Multi-nuclide Removal Equipment

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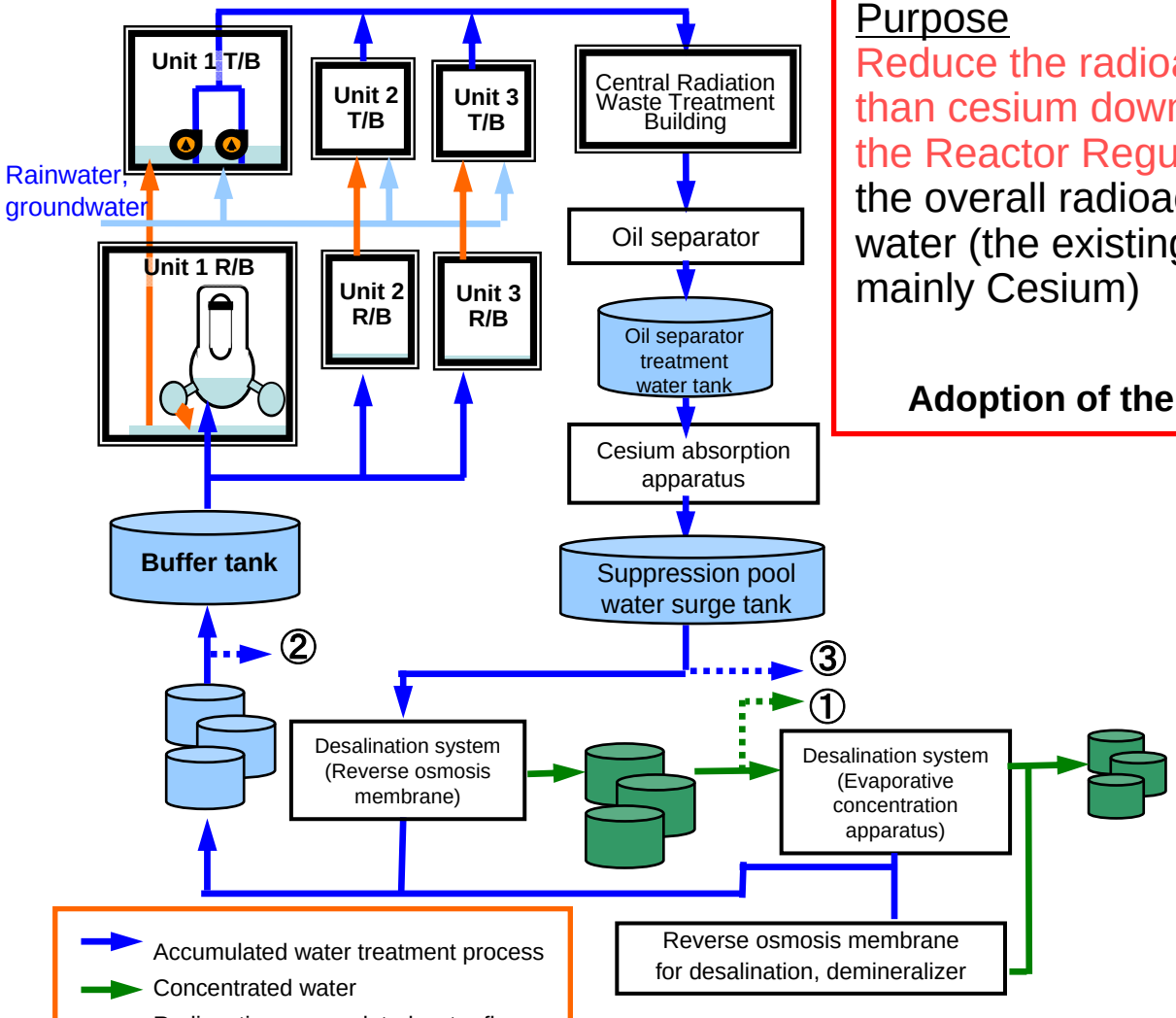
Tokyo Electric Power Company

