Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

A Study on Environmental Effect Around the Site for the Establishment of a Marine Healing Center

Young Bin Cho[1,2], Beob Woong Yoon[2], Ju-Hyung Yun[3*]

[1]*Ph.D Candidate, Department of Electrical Engineering, Incheon National University, Korea, binswon@ktr.or.kr*
[2]*Researcher, Water Environmental Analysis Center, Korea Testing & Research Institute (KTR), Korea, yun0460@ktr.or.kr*
[3]*Professor, Department of Electrical Engineering, Incheon National University, Korea, juhyungyun@inu.ac.kr*

In October 2017, the Ministry of Oceans and Fisheries finally selected Goseong-gun (Gyeongsangnam-do), Uljin-gun (Gyeongsangbuk-do), Wando-gun (Jeollanam-do), and Taean-gun (Chungcheongnam-do) as cooperative local governments for discovering marine healing resources and fostering industries, and is promoting the construction of marine healing centers. In this research, the impact of the surrounding environment on seawater and soil in four regions has been evaluated with the establishment and operation of the Marine Healing Center. The environment standards to manage the marine healing center have been tabulated and analyzed, and the domestic standards corresponding to ISO 17680 (Tourism and related services - Thalassotherapy Service Requirements), and the international standardization (ISO) standard for marine healing centers, were compared and analyzed. An environmental analysis was conducted in the seawater and soil in four regions. The analyzed detection items were compared and tabulated with domestic and foreign environmental standards, and compared with mapping the Potentially Affected Fraction (PAF) of monitoring data of coastal seawater and soil for 10 years, which can provide the insight on the effect of environmental conditions of seawater and soils around the seashore in South Korea. This study would contribute to the systematic management of marine healing resources in the long term by preparing standards for the environmental impact of the surrounding seawater and soil on the establishment and operation of marine healing centers and by establishing environmental standards.

Keywords: Maritime Healing Service, Maritime Healing Facilities and Equipment, Quality Management, Marine environment

1. Introduction

The global wellness market, based on relaxation, is rapidly expanding and emerging as a major industry. The wellness market is continuing to expand due to changes in tourism trends, aging, and the growth of nature-oriented leisure activities. This expansion is driving the tourism industry to shift towards forms of travel focused on wellness, relaxation, and healing. According to a report released by the Global Wellness Institute in 2017, the economic value of the wellness market grew from $3.7 trillion in 2015 to $4.5 trillion in 2018, with an average annual growth rate of 6.7%. The wellness market is now valued at 5.3% of global economic output and is considered a major industry. Yeung, (2017) In particular, the wellness tourism is one of the fastest growing sectors in the wellness industry, estimated to be worth $436 billion out of total global wellness market. Maria, (2023) In particular, after the COVID-19 pandemic, the healing market, including marine healing, is expected to gradually expand Djaba et. al (2022). As hygiene and safety are emphasized, along with the rise of healing, and a preference for nature, the healing market is expected to continue to grow. In line with this, Marine healing industry expands the use of marine resources for the healing of the mind and body, beyond the use of existing marine areas as tourist destinations. The medical efficacy of Korea's major marine therapeutic resources has been clinically verified by many specialized medical institutions Ministry of Oceans and Fisheries (2020). Furthermore, scientific validation has been conducted internationally, and based on this, marine therapeutic resources are being used in the wellness industry and the bio industry (Ministry of Oceans and Fisheries, 2020; Soudeh et. al, 2020; Byeon et. Al, 2023). Overseas, France and Germany recognize the preventive and rehabilitative effects of marine healing and reimburse the cost of use through social security. Japan is growing autonomously by the private sector, such as local universities and marine healing facilities, without government intervention in marine healing. In other words, Europe is approaching marine healing from the perspective of disease prevention and treatment, while Japan is approaching it from the perspective of tourism and resource development. In Korea, the healing policy has been developed mainly around the forest healing policy using forest resources since the 2000s. The domestic marine healing policy started in earnest with the selection of partner local governments and the enactment of the "Marine Healing Resources Act". The enactment of the "Marine Healing Resources Act" in 2020 provided a legal and institutional basis for the promotion of marine healing policies, and the "Marine Healing Industry Activation Plan" set out the basic direction for the promotion and execution of marine healing policy Luo et. al (2018) . After the COVID-19 pandemic, it is expected that the tourism trend will change and the healing and leisure culture enjoyed in natural spaces will become more widespread. In October 2017, the Ministry of Maritime Affairs and Fisheries selected Goseong-gun (Gyeongsangnam-do), Ulleung-gun (Gyeongsangbuk-do), Wando-gun (Jeollanam-do), and Taean-gun (Chungcheongnam-do) as cooperative local governments for the discovery and development of marine healing resources. The ministry is also promoting the "Research on the Discovery and Commercialization of Marine Healing Resources for the Activation of Marine Industries (hereinafter referred to as Marine Healing R&D Project)". Therefore, the certification of facilities and service quality for the systematic management and operation of marine healing centers should be urgently revised based on the review of domestic and foreign regulations and operating cases related to the introduction functions of marine healing centers The establishment of a certification system for marine healing policy projects through the review of marine healing resources and facility conditions will contribute to the provision of marine healing services to the public as well as the activation of marine healing industries. In this study, a study on the environmental impact of the surrounding marine water and soil due to the construction and operation of marine healing centers, using marine water and soil from four regions was conducted. This study aims to propose management standards by selecting detailed analysis items for the use of major healing resources used in marine healing centers (seawater: surface, deep water/marine organisms: seaweed / marine minerals: salt, mud, sand, marine stones, etc.) and analyzing physical, chemical, and composition analysis and feasibility of use.

2. Management Environment Standards for Marine Healing Centers

2.1. Analysis of Management Standards for Marine Healing Resources

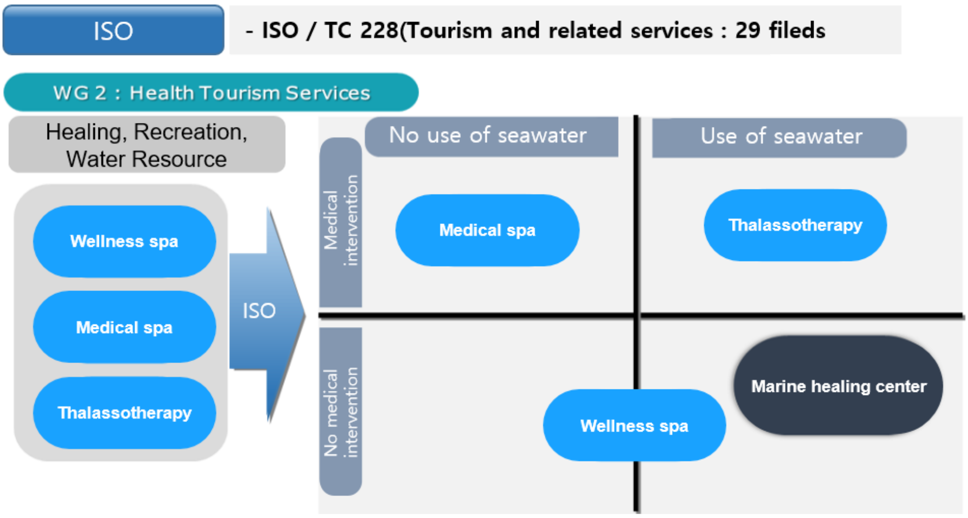

Figure 1: Classification of marine healing facilities according to international standards (ISO)

The international standard for marine healing centers is ISO 17680 (Tourism and related services - Thalassotherapy Service Requirements). This standard (1) includes definitions of marine healing facilities and service requirements, (2) requires environmental research to ensure that marine healing centers are located in a healthy natural environment, taking into account the impact of seawater used in accordance with national regulations, and (3) regulates the qualifications and other requirements for employees working in marine healing facilities. It (4) specifies standards and management for healing resources (seawater, seaweed, and mud), and (5) includes regulations on hygiene, customer service, and control.

2.2 Investigation of Evaluation Items for Domestic Seawater (Or Water Quality) Standards

According to the data for domestic standards, seawater or water quality in marine environment is regulated in accordance with the standards of Article 2 (Environmental standards) of the Enforcement Decree of the Framework Act on Environmental Policy and Article 8 of the Marine Environment Management Act. As summarized in Tables 1 to 4, water quality is divided into living environment standards (3 items, such as pH, total coliform count, and solvent-extractable oil), ecological base standards, marine ecosystem protection standards (short-term and long-term standards for 8 heavy metals, such as copper, lead, and mercury), and human health protection standards (19 items, such as heavy metals). As shown in Table 5, swimming pool water quality standards are regulated in accordance with the standards of Schedule 6 of Article 23 (Safety and sanitation standards) of the Enforcement Decree of the Law on the Establishment and Use of Sports Facilities, and in the case of using seawater, the standards of Article 2 (Environmental standards) of the Enforcement Decree of the Framework Act on Environmental Policy are followed. As shown in Table 6, the water quality standards for public baths are regulated in accordance with the standards of Schedule 2 of Article 4 (Water quality standards for bath water in public baths) of the Enforcement Decree of the Public Sanitation Act.

