. In terms of PA improvement, a large-scale fish and shell farm which includes seed culturing and breeding, using NPP thermal discharge water, has been installed and operated since 1999 within the Wolsong Plant site. Prior to this, a fish farm was set up in 1995 at the Yeong-Gwang Plant site, and has been operated since then. It has been accepted for PA improvement to pay a pretty amount of expenses for the installation and operation of such a large fish farm. In addition to the above mentioned aspects, this paper sought the measure of reducing liquid effluent activity at the stage just before releasing into the final environment with low expenses.

The liquid rad-waste treatment system of NPP collects and processes liquid effluent which is continuously generated during either normal operation or maintenance outage. While the collecting and processing capacity of the above said system is limited, the case of sudden and large generation of highly contaminated liquid effluent, depending on some NPP conditions, does not allow enough decontaminating time. Such a case causes inevitable discharging a very small amount of activity to environment.

Even the case that the activity level is measured to be very low or N/D which does not need decontamination in the liquid effluent also needs quite a lot of time to process liquid effluent in basic. Thus the time to measure activity of liquid effluent sample is limited to an average of 40 minutes, not allowing tens of thousands seconds as for measuring environmental samples.

Accordingly, the MDA of liquid effluent sample can not become as low as that of environmental radioactivity sample, though the difference is a very little. The terminology N/D being used in sample activity measurement is not concept

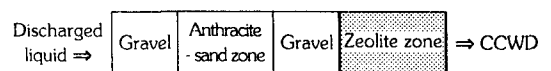
meaning equal to 'zero', while means the value existing somewhere between 0 to MDA, and in some cases, the value may come very close to the MDA. However, the MDA value itself is extremely small and N/D is practically zero, so the fact that liquid effluent with N/D value has been released in tens of times(20~100m³ per each release) does not mean that a meaningful amount of radioactivity have been released. When N/D activity and/or "detection-recorded activity" in liquid effluent have been discharged from a NPP into the oceanic environment over a long period of time, most of those activity are diffused or diluted along with ocean currents and tides, part of them are deposited on sediment or benthos at the bottom ground of sea around the discharge outfall.

As a result of this, the activity level may be measured to be higher than the natural level. In this case, it may give a negative effect to PA(Public Acceptance) though its practical effect is negligible. Therefore it is thought desirable to make most of released effluent activity adsorbed at "the non-powered, artificially made deposition bed" in advance before this activity is deposited onto the environment around the discharge outfall. The activity absorption media used in the above deposition bed become replaced with a new media when its absorption capability approaches to saturation, and the spent absorption media become disposed depending on its condition and according to the relevant waste disposal regulations.

As noted in Section I-2 and Section II-1 above, the absorption medium should be selected so as to capture Cs and Co isotopic nuclides. Zeolite absorbs cations well and has a strong selectivity for Cs isotopes, and thus zeolite is also used in the selective ion exchange facility for absorbing Cs isotopic nuclides. The Zeolite is produced in a pretty amount in domestic and its price is cheaper

than that of organic ion exchange resin. So the zeolite is suitable as an absorption medium for removing Cs isotopic nuclides, while it does not have a great ion selectivity for Co isotopes. Meanwhile, various suspended solids in liquid effluent should be removed to the maximum in order to enhance the cation absorption capability of zeolite. More than 50% of all the Co isotopes contained in liquid effluent exist in a state which can be removed by 0.45μm filter, while the remaining dissolved Co exists mostly in a 2-valence cation state, but sometimes it becomes to a cation of 3-, 4-, or 1-valence, or is able to exist even as anion state, depending on the conditions. In addition, Co isotopes can exist as particulates or colloidal types as Co(OH)₂ is precipitated in an aqueous solution over pH 8 ~9. The most troublesome case is that they may combine with organic compounds contained in liquid effluent to form a complex which makes the ion exchange difficult.

In order to remove Co and other organic suspended solids in liquid effluent before their flowing into zeolite, considering the complicated chemical properties of Co isotopic nuclides, "a medium compounded of anthracite and sand by the ratio of 1:1", which is also utilized in the general water treatment, is to be used. Anthracite, a black-colored and porous filtering medium, is being used for a similar usage as charcoal. A shortish gravel zone is to be set at the front and rear side of the above-said compound medium. The absorption medium passage which the released liquid effluent flows through at the deposition bed is summarized as the following conceptual diagram.



In here the 'anthracite-sand compound medium' is to absorb activity contained in organic

suspended solids etc., especially focusing Co isotopic nuclides. The shortish gravel zone is to prevent the anthracite-sand compound medium from flowing out, adjusts the flow of liquid effluent, and will function filtering more or less. As the liquid effluent entering the zeolite zone is in a state that much of organic suspended solids are already removed, the zeolite medium is expected to effectively absorb various cations, especially like Cs isotopic nuclides.

