

Study on Reduction of Mixed Water Salinity by Sound Wave

—Toward Water Scarcity Issue-Solving in Isolated Islands in the World

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Abstract

There are so many Isolated Islands (inhabited islands) in the world, including Japan. However, at present islanders, there have been faced with the decline of industries, serious concerns of rapid aging and very low birthrate without children and water scarcity issues etc. It can be said that these situations are under the environment which shows a microcosm of Japanese and/or world survival society in the near future. In this paper, the experimental data on the reduction of the mixed water (seawater & rainwater) salinity by the sound wave when changing the volume ratio were first shown, taking into the characteristics of the Isolated Islands. Next, the main analysis result on the water qualities of mixed water with which sound wave was irradiated was shown and the consideration mainly based on the WHO drinking water quality standards was carried out. Finally, through a simple water quality improvement apparatus using small hydroelectric power, a consideration regarding a possibility of the purification of the water (to be a drinking water) based on the solar circulation energy (regenerative type's natural energy) such as small hydropower utilization, natural sunlight utilization, natural gravity utilization, natural oscillation utilization has been described in the paper.

Keywords

Mixed Water (Seawater and Rainwater), Salinity Reduction, Sound Wave, Isolated Islands, Water Scarcity

1. Introduction

Authors have conducted the study on the sustainable water resource conservation and rainwater resource utilization so far [1] [2]. A possibility on the purifi-

cation regarding the environmental water and rainwater using both a simple water circulation equipment and a waterwheel rotation has been discussed in the papers. And especially, regarding the rainwater purification using a waterwheel, a problem that only NO_2^- removal has been difficult has been described. Therefore, a biological method (Heterotrophic denitrification) was adopted as a method of removing the NO_2^- from the water. That is, this one is to remove NO_2^- by the proliferated bacteria. At that time, an appropriate amount of apple water with the organic matter was added to the rainwater passed through the waterwheel [2]. The NO_2^- could have been kept within a drinking water standards by this method, and we could suggest a possibility of the rainwater as a drinking water as a whole. By the way, there is another way (Change/Mix of raw water or purified water) to decrease NO_2^- [3]. This would also be the least cost method for the purification, *i.e.*, that is to decrease the NO_2^- by diluting a seawater with the rainwater properly. This method is also related not only to a decrease of the NO_2^- , but also to that of the salinity of the seawater itself.

In this study, we have tried the dilution of the salinity by changing the volume ratio of the mixed water (rainwater and seawater), and examined a possibility of the mixed water as a drinking water toward water scarcity issue-solving in Isolated Islands in the world in the 21 - 23 centuries [4] and the recent background mentioned above. In the literature [4], the author foresees a civilization society until 21-23 centuries. The base of the post-modern civilization should be there renewable energy, and describes in detail about the structure of the world that has the basic structure *i.e.*, “self-sustaining wide-area networking world” (*i.e.*, Post modern civilization that could respond to the conditions such as aging, depopulation, low energy consumption) in which the humankind will create after the modern. In addition, we have based on the solar circulation energy as a most important energy source to secure a maximum sustainability, and a hydroelectric power has been put in the base. This intends to a self-managed water quality control.

2. Seawater Utilization and Rainwater Utilization

Japanese prominent medical Dr. M. Kimura (preventive medicine/environmental medicine) says that “21st century will be an era of the water scarcity, and we need to put our focus on seawater utilization as a new resource”. And she also mentions in the literature that “mineral concentration distribution and mineral balance in human body fluids have positive correlation as is said that the origin of species starts with the seawater. The sea as a mother of life has a very important meaning for human health (Intent)” [5]. In case of utilization of seawater as a water resource especially drinking water, we should note the presence of infection (*Vibrio vulnificus* [Vv.] as an invasive streptococcus, *i.e.*, flesh-eating bacteria) etc., and that of Bisphenol A (a chemical substance well-known as an endocrine disrupting chemical which is floating with the plastics in the ocean appearing in the world news in recent years) etc. However, it is possible to remove the bacteria by the heat sterilization etc. regarding the bacteria in the former. And it is also

possible to remove the pollutions as endocrine disrupting chemicals by the point-of-use water treatment unit (water purifier) with appropriate filters, for example, RO filter which can remove that in the latter. However, this method is a little bit very expensive and has a high energy burden. Furthermore, the sustainability is left open to question. A possibility of the more sustainable, the more safe, the more secure and the more low-cost drinking water supply would be fundamentally expected by the water quality management based on the self-responsibility (self-help). Therefore, it is fundamentally thought that the flow such as 1) self-help → 2) mutual help → 3) public help in order will be good for achieving the sustainable drinking water supply goal in this system. Then, it is considered that the reduction of the salinity is the big point for the seawater as a drinking water. Regarding this, by doing properly the dilution and mixing of the raw water (*i.e.*, diluting the seawater with the rainwater) the reduction of both the NO_2^- and the salinity of seawater itself will also be expected as mentioned above. Therefore, it is thought that a possibility toward a way in which we could drink the seawater as a drinking water (application of the WHO standards) will be increased.