Table 1: living environment standards

Parameter	pH	Total Coliforms (Total Coliforms/10 mL)	Solvent extraction oil (mg/L)
Criteria	6.5 ~ 8.5	≤ 1,000	≤ 0.01

Table 2: Ecology-based seawater quality standards

Grade	Water Quality Index
I(very good)	Less than 23
II(good)	24 - 33
III(commonly)	34 - 46
IV(bad)	47 - 59
V(very bad)	More than 60

Table 3: Marine ecosystem protection standards

:(unit: µg/L)						
Metals	**Cu**	**Pb**	**Zn**	**As**	**Cd**	**Cr^{6+}**
short-term criteria*	3.0	7.6	34	9.4	19	200
long-term criteria**	1.2	1.6	11	3.4	2.2	2.8
* short-term criteria : Comparative application with one-time observations ** long-term criteria : Comparative application with the annual average value(data surveyed for at least four seasons)						

Table 4: Human health protection standards

Area	Parameter	Criteria(mg/L)
all waters	Hexavalent chromium	0.05
	Arsenic	0.05
	Cadmium	0.01
	Lead	0.05
	Zinc	0.1
	Copper	0.02
	CN	0.01
	Mercury	0.0005
	PCB	0.0005
	Diazinon	0.02

	Parathion	0.06
	Malathion	0.25
	1.1.1-Trichloroethane	0.1
	Tetrachloroethylene	0.01
	Trichloroenthlyene	0.03
	Dichloromethane	0.02
	Benzene	0.01
	Phenol	0.005
	ABS	0.5

Table 5: Safety and hygiene standards - swimming pool [8]

Classification		**Criteria**
G. Swimming pool business	Free residual chlorine	0.4 mg/l - 1.0 mg/l
	pH	5.8 - 8.6
	Turbidity	Less than 1.5 NTU
	Potassium permanganate	Less than 12 mg/L
	Total coliforms	No more than 2 positive test results among 5 test samples of 10 mL of water
	Arsenic	Less than 0.05 mg/L
	Mercury	Less than 0.007 mg/L
	Aluminum	Less than 0.5 mg/L
	Combined available residual chlorine	Not more than 0.5 mg/L

Table 6: Bath water quality standards and water quality inspection method pool

Classification		**Criteria**
Raw water	Color	5 degrees or less
	Turbidity	1 Nephelometric Turbidity Unit (NTU) or less
	pH	5.8–8.6
	Potassium permanganate	Less than 10 mg/L
	Total coliforms	Should not be detected in 100 mL
Bath water	Turbidity	1.6 Nephelometric Turbidity Unit (NTU) or less (If a product approved to be used in a public bath under other laws is used, the turbidity generated by the product is not counted.)
	Potassium permanganate	Less than 25 mg/L

	Coliform		Should not be detected more than 1 in 1 mg (In this case, if the number of colonies of bacteria formed on each plate is 30 or less, the average number of colonies of bacteria on the plate inoculated with the original solution is calculated, and the number of colonies must be indicated as a number per 1 mL.)
	In case of filtering by circulating the bathwater	In the case of not conducting chlorine disinfection	Legionella bacteria should not be detected more than 1,000 Colony Forming Unit (CFU)/L.
		In the case of conducting chlorine disinfection	Legionella bacteria should not be detected more than 1,000 CFU/L, and the free residual chlorine concentration should be between 0.2 mg/L and 0.4 mg/L.
In case of using seawater as bath water	Chemical Oxygen Demand (COD) (mg/L)	Raw water	Less than 2
		Bath water	Less than 4
	pH		7.8–8.3
	Total coliforms (Total coliforms/100mL)		Less than 1,000

Meanwhile, ISO 17680 provides microbiological criteria (E. coli, Salmonella, cholera, Pseudomonas aeruginosa, Staphylococcus aureus, and aerobic organisms) for seawater used in marine therapy, as well as physical criteria (total salinity, pH, and average density) for seawater, heavy metal criteria (cadmium, arsenic, lead, hydrogen, selenium, and chromium) for seawater, and component criteria (10 items including sodium and magnesium) for seawater. Detailed criteria are summarized in Tables 7 to 10.

Table 7: Microbiological criteria for seawater used in marine therapy- Annex A

Point of sampling	**Germs**	**Acceptable limits**
Water intake points	Total coliforms	≤ 500 ufc/100 mL
	Termo-tolerant coliforms	≤ 100 ufc/100 mL
	Intestinal enterococci	≤ 100 ufc/100 mL
	Salmonella	absence/1 L
	Choleric vibrios	absence/1 L
	Enteroviruses	absence/10 L
Pool waters	Total coliforms	≤ 50 ufc/100 mL
	Termo-tolerant coliforms	≤ 10 ufc/100 mL
	Intestinal enterococci	≤ 10 ufc/100 mL
	Staphylococ cusaurens	absence/100 mL
	Pseudomonas aeruginosa	absence/100 mL

Drinking water	Total coliforms	absence/100 mL
	Thermo-tolerant coliforms	absence/100 mL
	Intestinal enterococci	absence/100 mL
	Sulfito reducing anaerobies	absence/50 mL
	Pseudomonas aeruginosa Abs	absence/100 mL

Table 8: Physical standard limits of seawater- Annex B

Parameters	Acceptable limits
Total salinity(g/L)	$20 \leq S$
pH	$7.5 \leq pH \leq 8.4$
Average density	$1.025 \leq d \leq 1.030$

Table 9: Limits of heavy metals in seawater used for thalassotherapy- Annex B

Parameters	Acceptable limits	
	Internal care(mg/L)	External care(mg/L)
Cadmium	≤ 0.01	≤ 0.05
Lead	≤ 0.05	≤ 0.05
Arsenic	≤ 0.05	≤ 0.05
Mercury	≤ 0.01	≤ 0.01
Selenium	≤ 0.01	≤ 0.05
Chromium	≤ 0.05	≤ 0.05

Table 10: Hydrocarbon limits in seawater- Annex B

Parameter	Acceptable limits	
	Internal care(mg/L)	External care(mg/L)
Total hydrocarbons	≤ 0.5	≤ 0.5
Polycyclic aromatic hydrocarbons(HAPs)	≤ 0.0002	≤ 0.0002
Surface active substances reacting to the Methylene blue(lauryl sulfate)	≤ 0.3	≤ 0.3

2.3 Investigation of Assessment Items for the Korean Soil Pollution Concern Standards

Marine soil in Korea is regulated in accordance with Article 2-5 (Soil Pollution Concern Standards) of the Enforcement Decree of the Soil Environment Conservation Act. The standards are summarized in Table 11. Specifically, the areas are divided into 1, 2, and 3 regions, and 1 and 2 regions, such as playgrounds, water and rivers, sports facilities, and amusement parks, fall within the scope of the standards.

Table 11: Soil Pollution Concern Criteria

Classification	Criteria (unit : mg/kg, for Dioxin : pg-TEQ/g)		
	Area 1	Area 2	Area 3
Cadmium	4	10	60
Copper	150	500	2,000

Arsenic	25	50	200
Mercury	4	10	20
Lead	200	400	700
Hexavalent chromium	5	15	40
Zinc	300	600	2,000
Nickel	100	200	500
Fluoride	400	400	800
Organophosphorus	10	10	30
PCB	1	4	12
Cyanide	2	2	120
Phenol	4	4	20
Benzene	1	1	3
Toluene	20	20	60
Ethylbenzene	50	50	340
Xylene	15	15	45
TPH	500	800	2,000
TCE	8	8	40
PCE	4	4	25
Benzo[a]pyrene	0.7	2	7
1,2-Dichloroethane	5	7	70
Dioxin(including furans)	160	340	1,000

2.4 Investigation of Assessment Items for Foreign Seawater (Or Water Quality) and Soil Standards

Tables 12 and 13 compare the environmental standards for seawater quality and soil in each country in North America (the United States and Canada), Europe, and Asia (Australia and Hong Kong). These countries also manage environmental standards by grade. Compared to the domestic standards, they are generally similar to the Health Protection Standards in Table 4 and the Safety and Hygiene Standards in Table 5. The soil environmental standards of the investigated countries are also similar to the 1 and 2 regions of the Korean Soil Pollution Concern Standards in Table 11.

Table 12: Water Quality Criteria by Country

Parameter	unit	Country					
		US-WQC		AUS-WQC		Canada-WQC	EU-WQS
		CMC	CCC	99% species protection level	95% species protection level		
Arsenic	μg/L	69	36	-	-	12.5	
Cadmium	μg/L	33	7.9	0.7	5.5	0.12	0.08~0.025
Hexavalent chromium	μg/L	1,100	50	0.14	4.4	1.5	
Copper	μg/L	4.8	3.1	0.3	1.3	-	
Lead	μg/L	210	8.1	2.2	4.4	-	7.2

Mercury	㎍/L	1.8	0.94	0.1	0.4	0.016	0.05
Zinc	㎍/L	90	81	7	15	-	

Table 13: Sediment Quality Guideline by Country

Parameter	unit	Country									
		Canada		Austrailia		USA		Hong Kong		Consense-based SQGs	
		ISQG	PEL	ISQG -Low	ISQG -High	ERL	ERM	ISQV-Low	ISQV-High	TEC	MEC
PAHs	ng/g dw	764	7,071	10,000	50,000	3,500	35,000	2,250	12,760	1,610	12,205
PCBs	ng/g dw	21.5	189	34	280	50	400	23	180	60	368
DDTs	ng/g dw	4.48	386.58	1.2	5.0	3	350	-	-	4.2	33.6
CHLs	ng/g dw	2.26	4.79	-	-	-	-	-	-	-	-
Dieldrin	ng/g dw	0.71	4.3	2.8	7.0	0.02	8	-	-	1.9	32
Endrin	ng/g dw	2.67	62.4	2.7	6.0	0.02	45	-	-	2.2	104.6
TBTs	ng Sn/g dw	-	-	-	-	60	-	0.15	0.15	-	-
NPs	ng/g dw	1.000	-	-	-	-	-	-	-	-	-
PCDDs/DFs	pg-TEQ/g dw	0.85	21.5	-	-	-	-	-	-	0.85	11.2
∑BHC	ng/g dw	-	-	-	-	-	-	-	-	3	62
Cu	mg/kg	18.7	108	65	270	34	270	65	110	-	-
Pb	mg/kg	30.2	112	50	220	46.7	218	75	110	-	-
Zn	mg/kg	124	271	200	410	150	410	200	270	-	-
Cd	mg/kg	0.7	4.2	1.5	10	1.2	9.6	1.5	4	-	-
Cr	mg/kg	52.3	160	80	370	81	370	80	160	-	-
Hg	mg/kg	0.13	0.7	0.15	1	0.15	0.71	0.5	1	-	-
As	mg/kg	7.24	41.6	20	70	8.2	70	12	42	-	-

3. Marine Healing Center Water Quality and Soil Standards

3.1 Establishment of Marine Healing Center Water Quality and Soil Standards

To establish the water quality and soil standards for marine healing centers, seawater and soil samples were collected and analyzed from the areas where marine healing centers are to be established. Seawater and soil samples were collected from the coastal areas of four planned marine healing center locations in Korea (Goseong, Uljin, Taean, and Wando) at five points per region (five seawater and five soil samples) in two rounds, first in May to July 2022 and second in September to October 2022. In addition, one underground saline sewage sample was collected from Uljin. A total of 20 seawater, 20 soil, and 1 underground water samples were collected. To analyze the relevant criteria for marine healing and marine water quality and soil in Korea and overseas, all items of the standards related to human health, including ISO 17680 (Tourism and related services – Thalassotherapy - Service requirements), standards for human health protection, and soil pollution concern standards, were analyzed.