東京電力
TEPCO

1. Installation of Multi-nuclide Removal Equipment

Multi-nuclide Removal Equipment

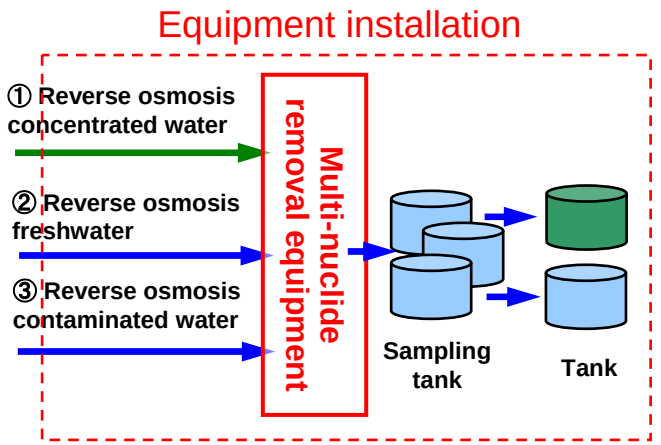
The document issued on February 27, 2012 was partially revised.



Purpose

Reduce the radioactivity densities of nuclides other than cesium down to the density limits specified by the Reactor Regulation* in order to further reduce the overall radioactivity density of the treatment water (the existing water treatment facilities remove mainly Cesium)