In addition, the seawater desalination technology in Saudi Arabia etc. is one of the great techniques. However, as mentioned above, it has a high energy burden issue. Therefore, the unlimited spread of it to the Isolated Islands in the world will be difficult in the future. Therefore, it is thought that this way in which the self-managed water quality control system with a small hydroelectric power based on the solar circulation energy (*i.e.*, a way of changing the lifestyle itself) will be wiser one in Isolated Islands in the world toward 21 - 23 centuries. Small is exactly beautiful in the future.

3. The Choice of Sustainable Energy Source toward 21 - 23 Centuries

We think that which energy source we should choose for humankind will be the most important keyword toward the 21 - 23 centuries. [6] [7] [8] Here, we briefly want to overview the energy source mentioned so far based on the “stability” as a keyword.

First, there is a petroleum energy (1). This stabilizes at the present stage. However, there still remains doubt about sustainability. And the areas where the petroleum is dug are politically volatile regions.

Second, there is a coal energy (2). This is also stable. However, the carbon dioxide (CO_2) emissions are large. And coal-fired power plant will have a high possibility of stranded assets in the future.

Third, there is a nuclear energy (3). Of course, although this can be the most stable supply, the risk brought about by an accident will have the maximum risk. Three areas were pointed out as major accidents caused by the nuclear power plant. That is, Three Mile Island (USA, 1979), Chernobyl (former Soviet Union, Current Ukraine, 1986) and Fukushima (Japan, 2011). All the accidents were beyond what one expected and did severe damage to the areas. That is no match

for the thermal power. In foreign countries, the plutonium as a by-product of nuclear power plant is used as a material of an atom bomb. However, in Japan it is held in storage or left in a foreign country. Therefore, Japan has the first or second largest amount of plutonium in the world. And then, there is LNG (liquefied natural gas). As this is burned as a thermal power, CO₂ often comes out. And the facilities are needed to liquefy the gas in Japan. Therefore, the cost is involved. Furthermore, although Japan has imported the LNG via the Middle East and Russia, the regions are also politically unstable.

Finally, there is a natural energy (regenerative type's natural energy) (4). There exist solar power, wind power, water power (hydropower), wave power (tidal power), geothermal power, biomass power and so on as the types of energy. At first, a problem of the solar power is that this uses lots of petroleum and energy to make the solar panels including the gathering of the materials. Next, regarding the wind power, the wind blowing in Japan is not stable. In addition to this, Japan typhoons are common natural events in the late summer and autumn in Japan. Due to this, the windmills are often crushed. On the other hand, the wind power is suitable or acceptable for Europe because of a few weak typhoons unlike Japan. Third, the water power is suitable or acceptable more or less permanently for the areas in which there are so many rain and the mountains for storing the rain water. Fourth, the wave energy is utilizing the energy due to the rise and fall of the tide (tide level). However, it can be said that it is unstable as this is also affected by the weather. Fifth, although the geothermal energy is also stable. However, when the volcanic activity occurs briskly the one will have to run away to avoid that. At last, there is a biomass energy. The power generator can stably generate power if only there are biomass sources such as feces and urine of livestock, died trees and so on. However, the cost will be costly due to the fuel transportation to the power plant and the generation of wood chips etc. in the case of woody biomass electric power generation. The almost all the energies ((1)~(4)) were overviewed as mentioned above. Of all energies it could be said that the energy having relatively high stability is the water power energy. In addition, it is considered that to make lots of small dams in valleys and on hill slopes is much safer in a practical application.

By the way, it can be said that it is necessary to make an effort to use all the energy technologies safely based on the cost in conclusion throughout all of the energies. For example, we use the drone (unmanned aircraft) as a weapon, on the other, as a liberation (reduction) apparatus from an agricultural workload etc. Then, it is important to improve the good point more, and correct the bad point further, respectively. Ultimately, it can be said that all the issues come down to a question of paradoxical one (trade-off/issue of choice).

Therefore, we have decided to choose the "water energy" in this paper with due consideration of all the energy features mentioned above. In addition, there is a problem, that is, "storage of electricity" as one of the unstable factors in the case of the water energy. However, there recently exists a super capacitor: Elec-

tric double-layer capacitor as one of the electricity storage technologies. This is a condenser (capacitor) which can store a large amount of energy utilizing a physical phenomenon of electric double layer. This is one of the storage batteries unlike usual ones. This has some capacity; then it has a substitution possibility as a part of battery if the performance has been improved further in the near future. And as this does not need the maintenance of the battery (free discharge slightly exists), it can be nearly used for good. It is adequately considered that there is a possibility (flexibility) to use it during day time and night time.

And then, we adopt the super capacitor etc. for the storage of electricity by building lots of small dams to generate hydroelectric energy at every Isolated Islands. Then, it is desirable to utilize both the seawater and the rainwater as natural waters which have existed in abundance in the Islands when thinking about the water scarcity in the world. Therefore, we think that it is very important to examine the mixed water (seawater and rainwater) as a drinking water based on the electromotive force which has little impact on all living things.