Table 14: Sampling seawater analysis items (ISO 17680, human health protection standard)

Standard	Parameter
ISO 17680	Physical parameters(Total salinity, pH, Average density), Heavy metal(Cd, Pb, As, Hg, Se, Cr), Hydrocarbons
Human health protection standard	Cr, As, Cd, Pb, Zn, Cu, CN, Hg, PCBs, Diazinon, Parathion, Malathion, 1.1.1-Trichloroethane, Tetrachloroethylene, Trichloroethylene, Dichloromathane, Benzene, Phenol, ABS

Table 15. Sampling Soil Analysis Items (Worrisome Levels of Soil Contamination)

Standard	Parameter
Worrisome Levels of Soil Contamination	Cd, Cu, As, Hg, Pb, Cr^{6+}, Zn, Ni, F, Organophosphorus, PCBs, CN, Phenol, Benzene, Toluene, Ethylbenzene, Xylene, TPH, TCE, PCE, Benzo[a]pyrene, 1,2-Dichloroethane

Worrisome Levels of Soil Contamination Cd, Cu, As, Hg, Pb, Cr6+, Zn, Ni, F, Organophosphorus, PCBs, CN, Phenol, Benzene, Toluene, Ethylbenzene, Xylene, TPH, TCE, PCE, Benzo[a]pyrene, 1,2-Dichloroethane

3.2 Sampling of Seawater and Soil

Seawater and soil sampling was conducted in two rounds. As shown in Figure 2, seawater and soil samples were collected from four regions where marine healing centers are to be established. The reference locations include: (1) Goseong Marine Healing Center (108, Songcheon-ri, Haimyeon-myeon, Goseong-gun, Gyeongsangnam-do) - First sampling (July 28, 2022) and second sampling (September 30, 2022) of seawater and soil from the same location (2) Wando Marine Healing Center (153-7, Sinri, Sinji-myeon, Wando-gun, Jeollanam-do) - First sampling (May 19, 2022) and second sampling (October 11, 2022) of seawater and soil from the same location (3) Uljin Marine Healing Center (388, Wolsong-ri, Pyonhae-eup, Uljin-gun, Gyeongsangbuk-do) - First sampling (June 20, 2022) and second sampling (September 29, 2022) of seawater and soil from the same location (4) Taean Marine Healing Center (85-54, Dalsanpo-ro, Nammyeon, Taean-gun, Chungcheongnam-do) - First sampling (May 26, 2022) and second sampling (October 11, 2022) of seawater and soil from the same location.

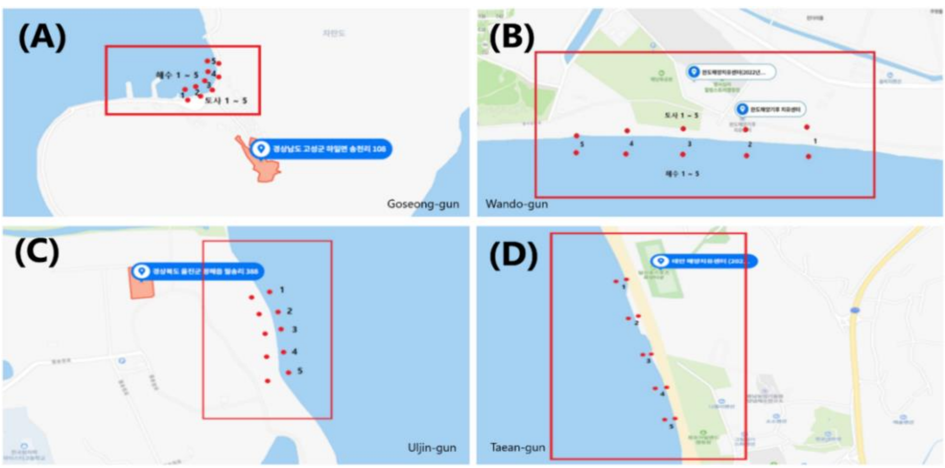

Figure 2: Seawater and soil sampling location (A) Go-seong sampling location, (B) Wan-do

sampling location, (C) Ul-jin sampling location, (D) Tae-an sampling location

3.2.1 Methods for analyzing seawater and soil samples

The seawater samples were analyzed in accordance with the “National Fisheries Research Institute Notification No. 2021-7, Marine Environmental Testing Standards”, which is summarized in Table 16. The soil samples were analyzed in accordance with the “National Institute of Environmental Research Notification No. 2022-38, Soil Pollution Testing Standards”, which is summarized in Table 17.

Table 16: Test method for evaluation target substance – seawater

Classification		**Measuring instrument**	**Analytical method**
Seawater	As, Cd, Cr, Cu, Pb, Zn, Hg, Se	ICP-MS (Nexion 2000B, PerkinElmer)	[inductively coupled plasma mass spectrometry] - Filter the sample through a 0.45 μm filter, then pre-treat it with the seaFAST device and analyze it with an inductively coupled plasma mass spectrometer.
	Diazinon, Parathion, Malathion	GC-NPD (7890A, Agilent)	[Solvent extraction / Gas chromatography] - Extract the sample with dichloromethane, concentrate it with a nitrogen condenser, and analyze it with a gas chromatography-nitrogen phosphorus detector
	1.1.1-Trichloroethane, Tetrachloroethylene, Trichloroethylene, Dichloromathane, Benzene	Headspace-GC/MS (Claus600T, Perkinelmer)	[Headspace / gas chromatography-mass spectrometry] - Add an internal standard (1,2-Dichlorobenzene-d4 & Fluorobenzene) to 10 mL of sample and analyze it with headspace-GC/MS
	PCBs	Headspace-GC/MS (7697A-5977B, Agilent)	[Solvent extraction / Gas chromatography] - Extract the sample with dichloromethane, concentrate it with a nitrogen condenser, and analyze it with a gas chromatography-electron capture detector
	Phenols	Autoanalyzer (FUTURA, Aliance)	[Continuous flow method] Distill the sample under acidic conditions, then add 4-aminoantipyrine solution and potassium ferricyanide solution under basic conditions. Measure the absorbance of the resulting red antipyrine-based pigment at 510 nm.
	CN	Autoanalyzer (FUTURA, Aliance)	[Continuous flow method] - Heat and distill the sample under acidic conditions, then collect the distillate. Add Chloramin T to the distillate to generate cyanide chloride, which then reacts with a color reagent to produce a blue color. Measure the intensity of the blue color at 600-610 nm.
	ABS	Autoanalyzer (FUTURA, Aliance)	[Continuous flow method] - React the sample with alkaline methylene to produce a blue complex, extract the complex, and measure the absorbance at 650 nm.

	Salinity	pH/Cond meter (S213, Mettler Toledo)	[Electro-analysis] - Insert the sensor electrode to be measured into the sample and measure it
	pH		
	Density	Density meter (DMA 4500, Anton Paar)	[U-tube method] - Measure the density of the sample using a vibrating U-tube densitometer
	PAHs	GC-MS (7890B, Agilent)	[Solvent extraction /gas chromatography-mass spectrometry] - Extract the sample with DCM, concentrate it with a nitrogen condenser, and analyze it with GC-MS
	Hydrocarbon Oil index	GC-FID (Clarus 600, Perkinelmer)	[Solvent extraction / Gas chromatography-flame ionization detector] - Extract the sample with DCM, concentrate it with a nitrogen condenser, and analyze it with GC-FID

Table 17: Test method of evaluation target substance – soil

Parameter		**Instrument**	**Mehtod**
Soil	Cd, Cu, Pb, Zn, Ni, As	ICP-OES (Optima 5300, PerkinElmer)	[inductively coupled plasma atomic emission spectroscopy] - Treat the sample with hydrochloric acid and nitric acid for acid digestion, and analyze it with inductively coupled plasma atomic emission spectrometry
	Hg	Direct Mercury Analyzer (DMA-80 evo, Milestone)	[Thermal decomposition amalgam atomic absorption spectrometry] - Decompose mercury in the sample by thermal decomposition, and analyze the mercury vapor captured by a gold amalgam at 253.7 nm by atomic absorption spectrometry
	Cr^{6+}	UV/VIS (V-650, JASCO)	[Ultraviolet and visible spectroscopy] - Measure the absorbance of the red-colored complex formed by reacting the hexavalent chromium in the sample with diphenylcarbazide at 540 nm
	F	UV/VIS (V-650, JASCO)	[Ultraviolet and visible spectroscopy] - Inject lime into the sample, and then boil and distill it. Then, measure the absorbance of the distillate at 570 nm
	Organophosphorus	GC-NPD (7890A, Agilent)	[Gas chromatography] - Extract the sample with a mixture of hexane and acetone using a Soxhlet extractor, and then take the concentrated solution for analysis
	CN	UV/VIS (V-650, JASCO)	[Ultraviolet and visible spectroscopy] - Heat and distill the sample in an acidic condition, collect it, and then add a mixture of chloramine T and pyridine-pyrazolone, and measure the resulting blue color at 620 nm
	PCB	GC-ECD	[Gas chromatography]

		(7890A, Agilent)	- Extract the sample with a mixture of hexane and acetone using a Soxhlet extractor, and then take the concentrated solution for analysis
	Phenols	GC-FID (6890N, Agilent)	[Gas chromatography] - Extract the sample with a mixture of hexane and acetone using a Soxhlet extractor, and then take the concentrated solution for analysis
	Benzene, Toluene, Ethylbenzene, Xylene	P-T GC/MS (7890B, Agilent)	[Purge-and-trap gas chromatography-mass spectrometry] - Add the sample to methyl alcohol and shake it strongly, then take the supernatant for analysis
	TPH	GC-FID (6890N, Agilent)	[Gas chromatography] - Add the sample to dichloromethane and ultrasonically treat it, then take the concentrated solution for analysis
	Benzo[a]pyrene	GC/MS (HP5973, Agilent)	[Gas chromatography-mass spectrometry] - Extract the sample with a mixture of hexane and acetone using a Soxhlet extractor, and then take the concentrated solution for analysis
	TCE, PCE	P-T GC/MS (7890B, Agilent)	[Purge-and-trap gas chromatography-mass spectrometry] - Add the sample to methyl alcohol and shake it strongly, then take the supernatant for analysis
	1,2-Dichloroethane	P-T GC/MS (7890B, Agilent)	[Purge-and-trap gas chromatography-mass spectrometry] - Add the sample to methyl alcohol and shake it strongly, then take the supernatant for analysis

3.2.2 Results of Analysis of Seawater and Soil Samples

The results of the analysis of seawater samples collected in two rounds from different regions are shown in Tables 18-25, and the results of the analysis of soil samples collected in the first round are summarized in Tables 26-29.