Adoption of the multi-nuclide removal equipment

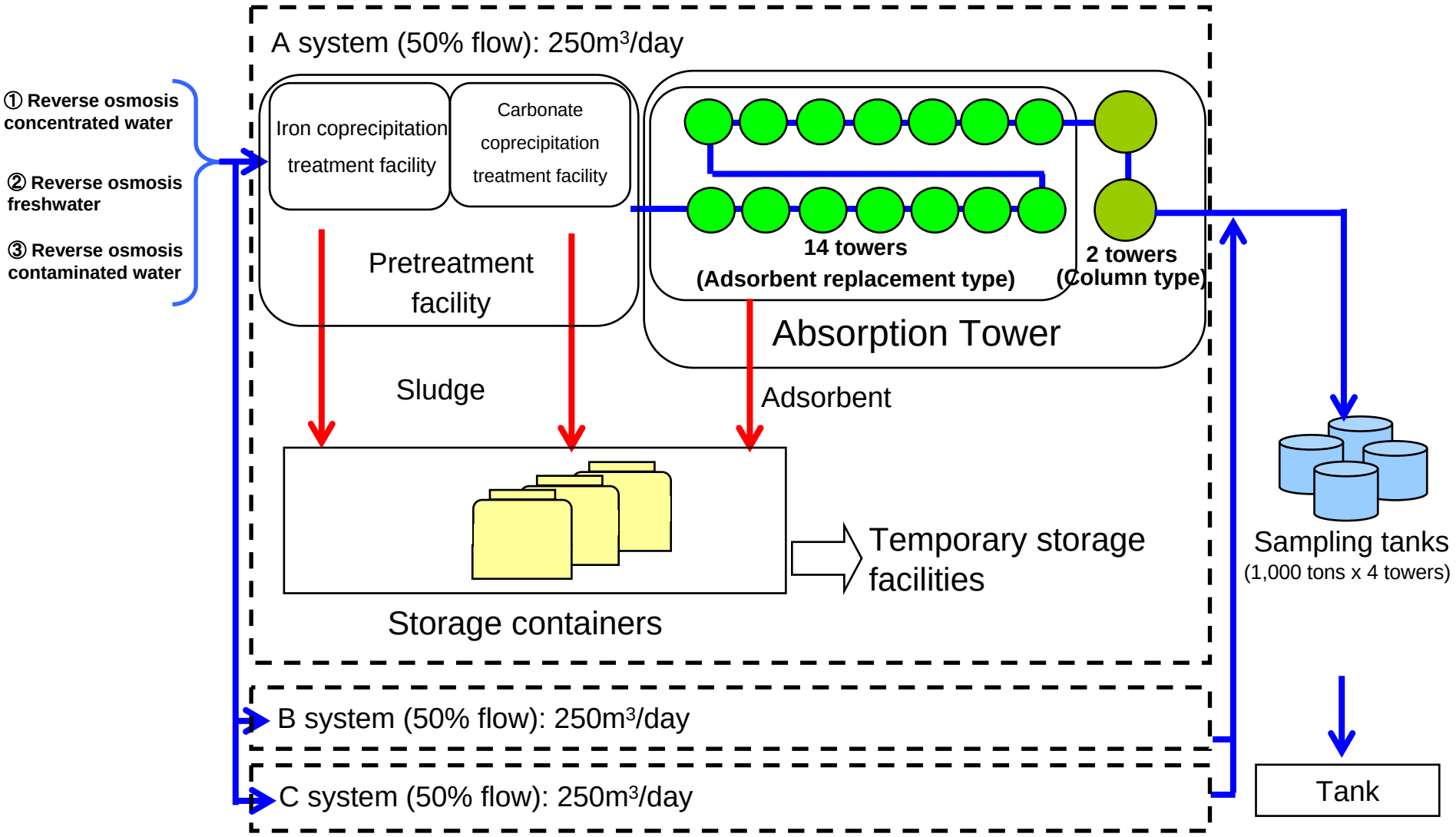


*Rules for the Installation, Operation, etc. of Commercial Power Reactors

2. Outline of the Multi-nuclide Removal Equipment (ALPS)

ALPS（Advanced Liquid Processing System）

Excerpt from the document issued on February 27, 2012



2. Outline of the Multi-nuclide Removal Equipment (ALPS)

Excerpt from the document issued on February 27, 2012

1. System Structure

-50% two lines operation (500m^3/day)

-One of the lines is suspended or on standby when replacing adsorbent.

2. Main Equipment Components

[Pretreatment facilities]

-Iron coprecipitation treatment facility: Removes α nuclides, Co-60, Mn-54, etc.

-Carbonate coprecipitation treatment facility: Removes the adsorption blockade ion (Mg, Ca, etc.)

[Absorption Towers]

-Absorption towers (Adsorbent replacement type, column type): Removes radioactive materials utilizing appropriate adsorbents (active carbon, artificial mineral, chelate resin etc.).

[Waste storage container handling equipments]

-Crane

-Waste transfer pumps and pipes

3. Basic Test Results

Basic Test Results of the Mule-nuclide Removal Equipment (1/2)

The subjects of the basic test were ① Reverse osmosis concentrated water and ③ reverse osmosis contaminated water with high radioactivity densities. The result shows that the radioactivity densities of all the target nuclides (62) can be reduced down to the density limits specified by the Reactor Regulation.

-The radioactivity densities of γ nuclides (45) were reduced to less than the detection limits (ND) .
-The radioactivity densities of 5 out of 8 β nuclides were reduced to less than the detection limits (ND) and it was confirmed in all β radiation measurement that the densities can be reduced to approx. one-millionth to ten-millionth of the original densities. However, further improvement of equipment will be necessary since some β nuclides (Sr-89, Sr-90 and Y-90) were still detected.
-All β radiation measurement result shows that a substantial amount of naturally derived K-40 was detected as well as Sr-89, Sr-90 and Y-90.
-All α radiation measurement result shows that the radioactivity densities of α nuclides (9) are all below the detection limits (ND) and sufficiently low compared to the density limits specified by the Reactor Regulation.

3. Basic Test Results

Basic Test Results of the Mule-nuclide Removal Equipment (2/2)

Unit: Bq/L

		Density limit	① Reverse osmosis concentrated water		③ Reverse osmosis contaminated water	
			Before treatment	After treatment	Before treatment	After treatment
γ nuclides	Cs-134 (Approx. 2 yrs)	60	2500	ND < 0.27	4300	ND < 0.26
	Cs-137 (Approx. 30 yrs)	90	3900	ND < 0.32	6100	ND < 0.30
	Mn-54 (Approx. 310 days)	1000	45000	ND < 0.12	14000	ND < 0.11
	Co-58 (Approx. 71 days)	1000	1200	ND < 0.12	ND < 540	ND < 0.11
	Co-60 (Approx. 5 yrs)	200	14000	ND < 0.12	3900	ND < 0.16
	Ru-103 (Approx.40 days)	1000	510	ND < 0.14	ND < 970	ND < 0.13
	Ru-106 (Approx.370 days)	100	7800	ND < 1.1	35000	ND < 1.1
	Sb-124 (Approx.60 days)	300	270	ND < 0.28	ND < 490	ND < 0.27
	Sb-125 (Approx. 3 yrs)	800	140000	ND < 0.37	63000	ND < 0.38
	Ba-140 (Approx.13 days)	300	ND < 1700	ND < 0.51	ND <3400	ND < 0.48
All β			43000000	68	230000000	31
All α			0.46	ND < 0.066	16	ND < 0.066

* “ND” indicates that the measurement result is below the detection limit (indicated as “<○○”).
* The half-life of each nuclide is provided in parenthesis.

