Summary of major responses to the RFI (classified into items and categories) [Topic 3 : Removal of radioactive materials from the seawater in the harbor]

Particularly-Requested Technologies for Contaminated Water Issues		Responses to the RFI				Trends of technical information in the responses	Expert Review Panel's comments
Items	Sub items	Categories		No.	Key words		
(1) Removal of radioactive cesium and strontium in seawater	Suction method (Pump up ⇒ purification; ex situ)	A: Adsorption	Sorbent (proposals mainly on a suction method)	4, 12, 17, 23, 37, 45, 126, 131, 138, 139, 221, 222, 329, 353, 370, 394, 470, 505, 514, 537, 738, 753, 773	Inorganic sorbent (minerals etc.)	The proposals regarding to removal of radioactive Cs & Sr in seawater are classified into the following Sub items. - Pumping up and purifying the seawater from harbor - In-situ purification in the harbor - Others For the water purification with pumping-up operation, proposals are categorized as follows;. A:absorption B:precipitation C:separation D:evaporation E: biological method As for the proposals on adsorption, 50 proposals were about sorbent, and 7 were about adsorption processing system. Among these proposals, multiple proposals were based on actual plant operations. There were proposals (No. 266, 466) based on the processing results of radioactive Cs & Sr in seawater, indicating issues concerning upsizing, higher efficiency, and improvement of Sr adsorption capacity. Concerning the proposals on sorbents, they are still in the stage of validation in laboratories, in the experiment condition, and the information on the result is varied. Regarding precipitation, there are 13 proposals about the cohesion processing, 5 about the coprecipitation processing, and 6 about other processing methods. Furthermore, there were proposals (No. 347, 640, 750) based on the overseas plant results. There are 5 proposals for the reverse osmosis membrane and for various processing methods of the separation. There was a proposal about evaporation. There was a suggestion based on the results of using a microbe that treats radioactive effluent including oil.	The R&D efforts such as feasibility studies on the development of efficient sorbents for Cs and Sr removal from the actual seawater are required. It is important to understand radiochemical state of the seawater sufficiently at first, and to assess the removal technologies. The removal of the radioactive ionic Cs from the seawater is not an issue since sorbents have been almost proved to be efficient in the seawater. However, the removal of the radioactive Sr is known to be theoretically difficult, and it takes a long term to further purify the seawater because of its huge volume. Due to this, selection of materials that efficiently remove radioactive materials from the seawater should be made as a short-term measure. In addition, R&D efforts on the development of promising techniques to remove radioactive Cs and Sr should also be increased in a continuous manner. In view of the existence of stable (non-radioactive) Sr and the concentration of Ca and Mg in the seawater, it is realistic to adopt proposals which are grounded on scientific evidence, and consider the amount of precipitant added in the co-precipitation method. There is some promising sorbent for recovery of Sr in the seawater. Not only the co-precipitation based process but also the absorption process should be selected and preferentially applied from the viewpoint of ensuring sufficient decontamination efficiency and minimizing the volume of secondary waste generated. An ex-situ approach for an immediate application (pump-up and purification) may be desirable compared to an in-situ approach because the target seawater cannot be stirred enough, and the purification speed is low in an in-situ approach. In addition, the co-precipitation process should not be applied for an in situ purification since the active precipitate could settle at the bottom of the sea. It will result in difficulties of deposit collection. When evaluating the applied technologies, it is necessary to keep in mind that the harbor is connected to the open sea because it is only divided by a silt fence. Closure of the harbor should be considered as an option because without closing the harbor from the open sea, the unrealistic amount of stable Sr should be removed from the seawater. If it is hard to close the entire harbor from the open sea because of the unknown amount of groundwater inflow or from an economic aspect, it is effective to close only the open conduit which has a high concentration of radioactive materials, and purify the seawater within it. The biological-based processes could represent an innovative way to treat the contaminated water. Further study should be undertaken in a mid-long term perspective.