Table 18: Seawater analysis results in Go-seong area: 1st

(unit : μg/L)

Parameter	**1st**				
	Gosung 1	**Gosung 2**	**Gosung 3**	**Gosung 4**	**Gosung 5**
As	1.769	1.729	1.770	1.792	1.769
Cd	Not Found	Not Found	Not Found	Not Found	Not Found
Cr	0.104	0.094	0.099	0.092	0.098
Cu	0.840	0.766	0.765	0.814	0.704
Pb	Not Found	Not Found	Not Found	Not Found	Not Found
Zn	0.632	0.655	0.495	0.642	0.533

Hg	Not Found	Not Found	Not Found	Not Found	Not Found
PCBs	Not Found	Not Found	Not Found	Not Found	Not Found
Diazinon	Not Found	Not Found	Not Found	Not Found	Not Found
Parathion	Not Found	Not Found	Not Found	Not Found	Not Found
Malathion	Not Found	Not Found	Not Found	Not Found	Not Found
1.1.1-Trichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found
Tetrachloroethylene	Not Found	Not Found	Not Found	Not Found	Not Found
Trichloroenthlyene	Not Found	Not Found	Not Found	Not Found	Not Found
Dichloromethane	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found
ABS	Not Found	Not Found	Not Found	Not Found	Not Found
Salinity(psu)	31.7	32.1	31.8	31.9	32.2
pH	8.05	8.05	8.04	8.03	8.03
Density(kg/m3)	1023	1023	1023	1023	1023
Hydrocarbon Oil index	Not Found	Not Found	Not Found	Not Found	Not Found
PAHs	Not Found	Not Found	Not Found	Not Found	Not Found
Se	0.003	0.002	Not Found	0.005	Not Found

Table 19: Seawater analysis results in Go-seong area: 2nd

(unit : μg/L)

Parameter	**2nd**				
	Gosung 1	**Gosung 2**	**Gosung 3**	**Gosung 4**	**Gosung 5**
As	1.693	1.705	1.602	1.584	1.681
Cd	Not Found	Not Found	Not Found	Not Found	0.003
Cr	0.186	0.108	0.119	0.135	0.147
Cu	1.966	1.791	2.022	2.204	2.304
Pb	0.020	Not Found	0.006	0.033	0.014
Zn	3.752	0.940	1.083	7.555	0.955
Hg	0.085	0.133	0.087	0.280	0.085
PCBs	Not Found	Not Found	Not Found	Not Found	Not Found
Diazinon	Not Found	Not Found	Not Found	Not Found	Not Found
Parathion	Not Found	Not Found	Not Found	Not Found	Not Found
Malathion	Not Found	Not Found	Not Found	Not Found	Not Found
1.1.1-Trichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found
Tetrachloroethylene	Not Found	Not Found	Not Found	Not Found	Not Found
Trichloroenthlyene	Not Found	Not Found	Not Found	Not Found	Not Found
Dichloromethane	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found

ABS	Not Found	Not Found	Not Found	Not Found	Not Found
Salinity(psu)	30.0	30.0	30.0	29.9	30.4
pH	7.92	7.91	7.91	7.92	7.91
Density(kg/m3)	1023	1023	1023	1023	1023
Hydrocarbon Oil index	Not Found	Not Found	Not Found	Not Found	Not Found
PAHs	Not Found	Not Found	Not Found	Not Found	Not Found
Se	0.004	0.004	0.004	0.004	0.004

Table 20: Seawater analysis results in Wan-do area: 1st

(unit : μg/L)

Parameter	1st				
	Wan-do 1	**Wan-do 2**	**Wan-do 3**	**Wan-do 4**	**Wan-do 5**
As	1.370	1.625	1.409	1.370	1.542
Cd	Not Found	Not Found	Not Found	Not Found	Not Found
Cr	0.112	0.116	0.114	0.104	0.102
Cu	0.179	0.243	0.264	0.682	1.233
Pb	Not Found	Not Found	Not Found	Not Found	Not Found
Zn	0.430	0.488	0.568	0.929	1.303
Hg	0.005	0.008	0.011	0.010	0.009
PCBs	Not Found	Not Found	Not Found	Not Found	Not Found
Diazinon	Not Found	Not Found	Not Found	Not Found	Not Found
Parathion	Not Found	Not Found	Not Found	Not Found	Not Found
Malathion	Not Found	Not Found	Not Found	Not Found	Not Found
1.1.1-Trichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found
Tetrachloroethylene	Not Found	Not Found	Not Found	Not Found	Not Found
Trichloroenthlyene	Not Found	Not Found	Not Found	Not Found	Not Found
Dichloromethane	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found
ABS	Not Found	Not Found	Not Found	Not Found	Not Found
Salinity(psu)	32.0	31.6	30.9	31.2	29.3
pH	8.0	8.0	8.0	8.0	7.9
Density(kg/m3)	1023	1024	1023	1024	1025
Hydrocarbon Oil index	Not Found	Not Found	Not Found	Not Found	Not Found
PAHs	Not Found	Not Found	Not Found	Not Found	Not Found
Se	0.011	0.014	0.009	0.010	0.007

Table 21: Seawater analysis results in Wan-do area: 2nd

(unit : µg/L)					
Parameter	**2nd**				
	Wan-do 1	**Wan-do 2**	**Wan-do 3**	**Wan-do 4**	**Wan-do 5**
As	1.831	1.985	1.947	1.971	1.880
Cd	Not Found	Not Found	0.005	Not Found	Not Found
Cr	0.184	0.165	0.169	0.185	0.176
Cu	1.893	2.092	2.128	1.826	1.987
Pb	Not Found	0.007	0.002	0.006	Not Found
Zn	1.193	0.516	0.925	0.639	0.315
Hg	1.541	1.393	0.732	0.665	0.278
PCBs	Not Found	Not Found	Not Found	Not Found	Not Found
Diazinon	Not Found	Not Found	Not Found	Not Found	Not Found
Parathion	Not Found	Not Found	Not Found	Not Found	Not Found
Malathion	Not Found	Not Found	Not Found	Not Found	Not Found
1.1.1-Trichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found
Tetrachloroethylene	Not Found	Not Found	Not Found	Not Found	Not Found
Trichloroenthlyene	Not Found	Not Found	Not Found	Not Found	Not Found
Dichloromethane	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found
ABS	Not Found	Not Found	Not Found	Not Found	Not Found
Salinity(psu)	30.7	29.6	28.8	30.7	30.7
pH	8.0	7.9	7.9	7.9	8.0
Density(kg/m3)	1024	1023	1022	1024	1024
Hydrocarbon Oil index	Not Found	Not Found	Not Found	Not Found	Not Found
PAHs	Not Found	Not Found	Not Found	Not Found	Not Found
Se	0.004	0.004	0.004	0.004	0.004

Table 22: Seawater analysis results in Ul-jin area: 1st

(unit : µg/L)					
Parameter	**1st**				
	Ul-jin 1	**Ul-jin 2**	**Ul-jin 3**	**Ul-jin 4**	**Ul-jin 5**
As	1.621	1.715	1.585	1.532	1.522
Cd	Not Found	Not Found	Not Found	Not Found	Not Found
Cr	0.140	0.327	0.132	0.142	0.129
Cu	0.314	0.273	0.345	1.289	7.761
Pb	Not Found	Not Found	Not Found	Not Found	Not Found
Zn	0.801	0.565	1.144	1.607	3.259
Hg	0.009	0.008	0.010	0.008	0.009
PCBs	Not Found	Not Found	Not Found	Not Found	Not Found

Diazinon	Not Found	Not Found	Not Found	Not Found	Not Found
Parathion	Not Found	Not Found	Not Found	Not Found	Not Found
Malathion	Not Found	Not Found	Not Found	Not Found	Not Found
1.1.1-Trichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found
Tetrachloroethylene	Not Found	Not Found	Not Found	Not Found	Not Found
Trichloroenthlyene	Not Found	Not Found	Not Found	Not Found	Not Found
Dichloromethane	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found
ABS	Not Found	Not Found	Not Found	Not Found	Not Found
Salinity(psu)	29.9	30.7	30.0	30.4	30.8
pH	8.09	8.09	8.09	8.1	8.09
Density(kg/m3)	1024	1024	1023	1023	1024
Hydrocarbon Oil index	Not Found	Not Found	Not Found	Not Found	Not Found
PAHs	Not Found	Not Found	Not Found	Not Found	Not Found
Se	0.013	0.012	0.012	0.006	0.010

Table 23: Seawater analysis results in Ul-jin area: 2nd

(unit : $\mu g/L$)