4. Experimental Procedure

4.1. Small Waterwheel System

Figure 1 shows a schematic image of water quality improvement apparatus using a small hydroelectric power. The outline of the improvement of the water quality

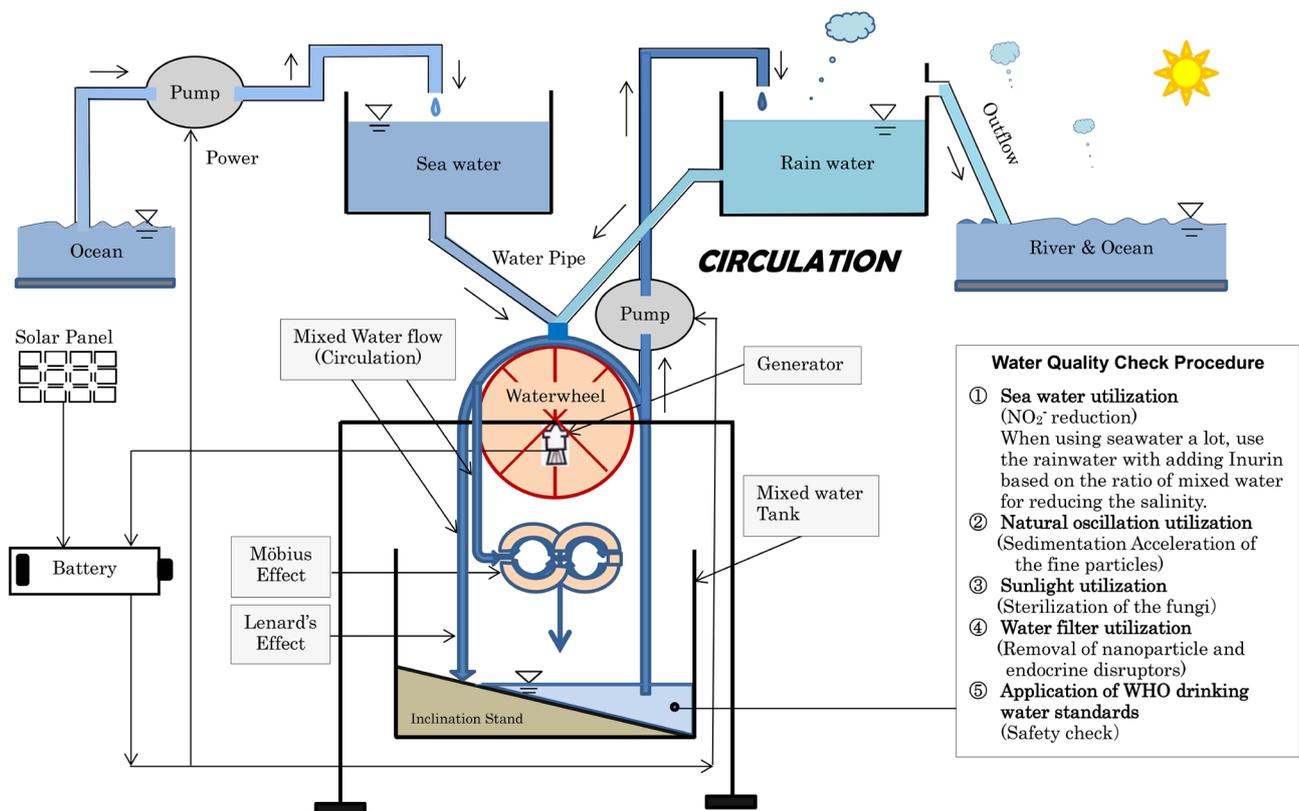


Figure 1. Schematic image of water quality improvement apparatus using hydroelectric power (This figure was reproduced based on our previous literature [2]).

of the mixed water in the apparatus is as follows. First, we store the rainwater brought about by the solar circulation energy. Second, we prepare the mixed water, that is, the mixture of the rainwater and the seawater by the volume ratio. Third, we rotate the waterwheel by pouring the mixed water on that. The generator starts by the rotation of the waterwheel in battery-based energy. We have ever stored the electricity in the style of battery. But that style should be changed into the lithium-ion batteries. (It is said that batteries are an important technology in enabling the world to move away from fossil fuels. Incidentally, the 2019 Nobel Prize in chemistry has been awarded to a trio of scientists (Japanese, American, British) for the development of lithium batteries.) As the mixed water circulates with the apparatus, the storage of the electricity is continuously acted by the water power and the electric power of the solar panel. Therefore, the required energy for improving the water quality is sustainably and stably supplied. Fourth, the mixed water quality passing through the waterwheel is more purified by both the Möbius effect and the Lenard's effect. Finally, we check whether we can drink the mixed water or not. If the standard we set up this time is recognized as being effective in the WHO standard after some refinements, it would be possible to drink this as a drinking water in the Islands in the world in the near future.

The outline of this apparatus is as follows. First, the rainwater which is continuously produced by the solar circulation energy is stored in the tank that was set up in a high location. Next, the waterwheel is rotated by the small hydro-electrical power energy produced by the difference in height, and the energy generation by the power of the rotation takes place. And then, the water circulation by the power generation occurs. The authors have tried a possibility of the rainwater purification using the apparatus (model) in 2019 [1] [2]. This time, a possibility (especially, as a drinking water) of the purification on both the rainwater and the mixed water (seawater & rainwater) through the water circulation system was examined adding the new data to the data obtained by the previous experiment (2019). The final water quality procedure 1) Seawater Utilization → 2) Natural Oscillation Utilization → 3) Sunlight Utilization → 4) Water Filter Utilization → 5) Application of WHO Drinking Water Standards) is as shown in the figure.