At Section II-4 of this paper, the design concepts of the deposition bed are illustratively presented on the basis that the liquid effluent tank has the capacity of 100m³. But the design of more concrete deposition bed should incorporate each plant's liquid effluent treatment facility design and the NPP site condition.

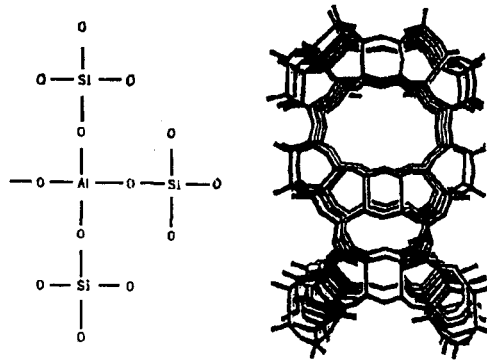
The deposition bed, if installed, will be zoned and managed as RCA(Radiologically Controlled Area) on characteristic like "to treat liquid rad-waste", even though radioactive contamination spread is rarely possible. It is also necessary to establish and implement the deposition bed operating procedures which covers and regulates various matters such as absorption medium sampling and its period, sample analysis and evaluation, absorption medium replacement, facility integrity surveillance, disposal of used asorption medium etc... In conclusion, this deposition bed was presented as new idea, and also as an option of measures to improve PA being related with liquid effluent release.

Attached:

1. The Tetrahedron Structure of Zeolite
2. The Conceptional Diagram of the Connection of the Deposition Bed to the Existing Pipeline & The Plan of the Deposition Bed
3. Cross Section of the Deposition Bed Structure

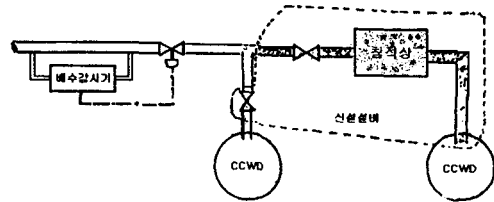
Attachment 1

- The Tetrahedron Structure of Zeolite

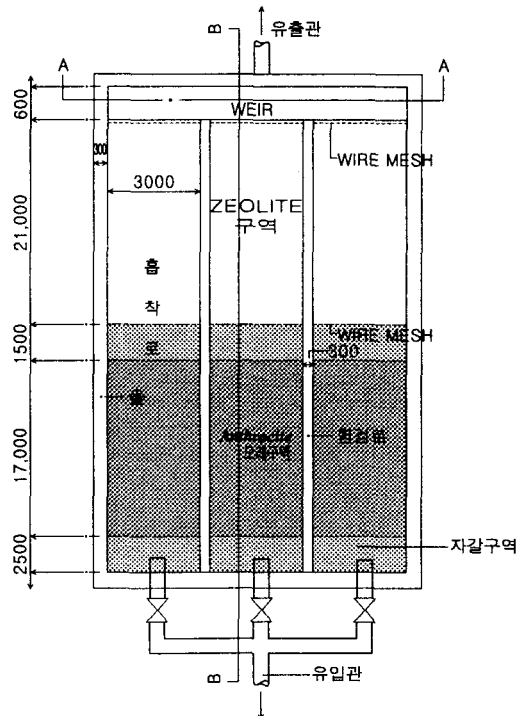


Attachment 2

- The Concept of the Connection of the Deposition Bed to the Existing Pipeline



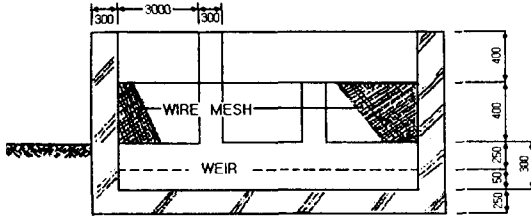
- The Plan of the Deposition Bed (Based on 100 m³ capacity of the liquid effluent discharge tank) - Non-Scale



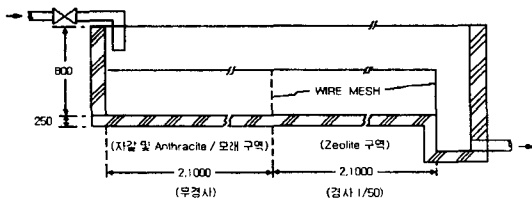
Attachment 3

References

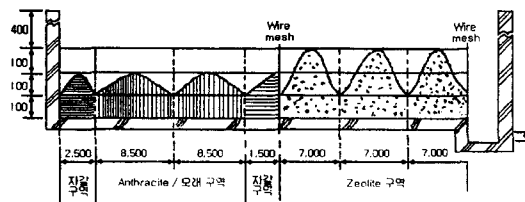
- The Width Cross Section of the Structure - Non-scale



- Length Cross Section of the Structure - Non-scale



- Cross Section of the Asorption Medium- Non-scale



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