2021 年臺灣國際科學展覽會
優勝作品專輯

作品編號	200024
參展科別	環境工程
作品名稱	Considering Fukushima’s contaminated water treatment system using algae ～ To protect the oceans from radioactive emissions
得獎獎項	大會獎 三等獎

國　　家 Japan

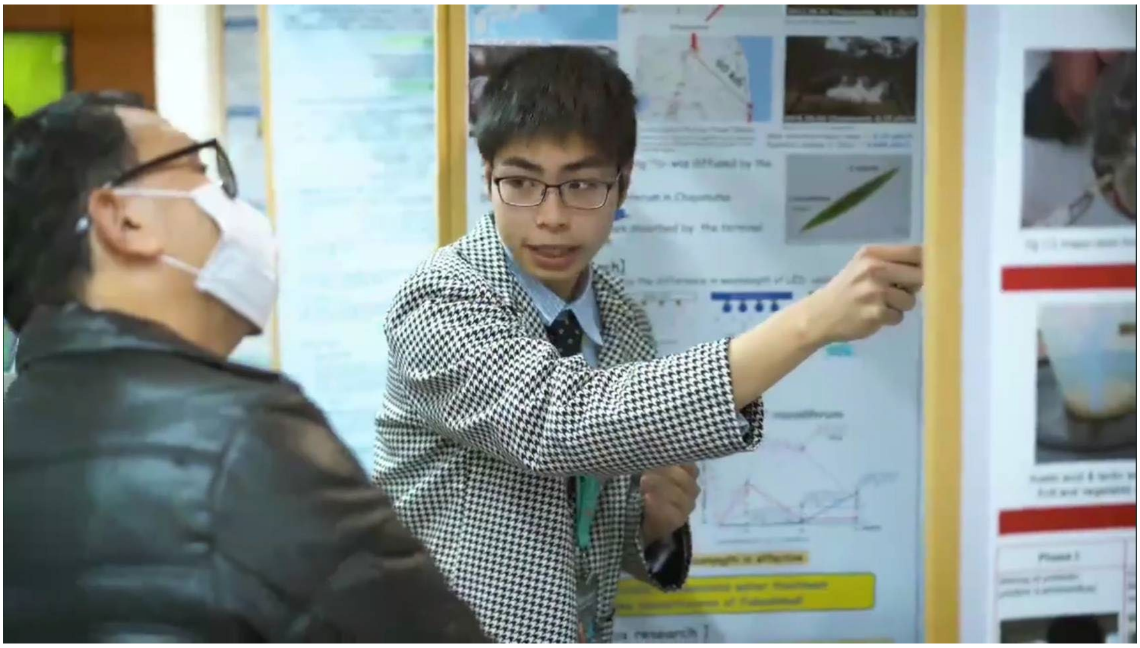
就讀學校 Fukushima Seikei High School

指導教師 Go Yamamoto

作者姓名 Keisuke Nemoto

關鍵詞 Fukushima radioactive emissions

作者照片



1. background and motivation

Nine years ago, the Great East Japan Earthquake caused the spread of a large amount of radioactive materials. Even now, the amount of contaminated water is increasing at a rate of 180 tons per day, and it is said that the storage tanks for the contaminated water will run out of space in the next two years (Fig. 1).

If the contaminated water is discharged into the ocean, it will cause reputational

Fig.1 State of Fukushima Daiichi Nuclear Power Station (Google Earth)

damage to the fishing industry, and the environmental pollution. We are conducting to research to prevent it from happening.

In the wake of the nuclear accident, the senior started water quality surveys at Chaya Marsh near the school. During the survey, they found (*Chara braunii*, Fig. 2), (*Nitella axilliformis*, Fig. 3), *Closterium moniliferum* (Fig. 4), and (Nostoc *commune*, Fig. 5).

Fig 2.

Fig 3.

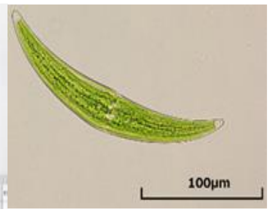


Fig 4.

Fig 5.

according to the literature , that *Chara braunii,* adsorbs Ca, and *Nitella axilliformis* absorbs *Cs*, *Closterium moniliferum* absorbs Sr, and Nostoc *commune* absorbs *Cs* and Sr. This led us to start researching algae to see if they could be used to recover radioactive materials. In addition, we thought that the volume of contaminated water could be reduced due to the fact of the Nostoc *commune* had a property to absorb water 30 times as large as the weight in dry state, and we started research on the treatment of contaminated water (tritiated water) using the Nostoc *commune*.