4.2. Experimental Condition

The research stance on the rainwater we have carried out so far [1] [2] has been fundamentally followed in this study. The volume ratio of the mixed water was 12 stages (10, 9, 4, 2.33, 1.5, 1, 0.67, 0.43, 0.25, 0.11, 0.05 and 0.03). The initial salinity of the seawater was 3.1% (Cl^- : 17,000 [mg/L]), and the initial NO_2^- of the rainwater was 0.07 mg/L, respectively. The soluble dietary fiber called Inurin (nutrition facts per 100 g/energy: 200 kcal, protein: 0 g, lipid: 0 g, carbohydrate (saccharide): 3.5 g, carbohydrate (dietary fiber): 92.9 g, Na: 0 g, ash: 0 g) was used as an additive for reducing the salinity. By the way, Prof. N. Nakamura *et al.* (Osaka Univ., Japan) have shown a feasibility of a new crystallization tech-

nique [9]. That is, they found that crystallization in a colloidal glass was rapidly accelerated by applying mechanical oscillation at a specific frequency (around 75 Hz). Referring to this example, we here used the other newly additive (powder agar (nutrition facts per 100 g/calorie: 0 kcal, protein: 0 g, lipid: 0 g, carbohydrate (saccharide): 0.04 g, carbohydrate (dietary fiber): 8.24 g, Na: 10.7 g) for accelerating the reduction of the salinity further. The irradiation experiment was carried out using an ultrasonic cleaner at a frequency of 116 KHz (43 dBm) in this study. Regarding the measurement of the sound, the output direct sound which reaches someone's ears directly was used in this experiment. The irradiation time is as follows: 1 min., 5 min., 10 min., 15 min. and 30 min. The temperature in the experiment was 28°C. In this experiment, 11 items such as Salinity (Cl^-), TOC, NO_2^- , pH, Ca, Mg, NO_3^- & NO_2^- , No. of General Bacteria, No. of Colitics Germ Logions, No. of Vibrio vulnificus, Bisphenol A were selected as the analytical ones. The water quality analyses in this time were 11 items previous items [including reference values]: TOC, NO_2^- , pH, Ca, Mg, NO_3^- & NO_2^- , No. of General Bacteria, No. of Colitics Germ Logions (2) new items: Cl^- , No. of Vibrio vulnificus, BPA [including reference values]). In addition, the sample data regarding the items such as TOC, Ca, Mg, NO_3^- & NO_2^- , No. of General Bacteria, No. of Colitics Germ Logions, No. of Vibrio vulnificus, Bisphenol A were used as the reference values which have been published in the previous papers. The rainwater used in this experiment was sampled in August 15th at home (Sakyo ward) in Kyoto city, and the seawater, in September 10th at Otomi fishing port (Takahamacho) in Fukui Pref., Japan 2019, respectively. In addition, the brackish water was sampled at Lake Suigetsu (Wakasa-cho) in Fukui Pref., Japan 2019 to compare the mixed water.

4.3. Analytical Method of Water Quality

First of all, the water quality analysis was conducted after the filtration using the filter named HARIO dripper which is available on the market. Pocket Salt Meter (PAL-SIO) Cat. No. 4100 (ATAGO Co., Ltd.) was used to measure the salinity. And, the measured salinity was converted to the Cl^- as the salinity has an almost proportional relationship with the chloride ion concentration (Cl^-). The conversion formula is as follows. [10]

$$\text{Salinity (\%)} = 1.80655 \times \text{chloride ion concentration (mg/L)} \times 10^{-3} \quad (1)$$

It is generally said that the seawater (34.3 ‰) includes the chloride ion concentration of around 19,000 mg/L [10]. As the salinity was 31.0 ‰, the chloride ion concentration (Cl^-) becomes 17,000 mg/L in this time. Regarding the Vibrio vulnificus [Vv.], the value of Vv measured in Japan falls in the range of 0 ~ 100 (MPN/ml) [11]. Then, we here use this data as the reference values. There is a research result in the public institution regarding the Bisphenol A (seawater: 0.05 µg/L, rainwater: 0.04 µg/L, raw water for water supply: 0.06 µg/L, purified water: 0.01 µg/L, Tap Faucet Water: 0.007 µg/L) [12] [13], then we used it as a reference value.

Regarding the other items such as TOC, NO_2^- , pH, Ca, Mg, NO_3^- & NO_2^- , General Bacteria, Colitis Germ Legions, as these data are same as until now, the data carried out based on the same water purification methods was used in this experiment [1] [2].

5. Results and Discussions

Table 1 shows the reduction of the mixed water salinity by the sound wave.

From **Table 1**, the reduction of both the salinity (8900 \rightarrow 160 mg/L) and the molar ratio of $\text{Cl}^-/\text{NO}_2^-$ ($1 \rightarrow 0.01$) with the reduction of the ratio of the mixed water was first confirmed, respectively. And it has also turned out that the salinity is reducing further in accordance with the volume ratio of the each mixed water by adding the soluble dietary fiber. And then, it was understood that these values (except for the ratio of 0.05 & 0.03) also show the further tendency of

Table 1. Reduction of mixed water salinity by sound wave.