Parameter	**2nd**				
	Ul-jin 1	**Ul-jin 2**	**Ul-jin 3**	**Ul-jin 4**	**Ul-jin 5**
As	1.450	1.414	1.428	1.461	1.501
Cd	Not Found	0.002	Not Found	0.003	Not Found
Cr	0.168	0.162	0.239	0.192	0.176
Cu	1.605	1.955	1.900	1.904	1.606
Pb	Not Found	Not Found	0.021	0.037	0.015
Zn	1.667	1.524	7.476	5.831	6.848
Hg	0.280	0.181	0.284	0.319	0.007
PCBs	Not Found	Not Found	Not Found	Not Found	Not Found
Diazinon	Not Found	Not Found	Not Found	Not Found	Not Found
Parathion	Not Found	Not Found	Not Found	Not Found	Not Found
Malathion	Not Found	Not Found	Not Found	Not Found	Not Found
1.1.1-Trichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found
Tetrachloroethylene	Not Found	Not Found	Not Found	Not Found	Not Found
Trichloroenthlyene	Not Found	Not Found	Not Found	Not Found	Not Found
Dichloromethane	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found
ABS	Not Found	Not Found	Not Found	Not Found	Not Found
Salinity(psu)	25.5	25.7	26.9	27.8	26.9

pH	8.03	8.03	8.02	8.01	8.02
Density(kg/m3)	1021	1021	1020	1021	1021
Hydrocarbon Oil index	Not Found	Not Found	Not Found	Not Found	Not Found
PAHs	Not Found	Not Found	Not Found	Not Found	Not Found
Se	0.004	0.004	0.005	0.005	0.004

Table 24: Seawater analysis results in Tae-an area: 1st

(unit : μg/L)

Parameter	**1st**				
	Tae-an 1	**Tae-an 2**	**Tae-an 3**	**Tae-an 4**	**Tae-an 5**
As	1.128	1.136	1.220	1.199	1.324
Cd	Not Found	Not Found	Not Found	Not Found	Not Found
Cr	0.074	0.066	0.068	0.073	0.096
Cu	1.375	2.599	1.238	0.827	1.003
Pb	Not Found	Not Found	Not Found	Not Found	Not Found
Zn	1.346	1.879	1.286	1.055	1.284
Hg	0.013	0.013	0.011	0.010	0.011
PCBs	Not Found	Not Found	Not Found	Not Found	Not Found
Diazinon	Not Found	Not Found	Not Found	Not Found	Not Found
Parathion	Not Found	Not Found	Not Found	Not Found	Not Found
Malathion	Not Found	Not Found	Not Found	Not Found	Not Found
1.1.1-Trichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found
Tetrachloroethylene	Not Found	Not Found	Not Found	Not Found	Not Found
Trichloroenthlyene	Not Found	Not Found	Not Found	Not Found	Not Found
Dichloromethane	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found
ABS	Not Found	Not Found	Not Found	Not Found	Not Found
Salinity(psu)	30.5	30.5	30.4	30.5	30.7
pH	8.0	8.0	8.0	8.0	8.0
Density(kg/m3)	1024	1024	1024	1024	1024
Hydrocarbon Oil index	Not Found	Not Found	Not Found	Not Found	Not Found
PAHs	Not Found	Not Found	Not Found	Not Found	Not Found
Se	0.014	0.008	0.015	0.011	0.008

Table 25: Seawater analysis results in Tae-an area: 2nd

(unit : μg/L)

Parameter	**2nd**				
	Tae-an 1	**Tae-an 2**	**Tae-an 3**	**Tae-an 4**	**Tae-an 5**
As	1.675	1.564	1.610	1.521	1.543
Cd	0.015	0.004	0.003	Not Found	0.003
Cr	0.123	0.132	0.140	0.105	0.168

Cu	2.268	1.951	1.839	1.811	2.109
Pb	0.013	0.025	0.036	Not Found	0.030
Zn	8.591	1.221	6.789	1.269	1.118
Hg	0.231	0.147	0.210	0.165	0.088
PCBs	Not Found	Not Found	Not Found	Not Found	Not Found
Diazinon	Not Found	Not Found	Not Found	Not Found	Not Found
Parathion	Not Found	Not Found	Not Found	Not Found	Not Found
Malathion	Not Found	Not Found	Not Found	Not Found	Not Found
1.1.1-Trichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found
Tetrachloroethylene	Not Found	Not Found	Not Found	Not Found	Not Found
Trichloroenthlyene	Not Found	Not Found	Not Found	Not Found	Not Found
Dichloromethane	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found
ABS	Not Found	Not Found	Not Found	Not Found	Not Found
Salinity(psu)	29.1	29.7	29.6	28.2	28.9
pH	8.0	8.0	8.0	8.0	8.1
Density(kg/m3)	1023	1023	1023	1022	1022
Hydrocarbon Oil index	Not Found	Not Found	Not Found	Not Found	Not Found
PAHs	Not Found	Not Found	Not Found	Not Found	Not Found
Se	0.004	0.004	0.004	0.003	0.004

Table 26: Soil analysis results in Go-seong area

(unit : mg/kg)					
Parameter	**1st**				
	Gosung 1	**Gosung 2**	**Gosung 3**	**Gosung 4**	**Gosung 5**
Cd	Not Found	Not Found	Not Found	Not Found	Not Found
Cu	4.8	8.1	6.7	7.3	9.1
Pb	10.5	11.6	10.9	15.0	12.9
Zn	31.4	36.3	33.2	30.9	33.8
Ni	5.5	6.0	5.9	5.9	6.6
Hg	Not Found	Not Found	Not Found	Not Found	Not Found
As	9.90	13.98	10.32	10.80	8.61
F	103	45	104	Not Found	58
Organophosphorus	Not Found	Not Found	Not Found	Not Found	Not Found
Cr6+	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found
PCB	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Toluene	Not Found	Not Found	Not Found	Not Found	Not Found

Ethylbenzene	Not Found	Not Found	Not Found	Not Found	Not Found
Xylene	Not Found	Not Found	Not Found	Not Found	Not Found
TPH	Not Found	Not Found	Not Found	Not Found	Not Found
TCE	Not Found	Not Found	Not Found	Not Found	Not Found
PCE	Not Found	Not Found	Not Found	Not Found	Not Found
Benzo[a]pyrene	Not Found	Not Found	Not Found	Not Found	Not Found
1,2-Dichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found

Table 27: Soil analysis results in Wan-do area

(unit : mg/kg)

Parameter	**1st**				
	Wan-do 1	**Wan-do 2**	**Wan-do 3**	**Wan-do 4**	**Wan-do 5**
Cd	Not Found	Not Found	Not Found	Not Found	Not Found
Cu	1.1	1.1	Not Found	Not Found	Not Found
Pb	Not Found	2.2	2.4	1.6	Not Found
Zn	12.5	14.9	12.4	7.7	11.8
Ni	3.1	3.5	2.7	1.7	3.0
Hg	Not Found	Not Found	Not Found	Not Found	Not Found
As	Not Found	Not Found	Not Found	Not Found	Not Found
F	Not Found	69	Not Found	16	128
Organophosphorus	Not Found	Not Found	Not Found	Not Found	Not Found
Cr6+	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found
PCB	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Toluene	Not Found	Not Found	Not Found	Not Found	Not Found
Ethylbenzene	Not Found	Not Found	Not Found	Not Found	Not Found
Xylene	Not Found	Not Found	Not Found	Not Found	Not Found
TPH	Not Found	Not Found	Not Found	Not Found	Not Found
TCE	Not Found	Not Found	Not Found	Not Found	Not Found
PCE	Not Found	Not Found	Not Found	Not Found	Not Found
Benzo[a]pyrene	Not Found	Not Found	Not Found	Not Found	Not Found
1,2-Dichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found

Table 28: Soil analysis results in Ul-jin area

(unit : mg/kg)

Parameter	**1st**				
	Ul-jin 1	**Ul-jin 2**	**Ul-jin 3**	**Ul-jin 4**	**Ul-jin 5**
Cd	Not Found	Not Found	Not Found	Not Found	Not Found
Cu	1.4	1.8	1.4	2.4	1.3
Pb	3.4	3.4	3.3	3.7	3.5
Zn	13.9	15.3	13.7	13.4	13.7

Ni	2.8	3.3	2.9	3.5	2.6
Hg	Not Found	Not Found	Not Found	Not Found	Not Found
As	4.52	4.63	4.36	4.16	Not Found
F	66	37	14	55	196
Organophosphorus	Not Found	Not Found	Not Found	Not Found	Not Found
Cr6+	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found
PCB	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Toluene	Not Found	Not Found	Not Found	Not Found	Not Found
Ethylbenzene	Not Found	Not Found	Not Found	Not Found	Not Found
Xylene	Not Found	Not Found	Not Found	Not Found	Not Found
TPH	Not Found	Not Found	Not Found	Not Found	Not Found
TCE	Not Found	Not Found	Not Found	Not Found	Not Found
PCE	Not Found	Not Found	Not Found	Not Found	Not Found
Benzo[a]pyrene	Not Found	Not Found	Not Found	Not Found	Not Found
1,2-Dichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found

Table 29: Soil analysis results in Tae-an area

(unit : mg/kg)

Parameter	**1st**				
	Tae-an 1	**Tae-an 2**	**Tae-an 3**	**Tae-an 4**	**Tae-an 5**
Cd	Not Found	Not Found	Not Found	Not Found	Not Found
Cu	Not Found	Not Found	Not Found	Not Found	Not Found
Pb	3.1	2.9	2.9	3.6	4.1
Zn	8.8	7.8	7.7	10.3	10.9
Ni	2.6	2.5	2.2	3.0	3.1
Hg	Not Found	Not Found	Not Found	Not Found	Not Found
As	Not Found	Not Found	Not Found	Not Found	Not Found
F	Not Found	Not Found	365	68	89
Organophosphorus	Not Found	Not Found	Not Found	Not Found	Not Found
Cr6+	Not Found	Not Found	Not Found	Not Found	Not Found
CN	Not Found	Not Found	Not Found	Not Found	Not Found
PCB	Not Found	Not Found	Not Found	Not Found	Not Found
Phenols	Not Found	Not Found	Not Found	Not Found	Not Found
Benzene	Not Found	Not Found	Not Found	Not Found	Not Found
Toluene	Not Found	Not Found	Not Found	Not Found	Not Found
Ethylbenzene	Not Found	Not Found	Not Found	Not Found	Not Found
Xylene	Not Found	Not Found	Not Found	Not Found	Not Found
TPH	Not Found	Not Found	Not Found	Not Found	Not Found
TCE	Not Found	Not Found	Not Found	Not Found	Not Found