2. Objectives of this study

(1) Sr adsorption by using *Chara braunii*,
(2) Sr adsorption by using *Closterium moniliferum*
(3) Water disappearance (evaporation) by using Nostoc *commune*

3. This study

(1) Sr adsorption experiment using the *Chara braunii*

【Previous study】

We predicted the mechanism of Sr adsorption based on the adsorption of Ca by the *Chara braunii*, as described in Reference 1). First, the *Chara braunii* also uses HCO_3^- for photosynthesis and emits OH- from specific locations (HCO_3^- → CO_2^+OH-). This causes the area around the *Chara braunii* to become basicity, with pH 7 ～ 9, and alkaline bands to form on the cell surface. Within this alkaline band, ①Sr_2^+ and HCO_3^- or ② Sr_2^+ and CO_2 in the environment combine to form $SrCO_3$ crystals on the cell surface ① Sr_2+HCO_3^- → $SrCO_3^-$H+
②CO_2+Sr^{2+}+H_2O → $SrCO_3$+2H+ (Fig. 6).

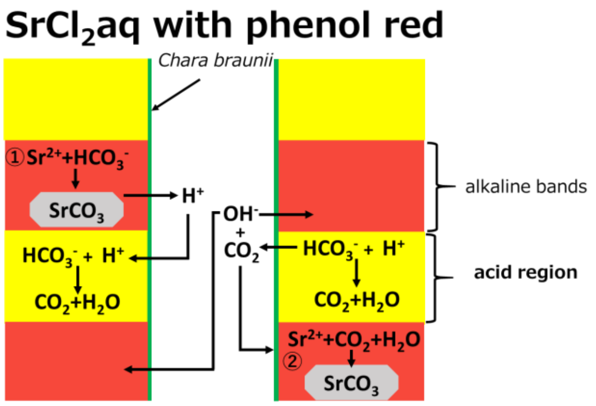


Fig 6. Mechanism to adsorb Sr

【Observation of alkaline bands】

We prepared the same medium as in the previous study, and put *Chara braunii* in to check whether alkaline bands could be observed as described in the literature.

【Experimental method】

The agar medium was prepared using phenol red solution and agarose [5)].

① 87ml of pure water was put into a 100ml screw tube, and stirring was performed with a stirrer.
② 0.5g of agarose was added while stirring.
③ Covered with plastic wrap and heated in a microwave oven until it came to boil. (About 1 minute and 40 seconds at 600w)
④ While stirring ③ again, add 10ml of phenol red (10mM) and 1ml of $NaHCO_3$ (20mM).

⑤ put *Chara braunii* in, and the alkaline band was produced by irradiating red, white, blue, and green LEDs.

[Results].

The observation revealed that the tip of the *Chara braunii* is the most likely to produce alkaline bands on the cell surface. [5)] To verify this, we conducted experiments using red, white, blue, and green LEDs to determine which wavelengths were most likely to produce alkaline bands. As a result, it was clarified that redLED was the most likely to produce alkaline bands (Fig. 7).

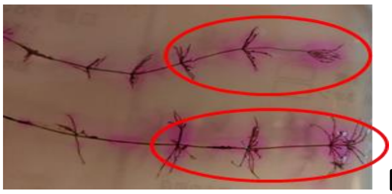


Fig 7. Alkaline band (irradiate by red LED) of *Chara braunii*

(2)-I. Observation of crystals containing alkaline earth metals adsorbed on the surface of *Chara braunii* using red LED

It was stated at calcium carbonate crystals were difficult to form when the *Chara braunii* were put into agar medium ($CaCl_2$aq 10mM, $NaHCO_3$aq 0.2mM, agarose 0.5 %) which photosynthesis inhibitor (DCMU) was added. Therefore, to increase the amount of adsorbed calcium carbonate, we expected it by activating photosynthesis, and observed the amount of adsorbed calcium carbonate in $CaCl_2$aq (10mM) and $SrCl_2$aq (10mM) using red LED.

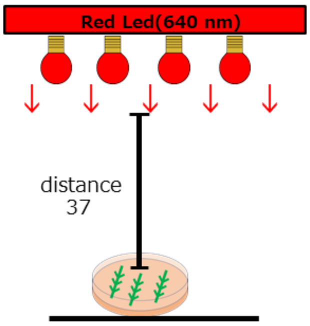


Fig 8. irradiation wavelength and irradiation distance

[Experimental Methods]

① 87ml of pure water was put into a 100ml screw tube, and stirring was performed with a stirrer.

② 0.5g of agarose was added while stirring.

③ Covered with plastic wrap and heated in a microwave oven until it came to boil. (about 1 minute and 40 seconds at 600w)

④ While stirring ③ again, 10ml of phenol red (10mM) and 1ml of $NaHCO_3$ (0.2mM) were added.
⑤ $CaCl_2$aq (10mM) and $SrCl_2$aq (10mM) were added to ④.
⑥ The mixture was poured into a Petri dish, and after solidification, *Chara braunii* cut to 5 cm from the tip was embedded.
⑦ Red LED was irradiated at a distance of 37cm with light phase: dark phase 12 hours: 12 hours irradiated (Fig. 8), and the same area was observed daily using a stereomicroscope.