3. Basic Test Results

Summary of Basic Test Results

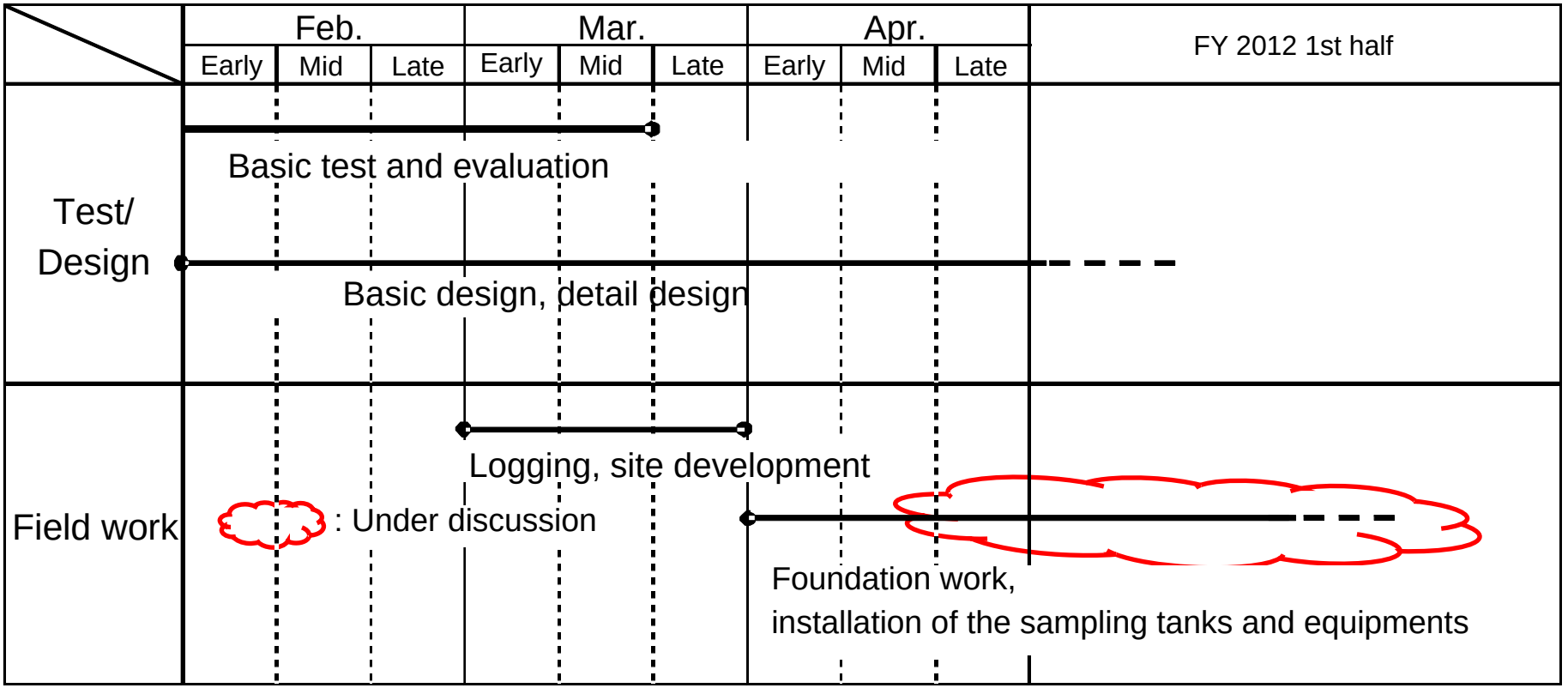
-As a result of the basic test done on the reverse osmosis concentrated water and reverse osmosis contaminated water, the radioactivity densities of the 62 nuclides subject to removal were reduced to less than the density limit specified by the Reactor Regulation after the treatment process.

-The radioactivity densities of other nuclides specified by the Reactor Regulation (except for tritium) were assessed below the density limit at the time of selecting removing nuclides.