PCE	Not Found	Not Found	Not Found	Not Found	Not Found
Benzo[a]pyrene	Not Found	Not Found	Not Found	Not Found	Not Found
1,2-Dichloroethane	Not Found	Not Found	Not Found	Not Found	Not Found

3.3 Analysis of the Probability of Exceeding Environmental Standards for the Results of the Analysis of Seawater and Soil Samples

The substances detected in the results of the first and second sampling analyses were selected as priority substances and compared with domestic and foreign environmental standards. The target substances for seawater detection were arsenic, cadmium, chromium, copper, lead, zinc, mercury, and selenium, and the target substances for soil detection were copper, lead, zinc, nickel, arsenic, and fluorine. In the case of marine water trace metals and soil heavy metals, 10 years of coastal seawater and soil monitoring data were added using data from the Marine Environment Monitoring Network (Marine Environment Corporation) (2012-2021) to compare the probability of exceeding environmental standards. The analysis results showed that the concentration of arsenic in seawater did not exceed the standard for either the domestic monitoring analysis data or the marine healing center sampling analysis data. In the case of cadmium in seawater, one sample from the marine healing center sampling analysis data exceeded the Canadian seawater standard of 0.12 µg/L. In the case of chromium in seawater, many of the domestic monitoring analysis data and marine healing center sampling analysis data exceeded the protection standard for 99% of species in the Australian seawater standard of 0.14 µg/L. In addition, some of the monitoring data exceeded the protection standard for 95% of species in the Australian seawater standard of 4.4 µg/L and the Canadian seawater standard of 1.5 µg/L. For copper in seawater, many of the domestic monitoring analysis data and marine healing center sampling analysis data exceeded the protection standard for 99% of species in the Australian seawater standard of 0.3 µg/L and the protection standard for 95% of species in the Australian seawater standard of 1.3 µg/L. In addition, some samples exceeded the acute and chronic reference values in the US seawater standard of 3.1 µg/L and 4.8 µg/L. In the case of lead in seawater, there were no samples that exceeded the standard in the marine healing center sampling analysis data, but some samples in the domestic monitoring analysis data exceeded the protection standard for 99% of species in the Australian seawater standard of 2.2 µg/L and the protection standard for 95% of species in the Australian seawater standard of 4.4 µg/L. In the case of zinc in seawater, some samples in the domestic monitoring analysis data and marine healing center marine healing center sampling analysis data exceeded the protection standard for 99% of species in the Australian seawater standard of 7 µg/L and the protection standard for 95% of species in the Australian seawater standard of 15 µg/L. For mercury in seawater, there were no samples that exceeded the standard in the marine healing center sampling analysis data, but some samples in the domestic monitoring data exceeded the Canadian seawater standard of 0.016 µg/L. In the case of selenium in seawater, there were no cases of exceeding the standard when compared to the marine healing center sampling analysis data and the ISO 17680 standard.

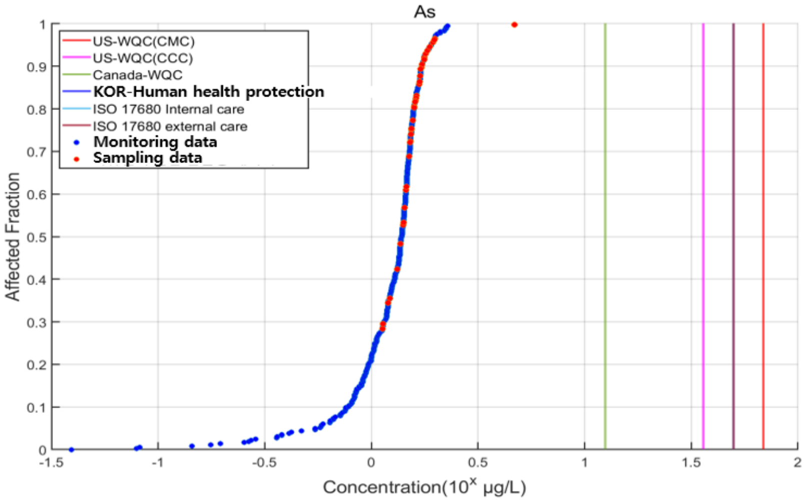

Figure 3: Comparison of domestic monitoring data and environmental standards for arsenic in seawater

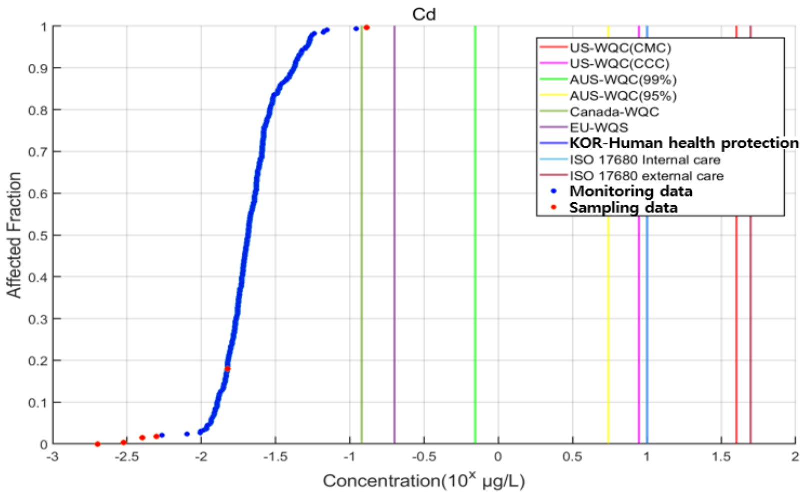

Figure 4: Comparison of domestic monitoring data and environmental standards for cadmium in seawater

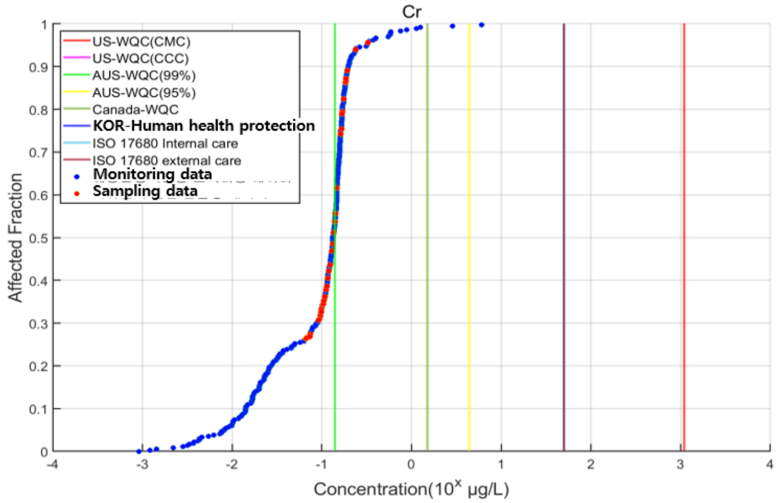

Figure 5: Comparison of domestic monitoring data and environmental standards for chrome in seawater

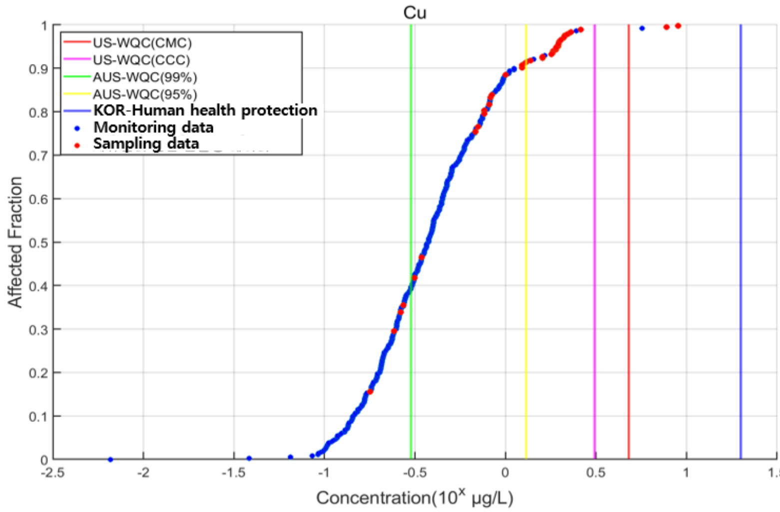

Figure 6: Comparison of domestic monitoring data and environmental standards for copper in seawater

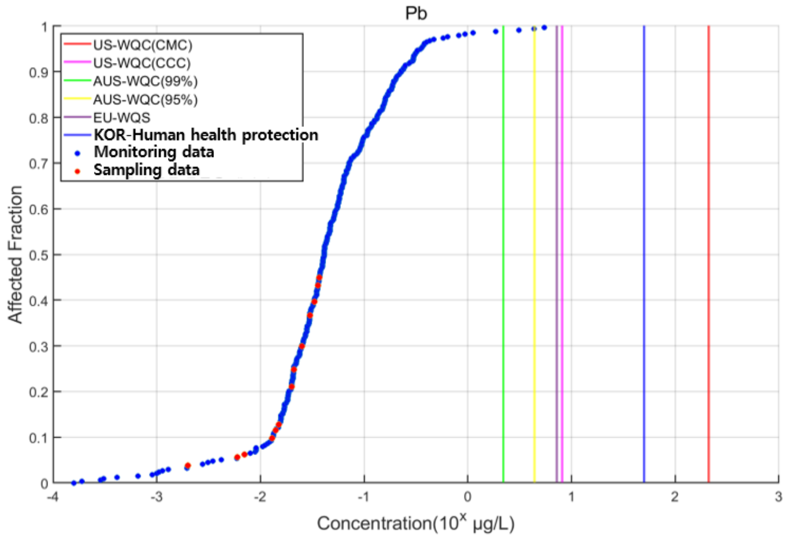

Figure 7: Comparison of domestic monitoring data and environmental standards for lead in seawater