【Results and Examination】

As a result of observation using an optical microscope, crystals were observed on the 7th day after being put into $CaCl_2$aq (10mM) (Fig. 9). In addition, observation of the *Chara braunii* fed into $CaCl_2$aq (10mM) on the 18th day revealed that the *Chara braunii* tended to adsorb more crystals where the branches were clustered (Fig. 10).
Furthermore, the cell condition of the *Chara braunii* after 28 days in $CaCl_2$aq (10mM) was good (Fig. 11).

＜ put in $CaCl_2$aq ＞

Fig 9. State of 7th day

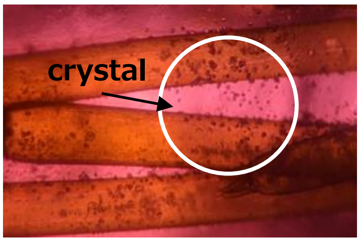


Fig10. State of 18th day

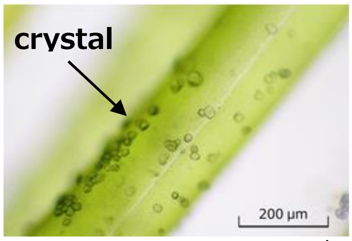


Fig11. State of 28th day

Crystals were observed on day 6 from the *Chara braunii* fed into $SrCl_2$aq (10mM), and by day 16, the crystals were larger than day 6 (Figs. 12 and 13). Observations also revealed that the cell condition of the *Chara braunii* submitted to $SrCl_2$aq (10mM) for a long period of time was worse than that submitted to $CaCl_2$aq (10mM) (Fig. 14). Furthermore, the *Chara braunii* in $SrCl_2$aq (10mM) showed more crystals where the branches were clustered.

＜put in $SrCl_2$aq＞


Fig 12. State of 6th day


Fig13. State of 16th day

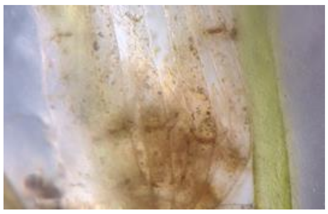


Fig14. State of 26th day

As the examination, the fact that crystals were observed on the seventh day . the *Chara braunii* grown in $CaCl_2aq$ (10mM) is thought to be due to the active photosynthesis caused by the red LED irradiation. In the case of the *Chara braunii* fed with $SrCl_2aq$ (10mM), many crystals were observed at the tip of the *Chara braunii* (Fig. 15). We predicted that was due to the formation of strong alkaline bands by the gathering of branches, which facilitated the adsorption of crystals.

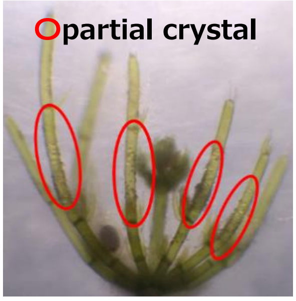


Fig 15 Bit of *Chara braunii* which was able to be crystallized

2-II. Observation of crystals containing alkaline earth metals by varying the irradiation distance

Adsorption of crystals containing Ca and Sr was observed on the surface of *Chara braunii* cells by irradiating them with red LED in 2-Ⅰ. In addition, when red LED was irradiated on *Closterium moniliferum* fed with $SrCl_2aq$ in our seniors' research, it was found that the amount of Sr_2^+ absorbed increased by changing the amount of photon quantity. Since the base of both *Closterium moniliferum and Chara braunii* are the same, we thought that the adsorption of Ca and Sr would be accelerated by changing the irradiation distance and the photon quantum quantity.

【Experimental conditions】

Red LEDs (640nm) were irradiated at the distance of 37cm (photon quantity : 7.5 $\mu molm^{-2}s^{-1}$) and 10cm (photon quantity : 16 $\mu molm^{-2}s^{-1}$) (Fig. 16), and $CaCl_2aq$ (10mM) and $SrCl_2aq$ (10mM), and observations were made on days 0, 7, 14, and 21. Irradiation time was 12 hours : 12 hours in the light phase and 12 hours : 12 hours in the dark phase.

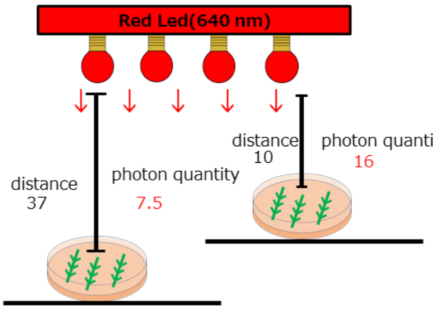


Fig16. wavelength and irradiation distance(cm), photon quantity($\mu molm^{-2}s^{-1}$)

【Experimental method】

① 87 ml of pure water was put into a 100 ml screw tube, and stirring was performed with a stirrer.