Seawater-Rainwater Ratio • SW: 17,000 (Cl^- [mg/L]) • RW: 0.07 (NO_2^- [mg/L])	Seawater chloride ion concentration (Cl^- [mg/L])	Seawater chloride ion concentration after adding soluble dietary fiber (Cl^- [mg/L])	Seawater chloride ion concentration after irradiating sound wave (Cl^- [mg/L])					Remarks Molar ratio of $\text{Cl}^-/\text{NO}_2^-$
			Irradiation Time of Sound Wave (116 Hz, 43 dBm) under adding the powder agar					
			1 min	5 min	10 min	15 min	30 min (): Bottom	
10	17,000	9600	9500	9200	9100	9000	8900 (7600)	-
9	13,600	8500	8450	8400	8300	8100	7850 (7200)	1
4	11,800	7650	7590	7480	7420	7370	7150 (5100)	0.80
2.33	10,500	6670	6600	6500	6440	6280	6100 (4900)	0.66
1.5	9000	5800	5700	5660	5560	5500	5220 (4390)	0.53
1	7500	5000	4780	4720	4660	4610	4500 (3780)	0.42
0.67	6150	4040	3990	3930	3880	3820	3770 (3380)	0.32
0.43	4100	3210	3160	3100	3050	2990	2930 (2330)	0.20
0.25	3300	2090	2035	1980	1925	1870	1815 (1540)	0.15
0.11	1600	1010	960	900	900	900	850 (750)	0.07
0.05	690	530	530	530	530	530	530 (420)	0.02
0.03	370	160	160	160	160	160	160 (160)	0.01

SW: Seawater; RW: Rainwater.

decreasing by the microoscillation using the sonic irradiation under adding the powder agar. Furthermore, the further decreasing of the salinity was confirmed over all the ratio (except for the ratio of 0.03) after checking with the salinity at the bottom of the specimen at the irradiation time of 30 min.

The salinity (Cl^-) at the irradiation time of 30 min. was 160 mg/L (Bottom: 160 mg/L) when the volume ratio of the mixed water is 0.03 (0.07%). This value meets the drinking water standards (WHO & Japan). By the way, the salinity (initial value) at the ratio 1 of the mixed water was 7500 mg/L (0.9%), and the value of the treated water at 30 min. after the sonic irradiation was 4500 mg/L (0.81%). It is said that the values are about the same level as the concentration (0.9%) of human amniotic fluid and blood. Therefore, it is considered that the examination based on the mixed water ratio 1 is important for exploring the possibility as a drinking water. Besides, this time we tried an analysis of the salinity of the brackish water (Lake Suigetsu, one of the Mikatafive lakes, Cl^- : 3300 mg/L, Fukui Pref. Japan) as a reference. This value is about the same as the situation in that the ratio of the mixed water is 0.25 (0.6%). In addition, the different point is just in case that NO_2^- becomes ≈ 0 . It can be said from this point of view that the brackish water will also have a possibility as a drinking water as the same as the mixed water.

Table 2 shows the result of water qualities obtained from the mixed water. We

Table 2. Result of water qualities obtained from the mixed water.

Water Quality Items	Experimental Condition	Additive Amount of Dietary Fiber at Seawater-Rainwater Ratio 1			Mixed Water Treated After 30 min Irradiation time	Drinking Water Qualities Standards mainly based on WHO	*Standard Decision
		None	Inurin (20 g)	Inurin (20 g) + Powder Agar (4 g)			
Major Water quality Items Examined							
Salinity Cl^- (mg/L)		7500 (1.35%)	5000 (0.90%)	4780 (0.86%)	4500 (0.81%)	250 (0.05%)	△
TOC (mg/L)		1 ~ 7 (Estimated)	—	—	120,000	—	○
NO_2^- (mg/L)		0.016	0.010	≈ 0	0 ~ 0.016	≤ 0.04 (mg/L)	○
pH		7.6	6.5	6.6	6.5 ~ 7.6	5.8 ~ 8.6	○
Ca (mg/L)		0.4 (Estimated)	"	"	"	≤ 300 (mg/L)	○
Mg (mg/L)		0.03 (Estimated)	"	"	"	≤ 300 (mg/L)	○
NO_3^- & NO_2^- (mg/L)		0.3 (Estimated)	"	"	"	≤ 10 (mg/L)	○
No. of General Bacteria (CFU/mL)		13 (Estimated)	"	"	"	≤ 100 (CFU/mL)	○
No. of Colitics Germ Logions		ND (Estimated)	"	"	ND (Estimated)	ND	○
No. of Vibrio vulnificus (CFU/mL)		0~100 (Estimated)	"	"	ND (Estimated)	ND	○
Bisphenol A BPA ($\mu\text{g/L}$)		0.045 (Estimated)	—	—	< 0.007 (Estimated)	125 ($\mu\text{g/L}$)	○ and/or △

*○: Meet the WHO standard. △: Depend on the decision-making to decide the WHO standard. (Unlearning the premise of the set standard.) ○ and/or △: Depend on the decision-making to decide the WHO standard. (Addition of a water quality item and the set of the standard. In addition, it is possible to remove this item (BPA) even now by using the high-class household water purifier.)