			Sorbent (proposals mainly on a suction method)	7, 201, 348, 359	Organic absorbent (ion exchange)		
				16, 22, 635, 712	Polymer, Gel, Rubber		
				49, 172, 256, 560	Prussian blue		
				234, 249, 312, 368, 411, 414	Porous medium, Nanostructure		
				97, 260, 490	Sorbent made from plant		
				8, 27, 295, 523, 535, 614	Others (charcoal, manganese dioxide, metal oxide, film, electric adsorption)		
			Processing method	265, 266, 288, 447, 466, 714	Adsorption processing by plant system (No.447,466 proposals include sorbents)		
				775	Adsorption processing with stirring water in tanks		
		B: Precipitation	Flocculation process	14, 55, 144, 268, 461, 463, 495, 497, 501, 521, 531, 518, 567	Flocculation method		
			Coprecipitation process	269, 347, 489, 640, 750	Coprecipitation processing using sulfate etc.		
			Other methods	101, 163, 235, 267, 538, 569	Others (multilayered carbon nanotube, special ozone water, new species of bacterium, silicic acid solution + calcium hydroxide silicate, electrochemistry etc.)		
		C: Separation	Reverse osmosis membrane	6, 203, 398, 450, 464	Reverse osmosis membrane		
			Other than the above	1, 26, 118, 140, 166, 198, 327, 539, 573, 682	Impurities separator, Water detoxification, Filtration technique, Photocatalyst + electrolyze, Affinity-type aperture diffusion method, Particle formation by an electric charge and the vacuum bubble, Sludge recovery, Solvent extraction, Magnetic separation		
		D: Evaporation		57, 66, 116, 291, 686	Concentration by evaporation		
				440, 633	Membrane distillation		
		E: Biological method		374, 375	Heterotrophic bacteria		
	In situ purification	F: Adsorption	Sorbent (proposals mainly on an in-situ purification method)	125, 364, 399, 437 438, 516, 618	Prussian blue	There were many proposals about in-situ adsorption processing in the harbor. A lot of proposals were about sorbents such as a non-woven fabric and particle. Furthermore, there were 13 proposals on using sorbents of powder, zeolite and mineral. In addition to 3 proposals on installing an adsorption fiber under seawater, two proposals (No.276, 408) with test results using the seawater were presented. For the purification of spent fuel pool, there were 3 proposals (No.315, 415, 641) of sinking filters in a pool. In addition, there were 2 proposals (No. 632, 695) of setting up an adsorption process unit on the floating body facility in the harbor. There was a proposal (No. 74) of the precipitation processing that utilized a mineral reaction. In addition, there was a proposal of precipitating seawater in a drainage system and settling deposits from the treatment process in the harbor, and a proposal of drawing radioactive Cs, Sr deposits on the seabed for precipitation work on the ocean. Furthermore, there was a proposal of employing biological process using microbe and bacterium.	
				119, 276, 408	Fiber sorbent		
				120, 544, 545, 711, 770	Zeolite		
				76, 77, 403, 579, 684	Minerals		
				212, 356, 362	Adsorbing powder		
			Processing method	315, 415, 641	Submersible removal unit		
				632, 695	Adsorption processing by plant system (on the ocean)		
				10, 20,650	Others (seaweed, stirrer with sorbent)		
		G: Precipitation	Flocculant	74	Biophosphate mineral		
			Processing method	381, 522	Drainage channel: flocculation and precipitation, Harbor: sedimentation basin		
		H:Biological method		40, 584	Aerobic microorganism, Special bacterium		

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Items	Sub items	Categories	No.	Key words		
	Others	I:Non-radioactivation	59, 275, 479	Beta-decay promotion, nuclear segregation, electric field water by alternating current	Proposals were as follows; - Offering of technology for the removal of radioactive Cs and Sr - Provision of information about process engineering - Proposal on leak simulation - Proposal on the implementation of property analysis in the seawater	
		J:Water processing proposal based on results	351, 384, 462, 759, 768	Available technology, Process engineering		
		K:Approach by civil engineering technology	296, 317, 679	Groundwater management, Leak simulation		
		L:Property investigation of seawater	764	Property analysis (chemical, physical, and physicochemical)		
(2) Installation of silt fence that absorbs radioactive materials		M-1: Silt fence adopting an sorbent	248	Zeolite sheet	The technical proposals about the silt fence which adsorbs radioactive material are categorized as follows; - Silt fence which incorporates sorbents (6 proposals) - Silt fence applying biological process (2 proposals) - Others (inner panel) (1 proposal) With respect to sorbents, similar to "Removal of radioactive cesium and strontium in the seawater", many proposals are on the validation stage in laboratories, and information regarding to the experiment condition and the results are varied. The adsorption effects on radioactive Cs, Sr of the silt fence which incorporates sorbents and biological process are on the validation stage in the laboratory. In addition, there was a proposal on the structure of fence, installation method, and the secondary waste treatment.	Silt fence technologies could be promising as complementary solutions for in-situ purification, although no large scale experience has been reported yet. Note that it is difficult to get high decontamination factor by silt fence technologies, compared with the water treatment systems. In order to verify the applicability to a large amount of seawater in the harbor, it is required to perform R & D such as feasibility studies on the actual seawater condition of Fukushima.