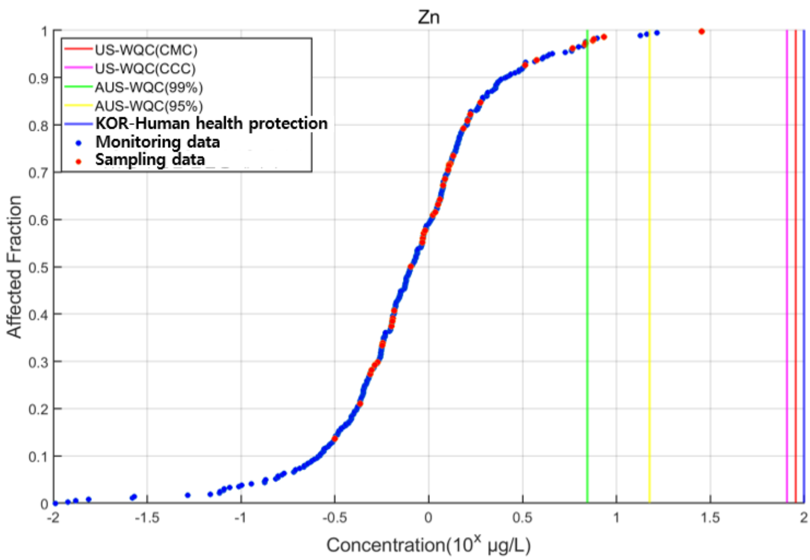

Figure 8: Comparison of domestic monitoring data and environmental standards for zinc in seawater

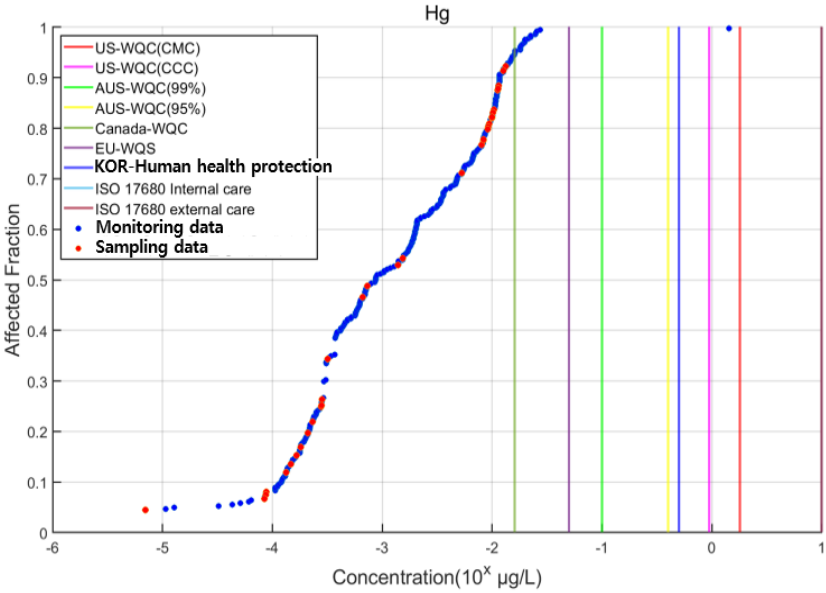

Figure 9: Comparison of domestic monitoring data and environmental standards for mercury in seawater

The analysis of the soil showed that in the case of cadmium, there were no cases of exceeding the standard in both the domestic monitoring analysis data and the marine healing center sampling analysis data. In the case of copper in soil, some samples from the domestic monitoring analysis data exceeded the Canadian soil standard of 18.7 mg/kg and the US soil standard of 34 mg/kg. In the case of lead in soil, some samples from the domestic monitoring analysis data exceeded the Canadian soil standard of 30.2 mg/kg, the US soil standard of 46.7 mg/kg, and the Australian standard of 50 mg/kg. In the case of zinc in soil, some samples from the domestic monitoring analysis data exceeded the Canadian soil standard of 124 mg/kg and the US soil standard of 150 mg/kg. In the case of mercury in soil, some samples from the domestic monitoring analysis data exceeded the Canadian soil standard of 0.13 mg/kg, the US and Australian soil standards of 0.15 mg/kg. In the case of arsenic in soil, some samples from the domestic monitoring analysis data and the marine healing center sampling analysis data exceeded the Canadian soil standard of 7.24 mg/kg, the US soil standard of 8.2 mg/kg, and the Hong Kong soil standard of 12 mg/kg.

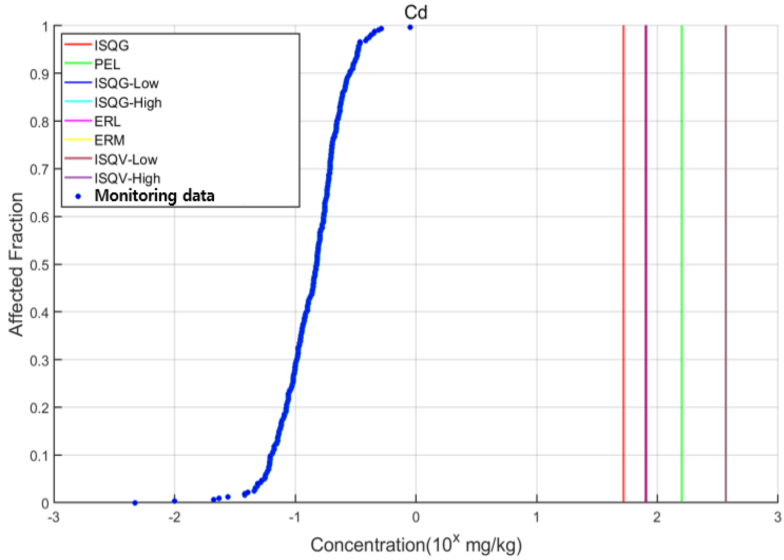

Figure 10: Comparison of domestic monitoring data and environmental standards for cadmium in soil

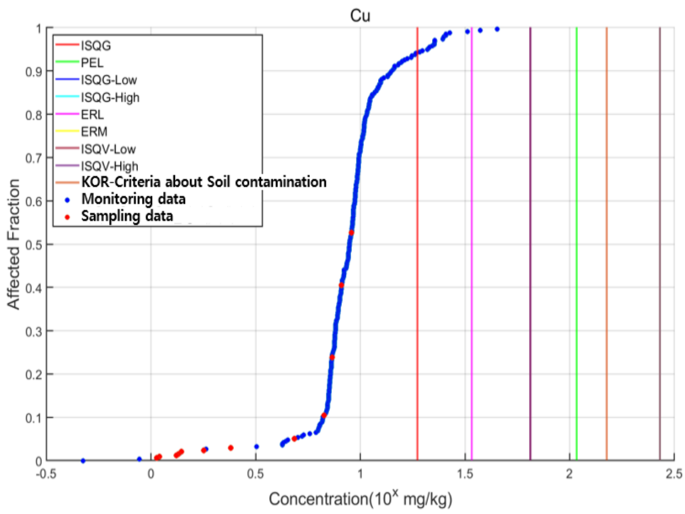

Figure 11: Comparison of domestic monitoring data and environmental standards for copper in soil

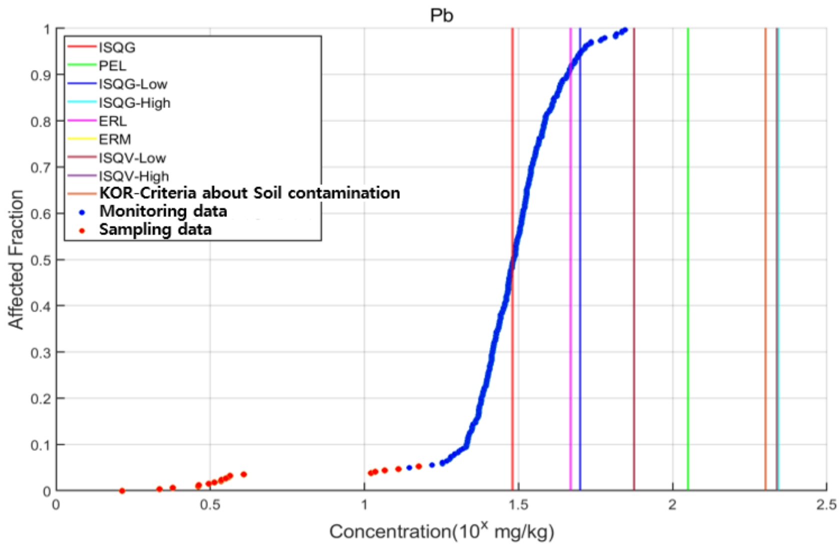

Figure 12: Comparison of domestic monitoring data and environmental standards for lead in soil

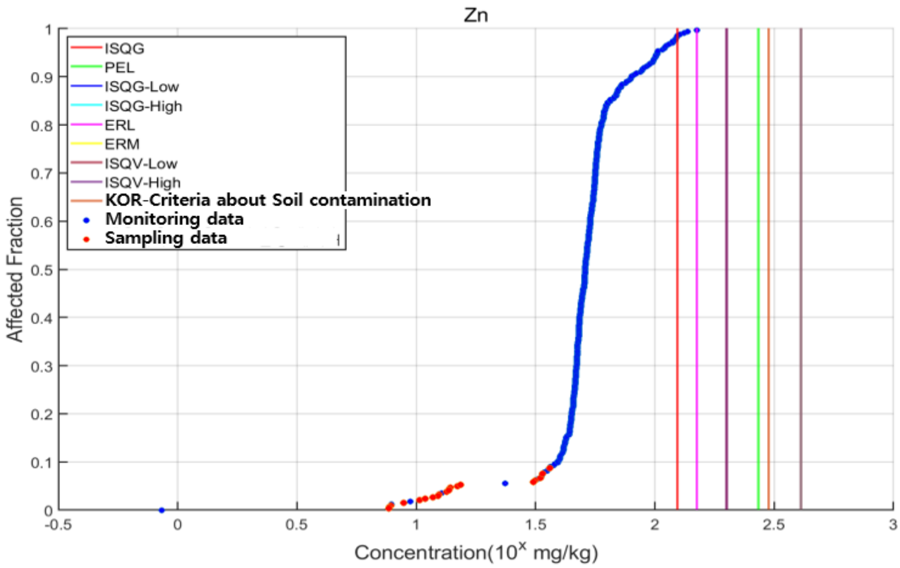

Figure 13: Comparison of domestic monitoring data and environmental standards for zinc in soil