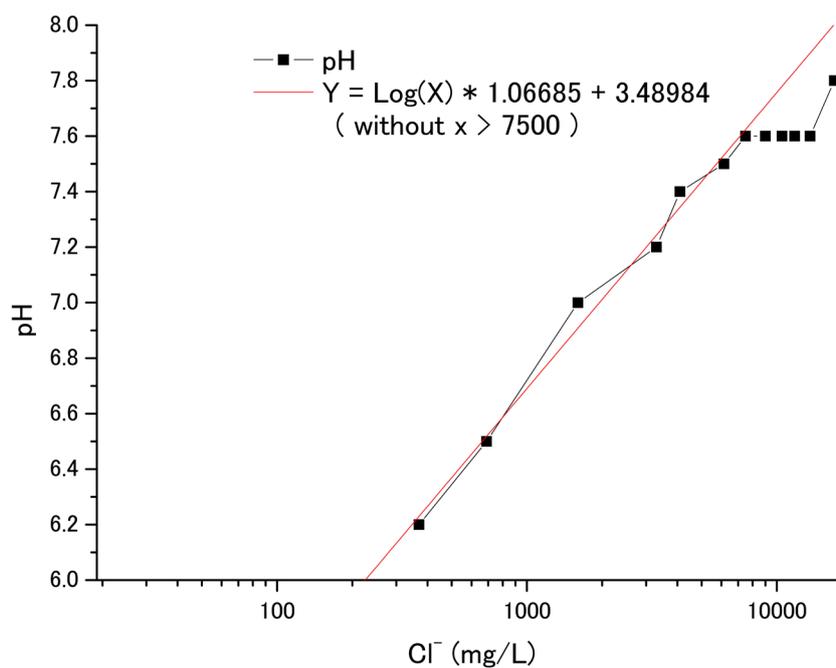
here examined a possibility of the mixed water as a drinking water based on the volume ratio 1. And the possibility which can be served as a drink was shown by the standard decision (\circ , \triangle , \circ and/or \triangle).

Regarding **Table 2**, the salinity (Cl^-) does not meet the WHO standards judging from the seawater vs. rainwater ratio 1. However, it is understood that the ratio meet the standards of both WHO (250 mg/L) & Japan (200 mg/L) viewed from the ratio 0.03. By the way, it is generally said that the major minerals per day for the human body are Na, Fe, Ca, Se, Cu, Zn, Mg, Cr, I etc. [14]. Some point out that it is rather important to take in the salinity properly as the natural salt obtained by seawater includes the minerals medically [15]. There is an aqueous solution of salt that is used for medical use, called Ringer's solution. It is said that this is made to conform to the blood components (salinity in human blood: about 0.9% [Cl^- : 5000 mg/L]). Therefore, if the salinity concentration of 0.9% [that is equivalent to the sea water vs. rain water ratio 1] is allowed, it will be possible to serve about 800 ml/day of mixed water as a drinking one to the people. Incidentally, it is said that about 2400 ml (drinking water \approx 1000 ml, Meal \approx 1100 ml, metabolic water \approx 300 ml) of water per day is necessary for human body. It is expected to consider the reviewing of the WHO standards on the salinity (Cl^-) in the future. TOC meets the criteria judging from WHO standards, but not Japanese ones [16]. In addition, the data by Prof. Inoue *et al.* was used as a reference value regarding the TOC (estimated) [17]. The previous data (2019) by the authors was used regarding Calcium, Magnesium, NO_3^- & NO_2^- , No. of General Bacteria and No. of Colitis Germ Legions [2]. In addition, it is fundamentally possible to sterilize both No. of General Bacteria and No. of Colitis Germ Legions by using the boiling (heating) and 6 hrs of sunlight irradiation (SODIS) [18]. Regarding No. of *Vibrio vulnificus* (Vv.: Invasive Streptococcus/flesh-eating bacteria), the value of this exists within a fixed range (about 0 - 100 (MPN/ml). Then this data was here used as a reference value [11]. Besides, V.v is also possible to sterilize by the boiling (heating) [19].

This one does not include the WHO standards (*i.e.*, non-standard item). Here we set this value to "ND". Bisphenol A (BPA) is one of the Persistent Organic Pollutants (POPs). This POPs was used in the past. However, its hazardousness was observed, and then the production and the use of that have been prohibited since 2004 (UNEP). However, it has turned out by the recent studies that the organic pollutants remained in the seawater are stuck together and won't come apart to the plastics [20]. Therefore, BPA was here taken up as one of the typical ones [20] [21]. In the literature [21], a famous prof. H. Takada (Tokyo University of Agriculture and Technology, Environmental Chemistry) introduces a greatest 20th century physicist: Albert Einstein's word, that is, "A clever person solves a problem. A wise person avoids it", and the author says that the change of one's life style is wiser to solve the plastics pollution issue at the explanation of Japanese version in this book. The data published by the public institution was used as a reference value as mentioned before (Section 3.3) [13]. We used the es-