-Based on the test results, the radioactive waste disposal method will be considered taking into account the properties of the secondary radioactive waste to be generated.

Reference 1: Future Schedule

Equipment Installation Schedule



Reference 2: Sample Selection

Selection of Samples (Nuclides Subject to Removal)

Calculate the estimated radioactivity densities of the fission products (FP nuclides), transuranic elements and corrosion products (CP nuclides) the in the accumulated water approx. a year after the earthquake. The nuclides with the estimated radioactivity densities which exceed one-hundredth of the density limit specified by the Reactor Regulation were selected as samples for the basic test.

-Fission products (FP nuclides): Nuclides generated by atomic fission and radioactive decay (Cs, Sr, etc.)

- Transuranic elements: Generated by reactor operation (Such as Pu)

-Corrosion products (CP nuclides): Radioactivated substances sourced from corrosion of equipments, devices, piping, etc. of reactor plant compositions

Reference 3: Basic Test Result Summary

Basic Test Result Summary

Category		Nuclide	Category		Nuclide	Category		Nuclide	Category		Nuclide
FP nuclides	1	Rb-86	FP nuclides	17	Sn-126	FP nuclides	33	Ce-141	Transuranic elements	49	Pu-240
	2	Sr-89		18	Sb-124		34	Ce-144		50	Pu-241
	3	Sr-90		19	Sb-125		35	Pr-144		51	Am-241
	4	Y-90		20	Te-123m		36	Pr-144m		52	Am-242m
	5	Y-91		21	Te-125m		37	Pm-146		53	Am-243
	6	Nb-95		22	Te-127		38	Pm-147		54	Cm-242
	7	Tc-99		23	Te-127m		39	Pm-148		55	Cm-243
	8	Ru-103		24	Te-129		40	Pm-148m		56	Cm-244
	9	Ru-106		25	Te-129m		41	Sm-151	CP nuclides	57	Mn-54
	10	Rh-103m		26	I-129		42	Eu-152		58	Fe-59
	11	Rh-106		27	Cs-134		43	Eu-154		59	Co-58
	12	Ag-110m		28	Cs-135		44	Eu-155		60	Co-60
	13	Cd-113m		29	Cs-136		45	Gd-153		61	Ni-63
	14	Cd-115m		30	Cs-137		46	Tb-160		62	Zn-65
	15	Sn-119m		31	Ba-137m	Transuranic elements	47	Pu-238			
	16	Sn-123		32	Ba-140		48	Pu-239			

: Below the density limit specified by the Reactor Regulation and the detection limit (ND) (γ nuclides: 45, β nuclides: 5)
The radioactivity densities of 9 α nuclides (Pu-238, 239, 240, Am-241, 242m, 243, Cm-242, 243, 244) were below the detection limit (ND) as a result of all α radiation measurement, and sufficiently low considering the individual density limit specified by the Reactor Regulation.

: Detected though the density is below the limit specified by the Reactor Regulation (3β nuclides)

Reference 4: Basic Test Result (Detailed Measurement Data) (1/6)

Basic Test Result of the Multi-nuclide Removal Equipment

Unit: Bq/L

No.	Nuclide (Half-life)	Density limit	①Reverse osmosis concentrated water		③Reverse osmosis contaminated water		Remark
			Before treatment	After treatment	Before treatment	After treatment	
1	Rb-86 (Approx. 19 days)	300	ND < 3500	ND < 1.5	ND < 4800	ND < 1.4	
2	Sr-89 (Approx. 51 days)	300	11000000	0.79 *1	51000000	0.65 *2	Detection limit (ND) *1: 0.18 *2: 0.18
3	Sr-90 (Approx. 29 years)	30	16000000	4.7 *3	120000000	2.6 *4	Detection limit (ND) *3: 0.066 *4: 0.061
4	Y-90 (Approx. 64 hours)	300	16000000	4.7 *5	120000000	2.6 *6	Detection limit (ND) *5: 0.066 *6: 0.061
5	Y-91 (Approx. 59 days)	300	ND < 73000	ND < 52	ND < 130000	ND < 47	
6	Nb-95 (Approx. 35 days)	1000	ND < 330	ND < 0.13	ND < 540	ND < 0.14	
7	Tc-99 (Approx. 210,000 years)	1000	17	ND < 0.40	6.9	ND < 0.40	
8	Ru-103 (Approx. 40 days)	1000	510	ND < 0.14	ND < 970	ND < 0.13	
9	Ru-106 (Approx. 370 days)	100	7800	ND < 1.1	35000	ND < 1.1	
10	Rh-103m (Approx. 56 minutes)	200000	510	ND < 0.14	ND < 970	ND < 0.13	
11	Rh-106 (Approx. 30 seconds)	300000	7800	ND < 1.1	35000	ND < 1.1	