			264	Non-woven fabric (Prussian blue, zeolite)		
			415	Non-woven fabric (absorbent for Cs, Sr)		
			494	Adsorption curtain (absorbent for Cs, Sr), Sink-float-type silt fence		
			506	Sorbent composed of zeolite and cellulose of used paper		
			694	Zeolite filter, organic and inorganic fiber sheet		
		M－2: Silt fence applying biological process	283	Microorganism, hollow double-helical model carrier		
			496	Bio-fence (shellfish, seaweed etc.)		
		M－3:Others	703	Zeolite concrete panel (inner panel)		
(3) Others	Monitoring	N:Dose rate measurements of seawater	436	Optical fiber	Proposals, which were not included in the items above, i.e. "(1) Removal of radioactive Cs & Sr in seawater", "(2) Installation of silt fence that absorbs radioactive materials", but related to purification of seawater in the harbor, were classified and arranged into the following five items. - Monitoring - Secondary waste treatment - Harbor closing - Sludge treatment - Others Proposals on monitoring include dose rate measuring technologies for seawater, and they have been developed to the actual application level. For the treatment of secondary wastes, which will be generated in large quantities during the work of seawater processing, there were 6 technical proposals about waste immobilization technologies, and 3 about volume reduction technologies. The waste immobilization technologies proposed were in practical use at overseas plants (No. 99, 656). Other immobilization technologies were on a laboratory level. The proposals on harbor closing include the installation of harbor closing gate which allows ships to pass through it. There were several technical proposals on the treatment of sludge on the seabed soil. In addition, there were suggestions on an idea level but with innovative details.	A monitoring technology, which allows to obtain a radioactive level in seawater by converting from a dose rate, is required. The process design and the verification of treatment technologies for secondary wastes are required in accordance with the wastes from the treatment process actually applied, including a comparison study between the proposed and conventional technologies. The necessity of harbor closure shall be studied and concluded at first, followed by confirmation of installation time frame and comparison of proposed technologies with conventional methods. The treatment or immobilization measures for sludge on the seabed and that floating in seawater in the harbor should be studied as mid-long term countermeasures, despite the fact that the necessity of sludge treatment is low because the seabed surface area with relatively high radiation has already been covered.
			533	ROV (Remotely operated vehicle) with γ－radiation detector		
	Treatment of secondary waste	O:Immobilization	35	Sodium tetraborate		
			656	Geopolymer		
			747	Immobilization of sediment by freezing		
			99, 757, 774	HIP (High Isostatic Pressure)		
		P:Volume reduction	21	Filter press		
			187, 701	Dewatering		
	Harbor closing	Q:Fence	205	Underwater separation curtain, Impermeable sheet		
			467	Double gate at the harbor entrance (of the ship trafficable type)		
			649	Silt fence at harbor entrance, Steel water gate		
	Sludge treatment	R:Separation	258, 642	Dewatering filter, Centrifugal separation		
		S:Dredging	402, 465, 527	Purification of the dredged soil		
	Others	T:Ideas	220, 628, 636	Storage, Meteorite power, Power of the earth crust plate		