estimated value (“0.007 $\mu\text{g/L}$ ”) as the result of the treated one. Besides, the BPA in the POPs is at present a suspected substance as one of the endocrine disrupting chemicals as the PCB and Nonylphenol etc. In addition, this item is at present an additional one that is not included in the standards such as WHO, EU, US-EPA and Japan. We here set the standard value to “125 $\mu\text{g/L}$ ” referencing the data (an estimation of evaluation value by TDI approach) of Tyl *et al.* [22]. If one could evaluate the BPA by this value, the standard on this is met as a drinking water. In addition, it is also said that the BPA can be decomposed by the chlorine (Cl) [23]. By the way, it is generally said, the seawater includes a mineral group (trace element) which is deeply involved in the human metabolism (basal metabolism, substitution). There are N (<10 g), Ca (600 mg), Se (0.13 mg), Cu (2.5 mg), Zn (15 mg), Mg (300 mg), Cr (0.29 mg), I (0.1 mg) etc. as major minerals. The amounts of mineral/day are here shown together with the minerals [14]. The natural salt in the seawater (*i.e.*, excellent in mineral balance) is a source of the mineral supplementation for human beings. It is said that the composition regarding the seawater, amniotic fluid, blood, intravenous drip (Ringer’s solution) is very similar to each other. It is also said that there exists hypertension excitation, myocardial infarction risk ratio up, worsening to diabetes, sympathicotonia, metabolism down, immunity down, cancer risk up etc. as negative effects of the low salt viewed from the preventive medicine [5] [15]. This is why the appropriate intake of the natural salt is necessary to the human body in a daily life.

Figure 2 shows the relation between pH and Cl^- . It is understood from this figure that the salinity (Cl^-) has also a tendency to decrease with the pH decrease. It is often said that the ocean is acidified due to the influence of the global warming. If this idea is right, the possibility of accelerating the decrease of the



salinity (Cl^-) of these a water by the acidification (pH decrease) of the ocean is estimated. In this regard, the width of the reduction falls within the range (5.8 ~ 8.6) of the standards. (The linear approximation equation: $\text{pH} = \text{Log}(\text{Cl}^-) \times 1.067 + 3.490$.) Then it is not necessary to have any anxiety for this.

Figure 3 shows the relation between Chlorideion (Cl^-) and Nitrite ion (NO_2^-) in the mixed water. A general expression of the chemical reaction between Cl^- and Nitrate ion (NO_3^-) is as follows [24].



It is understood from **Figure 3** that the salinity (Cl^-) decreases approximately linearly with decreasing of NO_2^- . (The linear approximation equation: $\text{Cl}^- = \text{NO}_2^- \times -1.486\text{E}6 + 31300$.)

It is thought that only proportional increase of NO_2^- in the rainwater increases fundamentally in the relation between the two. Then, the salinity reduction is accelerated with accumulating of NO_2^- by that amount.

However, it is understood from **Figure 3** that the reduction speed of Cl^- is weakened at a point (*i.e.*, NO_2^- (0.02 mg/L): changing point). There is an evaluation of the solid-liquid separation system of sewage sludge focused on the water quantity and water quality of the separated water. This is an evaluation technique using a consolidation point (changing point of sedimentation speed) [25]. Therefore, it is thought that this changing point of the salinity speed is one of the important points to examine the salinity reduction as this consolidation point in

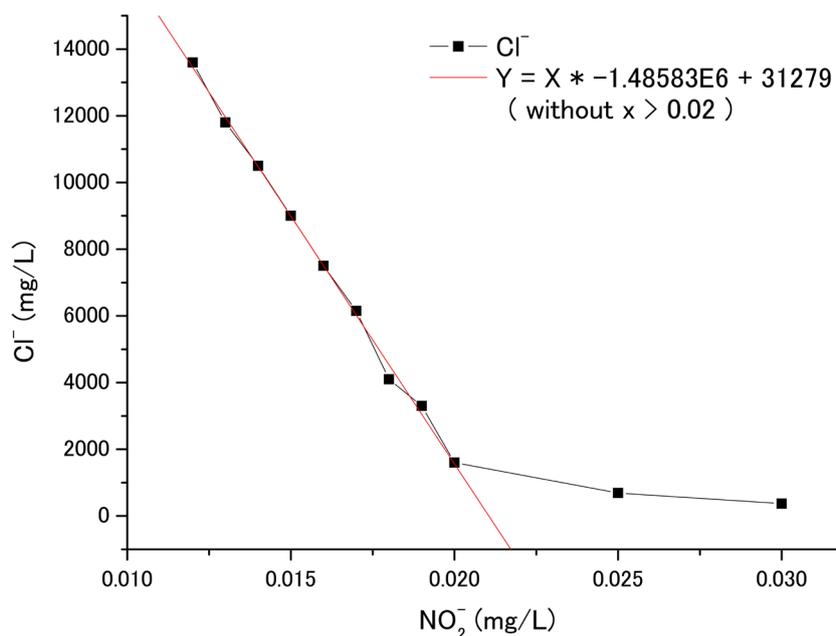
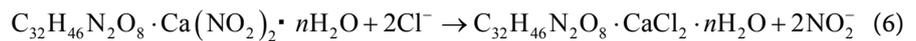


Figure 3. Relation between Cl^- and NO_2^- .

the future.