Reference 4: Basic Test Result (Detailed Measurement Data) (2/6)

Unit: Bq/L

No.	Nuclide (Half-life)	Density limit	①Reverse osmosis concentrated water		③Reverse osmosis contaminated water		Remark
			Before treatment	After treatment	Before treatment	After treatment	
12	Ag-110m (Approx. 250 days)	300	ND < 430	ND < 0.13	ND < 760	ND < 0.13	
13	Cd-113m (Approx. 15 years)	40	ND < 430	ND < 0.13	ND < 760	ND < 0.13	
14	Cd-115m (Approx. 45 days)	300	ND < 430	ND < 0.13	ND < 760	ND < 0.13	
15	Sn-119m (Approx. 290 days)	2000	140000	ND < 0.37	63000	ND < 0.38	
16	Sn-123 (Approx. 130 days)	400	ND < 57000	ND < 25	ND < 68000	ND < 22	
17	Sn-126 (Approx. 100,000 years)	200	140000	ND < 0.37	63000	ND < 0.38	
18	Sb-124 (Approx. 60 days)	300	270	ND < 0.28	ND < 490	ND < 0.27	
19	Sb-125 （約3年）	800	140000	ND < 0.37	63000	ND < 0.38	
20	Te-123m (Approx. 120 days)	600	ND < 710	ND < 0.12	ND < 1700	ND < 0.15	
21	Te-125m (Approx. 58 days)	900	140000	ND < 0.37	63000	ND < 0.38	
22	Te-127 (Approx. 9 hours)	5000	ND < 47000	ND < 18	ND < 94000	ND < 24	

Reference 4: Basic Test Result (Detailed Measurement Data) (3/6)

Unit: Bq/L

No.	Nuclide (Half-life)	Density limit	①Reverse osmosis concentrated water		③Reverse osmosis contaminated water		Remark
			Before treatment	After treatment	Before treatment	After treatment	
23	Te-127m (Approx. 110 days)	300	ND < 47000	ND < 18	ND < 94000	ND < 24	
24	Te-129 (約70分)	10000	ND < 7500	ND < 12	ND < 14000	ND < 10	
25	Te-129m (Approx. 34 days)	300	ND < 13000	ND < 4.2	ND < 22000	ND < 3.5	
26	I-129 (Approx. 16,000,000 years)	9	ND < 1500	ND < 0.90	ND < 1900	ND < 0.90	
27	Cs-134 (Approx. 2 years)	60	2500	ND < 0.27	4300	ND < 0.26	
28	Cs-135 (Approx. 3,000,000 years)	600	3900	ND < 0.32	6100	ND < 0.30	
29	Cs-136 (Approx. 13 days)	300	ND < 310	ND < 0.11	ND < 580	ND < 0.11	
30	Cs-137 (Approx. 30 years)	90	3900	ND < 0.32	6100	ND < 0.30	
31	Ba-137m (Approx. 3 minutes)	800000	3900	ND < 0.32	6100	ND < 0.30	
32	Ba-140 (Approx. 13 days)	300	ND < 1700	ND < 0.51	ND < 3400	ND < 0.48	
33	Ce-141 (Approx. 32 days)	1000	ND < 1300	ND < 0.30	ND < 3100	ND < 0.29	

Reference 4: Basic Test Result (Detailed Measurement Data) (4/6)