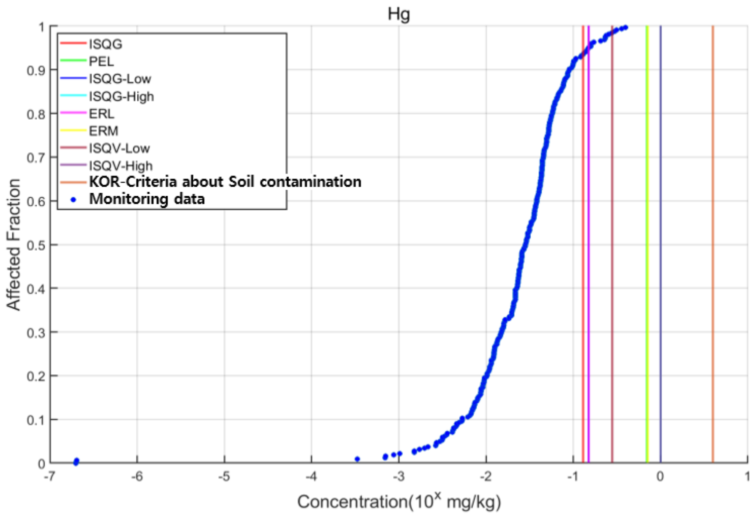

Figure 14: Comparison of domestic monitoring data and environmental standards for mercury in soil

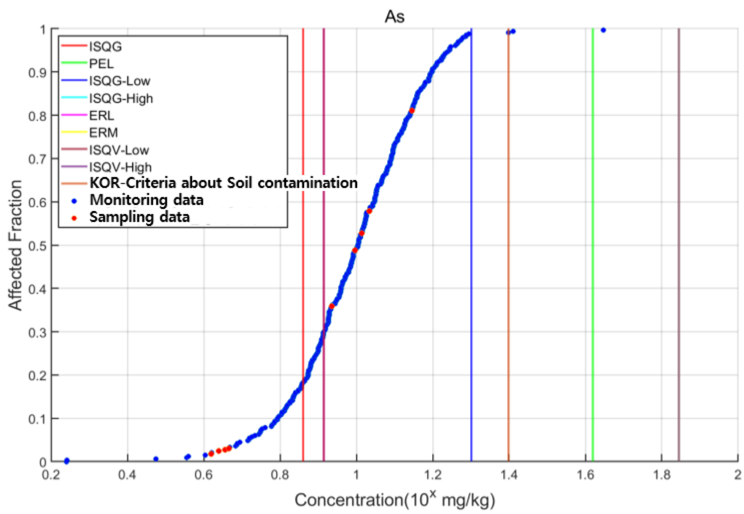

Figure 15: Comparison of domestic monitoring data and environmental standards for arsenic in soil

Table 30: Results of Physical Characteristics Analysis of Salt Groundwater in Ul-jin Area

Parameter	Result	ISO 17680 acceptable limits
Total salinity (g/L)	24.5	$20 \leq S$
pH	7.2	$7.5 \leq pH \leq 8.4$
Average density(kg/L)	1.019	$1.025 \leq d \leq 1.030$

Uljin marine healing center plans to use saline groundwater in the center. With the cooperation of Uljin-gun, saline groundwater to be used in the center was sampled and analyzed. [Table 30] The international standard ISO 17680 for marine healing centers specifies the physical properties of water that can be used as seawater. Applying this standard, saline groundwater does not meet the pH and average density standards and is therefore not available for use in the marine healing center. Not only saline groundwater, but also the second-year seawater sampling samples do not meet the average density standard specified by ISO 17680. The physical properties of seawater should be set based on the average salinity, pH, and density of seawater in Korea. If saline groundwater is to be used as a marine healing resource, a wider range of standards should be established.

4. Conclusion

To establish the groundwork for the revitalization of the marine healing industry, the Ministry of Maritime Affairs and Fisheries has selected Goseong-gun (Gyeongsangnam-do), Uljin-gun (Gyeongsangbuk-do), Wando-gun (Jeollanam-do), and Taean-gun (Chungcheongnam-do) as cooperating local governments for the discovery and cultivation of marine healing resources and the promotion of the industry. The Ministry is currently promoting the construction of marine healing centers in these areas. Therefore, it is necessary to systematically manage marine healing resources in the medium to long term to establish the foundation for the utilization and provision of marine healing resources. This study was conducted to establish criteria and set environmental standards for the establishment and operation of marine healing centers, and to investigate the environmental impact of surrounding seawater and soil. Samples of seawater and soil were collected from four different regions to study the influence of the surrounding environment and establish environmental standards. In analyzing the environmental management standards for marine healing centers, the international standards for marine wellness centers (ISO) were compared to the domestic standards corresponding to ISO 17680 (Tourism and related services - Thalassotherapy Service Requirements). For seawater, the items were investigated and compared to the standards for human health protection. In the case of soil, the standards were set and analyzed in response to the soil pollution risk standards. Seawater and soil samples were collected and analyzed from Goseong, Wando, Uljin, and Taean, which are the planned sites for the establishment of marine healing centers. The detected items were compared and analyzed with domestic and international environmental standards, and the probability of exceeding environmental standards was also compared and analyzed by adding monitoring data of coastal seawater and soil for 10 years. Currently, domestic and international seawater quality standards are set based on the assumption that seawater or organisms grown in seawater are consumed. For marine healing centers, seawater quality standards should be set based on the exposure scenarios of using seawater as a therapeutic resource at marine healing centers, taking into account the items detected in domestic monitoring data and seawater and soil sampling analysis data. In addition, for soil, human health risk assessment should be conducted by setting the skin contact scenario of soil according to the guidelines for the risk assessment of soil pollutants in Korea. The results of this study can provide a basis for the utilization assessment of marine healing resources used in marine healing centers and programs, as well as the investigation of environmental planning standards. Additionally, through the examination of the physical environment of marine healing spaces, a foundation for the management of marine healing facility resources can be established.

ACKNOWLEDGEMENTS

This study was carried out with the support of ‘R&D Program for Forest Science Technology (Project No. 2021408C10-2325-0101)’ provided by Korea Forest Service(Korea Forestry Promotion Institute).

References

1. Byeon W-J, Lee S-J, Khil T-G, Jeong A-Y, Han B-D, Sohn M-S, Choi J-W, Kim Y-H. (2023) Association between a Marine Healing Program and Metabolic Syndrome Components and Mental Health Indicators. Medicina, 59(7) 1263.DOI: https://doi.org/10.3390/medicina59071263
2. Djaba, S. A., Bertrand, T., Bernard, L., Lantei, L. B., Raphael, O. D. L. & Dede. S. A. (2022). Outlining the Challenges of the COVID-19 Pandemic on Africa's Maritime Industry: The Case of Marine and Seafaring Professionals. International Journal of Social Welfare Promotion and Management, 9(1), 71-100, doi:10.21742/IJSWPM.2022.9.1.05
3. Enforcement Decree of the Framework Act on Environmental Policy, Environmental standards (related to Article 2) - 3. Water quality and aquatic ecosystem
4. Enforcement Rules of the Public Health Control Act [Appendix 2] Water Quality Standards of Bathhouse and the Method of Testing Water Quality (Related to Article 4)
5. Environmental Testing and Inspection Act Article 6 「Official Test Standards for Environmental Pollution
6. Installation and Utilization of Sports Facilities Act」 Article 24 (Safety and Sanitary Standards)
7. ISO 17680:2015 Tourism and related services — Thalassotherapy — Service requirements, Available from: https://www.iso.org/standard/60244.html
8. Luo Y., Lanlung C.,Kim E., Tang L. R. & Song S. M. (2018) Towards quality of life: the effects of the wellness tourism experience. Journal of Travel & Tourism Marketing, 35(4) 410-424. DOI: 10.1080/10548408.2017.1358236
9. Maria K. (2023). Turmeric Latte Battle: the Commodification and Protection of Authenticity in Wellness Tourism. 2023 Global Marketing Conference at Seoul Proceedings: 530-532 DOI: https://doi.org/10.15444/GMC2023.06.05.04
10. Marine Environment Management Act」 Article 10 「Korean Standard Method of Examination for Marine Environment 」
11. Ministry of Oceans and Fisheries, Marine Healing Industry Revitalization Plan, Ministry of Oceans and Fisheries, (2020), Ministry of Oceans and Fisheries, (2020), Marine Healing Industry Revitalization Plan, Ministry of Oceans and Fisheries, Available from: https://www.mof.go.kr/doc/ko/selectDoc.do?docSeq=36639&menuSeq=851&bbsSeq=22
12. Soil Environment Conservation Act」 Article 4-2 (Worrisome Levels of Soil Contamination)
13. Soudeh B. N., Ahmad H., Brett I. P., Carmen S.-S., Carlos C.-Z., Roberto P.-S. (2020). Marine resources effective in controlling and treating diabetes and its associated complications. Process Biochemistry, 92, 313-342 DOI: https://doi.org/10.1016/j.procbio.2020.01.024
14. Yeung, O. M., & Johnston, K. (2017). Global Wellness Economy Monitor January 2017. Global Wellness Institute, Available from: https://globalwellnessinstitute.org/wp-content/uploads/2018/06/GWI_WellnessEconomyMonitor2017_FINALweb.pdf