Figure 4 shows relation between $\text{Cl}^-/\text{NO}_2^-$ and the sea water vs. rain water ratio in mixed water. As is seen from **Figure 4** the molar ratio of $\text{Cl}^-/\text{NO}_2^-$ decreases approximately linearly with decreasing of the sea water vs. rain water ratio. (The linear approximation equation: $\text{Cl}^-/\text{NO}_2^- = \text{Log}(\text{Sea water vs. Rain water Ratio}) \times 0.611 + 0.425$.) And regarding the salinity reduction, when the molar ratio of $\text{Cl}^-/\text{NO}_2^-$ is more than 0.2 (*i.e.*, sea water vs. rain water ratio: 0.43 [Salinity: 0.74%]), the effect is particularly notable, and vice versa “becomes a slight decrease in value” at the point. In general, Calcium ion (Ca^{2+}) includes about 400 mg/L in the seawater, and about 400 $\mu\text{g/L}$ in the rain water, respectively. Therefore, it is thought on this phenomenon that when the additive (soluble dietary fiber called INURIN: $\text{C}_{32}\text{H}_{46}\text{N}_2\text{O}_8$) interacts with Cl^- , an ion-exchange reaction occurs, and by that the INURIN adsorbs the Cl^- and at the same time, emits the NO_2^- [Equation (6)]. That is to say, we could obtain the salinity reduction phenomenon due to both of the absorbability of Cl^- and the releasability of NO_2^- (emitting property), *i.e.*, contrary properties, in the mixed water using the additive.



Therefore, we consider that the changing point (sea water vs. rain water ratio: 0.43 [Salinity: 0.74%] at the molar ratio of $\text{Cl}^-/\text{NO}_2^-$) will be an important point to consider the mixed water as a drinking water in the future.

6. Conclusions

In this paper, a reduction of mixed water salinity by the sound wave was confirmed toward water scarcity issue-solving in isolated islands in the world. That

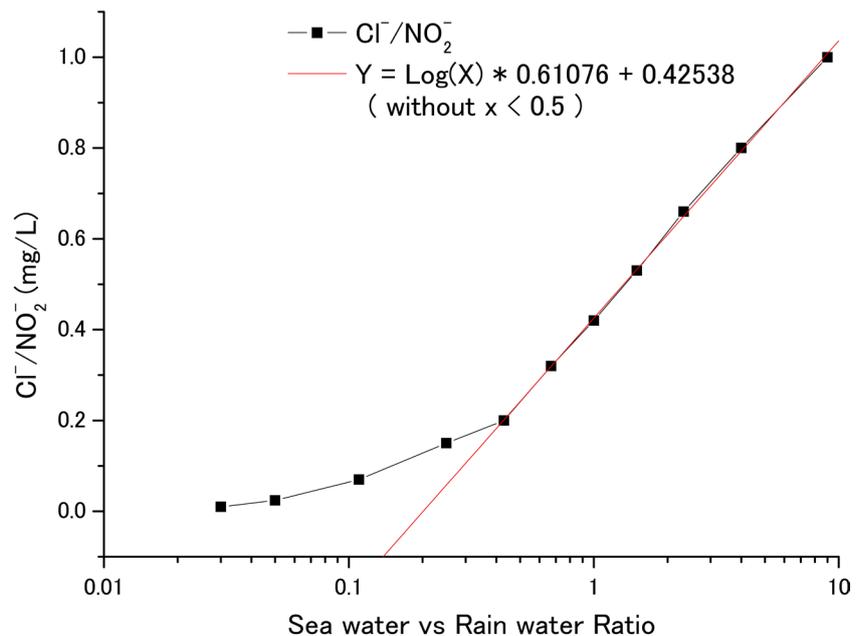


Figure 4. Relation between $\text{Cl}^-/\text{NO}_2^-$ and sea water vs. rain water ratio.

is, a feasibility of the mixed water as a drinking water (application of WHO standards) by sound wave using the additives such as both a dietary fiber and a powder agar was suggested. Main results are as follows.

1) The salinity (Cl^-) in the mixed water decreases approximately linearly with decreasing of the sea water vs. rain water ratio and the molar ratio of $\text{Cl}^-/\text{NO}_2^-$. In addition, it is considered that the changing point (sea water vs. rain water ratio: 0.43 [Salinity: 0.74%]) at the molar ratio of $\text{Cl}^-/\text{NO}_2^-$ will be an important point to consider the mixed water as a drinking water in the future.

2) The salinity (Cl^-) has a tendency to decrease (within WHO standards) with the pH decrease. In addition, an examination-confirmation of the purification a) general water quality such as a TOC, b) fungi such as a Vv. and c) endocrine disrupting chemical such as a BPA, especially an examination of bactericidal effect for b) of the mixed water at the condition of sea water vs. rain water ratio: 0.43 (Salinity: 0.74%) at molar ratio of $\text{Cl}^-/\text{NO}_2^-$ (or $\text{ClO}^-/\text{NO}_2^-$) based on the small hydroelectric energy could be pointed out in the near future.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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