Unit: Bq/L

No.	Nuclide (Half-life)	Density limit	①Reverse osmosis concentrated water		③Reverse osmosis contaminated water		Remark
			Before treatment	After treatment	Before treatment	After treatment	
34	Ce-144 (Approx. 280 days)	200	ND < 5000	ND < 0.98	ND < 14000	ND < 0.89	
35	Pr-144 (Approx. 17 minutes)	20000	ND < 47000	ND < 220	ND < 81000	ND < 180	
36	Pr-144m (Approx. 7 minutes)	40000	ND < 47000	ND < 220	ND < 81000	ND < 180	
37	Pm-146 (Approx. 6 years)	900	ND < 680	ND < 0.18	ND < 1300	ND < 0.18	
38	Pm-147 (Approx. 3 years)	3000	ND < 530	ND < 0.40	ND < 980	ND < 0.37	
39	Pm-148 (Approx. 5 days)	300	ND < 430	ND < 0.13	ND < 820	ND < 0.11	
40	Pm-148m (Approx. 41 days)	500	ND < 430	ND < 0.13	ND < 820	ND < 0.11	
41	Sm-151 (Approx. 87 years)	8000	ND < 530	ND < 0.40	ND < 980	ND < 0.37	
42	Eu-152 (Approx. 13 years)	600	ND < 2000	ND < 0.53	ND < 3800	ND < 0.48	
43	Eu-154 (Approx. 9 years)	400	ND < 530	ND < 0.40	ND < 980	ND < 0.37	
44	Eu-155 (Approx. 5 years)	3000	ND < 530	ND < 0.40	ND < 980	ND < 0.37	

Reference 4: Basic Test Result (Detailed Measurement Data) (5/6)

Unit: Bq/L

No.	Nuclide (Half-life)	Density limit	①Reverse osmosis concentrated water		③Reverse osmosis contaminated water		Remark
			Before treatment	After treatment	Before treatment	After treatment	
45	Gd-153 (Approx. 240 days)	3000	ND < 1100	ND < 0.40	ND < 2200	ND < 0.37	
46	Tb-160 (Approx. 72 days)	500	ND < 1100	ND < 0.40	ND < 2200	ND < 0.37	
47	Pu-238 (Approx. 88 years)	4	*7	*8	*9	*10	Refer to all α measurement result
48	Pu-239 (Approx. 24,000 years)	4	*7	*8	*9	*10	Refer to all α measurement result
49	Pu-240 (Approx. 6,600 years)	4	*7	*8	*9	*10	Refer to all α measurement result
50	Pu-241 (Approx. 14 years)	200	-	ND < 1	-	ND < 1	
51	Am-241 (Approx. 430 years)	5	*7	*8	*9	*10	Refer to all α measurement result
52	Am-242m (Approx. 150 years)	5	*7	*8	*9	*10	Refer to all α measurement result
53	Am-243 (Approx. 7,400 years)	5	*7	*8	*9	*10	Refer to all α measurement result
54	Cm-242 (Approx. 160 days)	60	*7	*8	*9	*10	Refer to all α measurement result
55	Cm-243 (Approx. 29 years)	6	*7	*8	*9	*10	Refer to all α measurement result

Reference 4: Basic Test Result (Detailed Measurement Data) (6/6)

Unit: Bq/L

No.	Nuclide (Half-life)	Density limit	①Reverse osmosis concentrated water		③Reverse osmosis contaminated water		Remark
			Before treatment	After treatment	Before treatment	After treatment	
56	Cm-244 (Approx. 18 years)	7	*7	*8	*9	*10	Refer to all α measurement result
57	Mn-54 (Approx. 310 days)	1000	45000	ND < 0.12	14000	ND < 0.11	
58	Fe-59 (Approx. 45 days)	400	ND < 600	ND < 0.24	ND < 780	ND < 0.22	
59	Co-58 (Approx. 71 days)	1000	1200	ND < 0.12	ND < 540	ND < 0.11	
60	Co-60 (Approx. 5 years)	200	14000	ND < 0.12	3900	ND < 0.16	
61	Ni-63 (Approx. 100 years)	6000	1400	ND < 9.9	570	ND < 10	
62	Zn-65 (Approx. 240 days)	200	ND < 630	ND < 0.25	ND < 820	ND < 0.26	
All β			43000000	68	230000000	31	
All α			0.46 *1	ND < 0.066 *2	16 *3	ND < 0.066 *4	

*7, 8, 9, 10: All α radioactivity densities include 9 α nuclides (Pu-238, 239, 240, Am-241, 242m, 243, Cm-242, 243, 244).

ND: The measurement result is below the detection limit. The detection limit indicated as "<○○".