② 0.5 g of agarose was added while stirring.

③ Covered with plastic wrap and heated in a microwave oven until it came to a boil. (about 1 minute and 40 seconds at 600w)

④ While stirring ③ again, 10ml of phenol red (10mM) and 1ml of $NaHCO_3$ (0.2mM) were added.

⑤ $CaCl_2$aq(10mM)+$NaHCO_3$aq(0.2mM), $SrCl_2$aq(10mM)+$NaHCO_3$aq(0.2mM) were added to ④.

⑥ the Petri dish containing the cells of the tip of the *Chara braunii* flowed into ⑤

⑦ Observations were made using an optical microscope and a stereo microscope on days 0, 7, 14, and 21.

【Results ・ Examination】

There was no significant difference in the adsorption of crystals in the *Chara braunii* fed into $SrCl_2$aq (10mM) when the irradiation distance was varied (Figs. 17, 18, 19). In the case of the *Chara braunii* in $CaCl_2$aq (10mM), more crystals were adsorbed in a shorter period of time in the sample with 10cm irradiation distance than in the sample with 37cm irradiation distance (Fig. 20). When the irradiation distance was compared between 10cm and 37cm, it was confirmed by observation that more crystals were formed on top of the crystals in layers in the 10cm sample, indicating that crystals were more easily adsorbed in the shorter irradiation distance (Figs. 21, 22).

As a result, the shorter the irradiation distance, the more crystals were adsorbed (Figs. 21, 22). As a discussion, when we compared the irradiation distance of 10cm and 37cm in $CaCl_2$aq (10mM), more crystals were adsorbed in 10cm. The fact that there was no significant difference in the adsorption of the *Chara braunii* between the samples 10cm and 37cm irradiation distance submitted to $SrCl_2$aq (10mM) is expected to be due to the fact that the cell condition was not favorable.

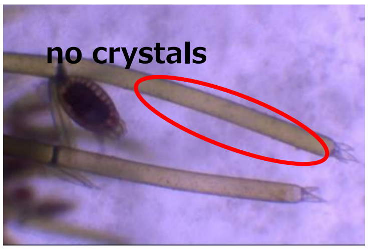


Fig 17.
pre-input state

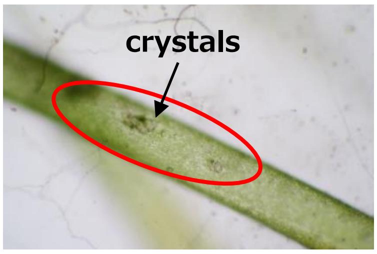


Fig 18.
irradiation distance 37 cm state on 7th day

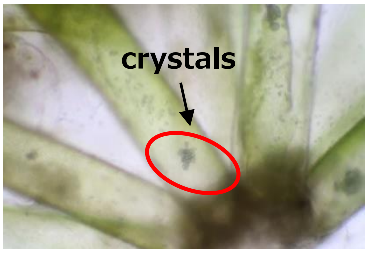


Fig 19.
irradiation distance 10 cm state on 14th day

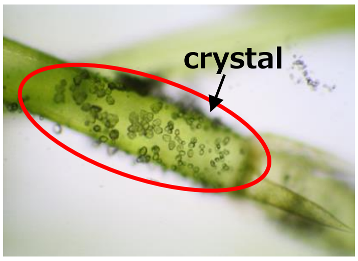


Fig 20.
irradiation distance 10 cm state on 7th day

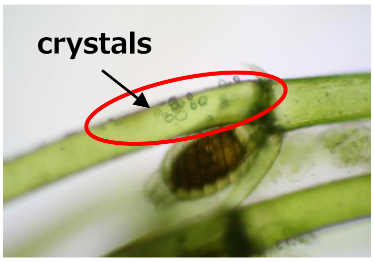


Fig 21.
irradiation distance 37 cm state on 14th day

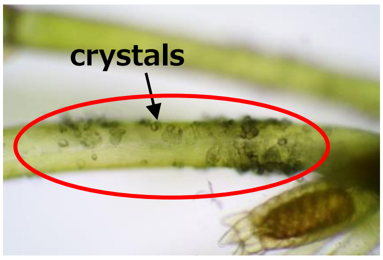


Fig 22.
irradiation distance 10 cm state on 14th day

2-III. Observation of crystals of alkaline earth metals including Sr with Ca as a nucleus

It was confirmed that the number of days that Ca and Sr crystals are adsorbed on the surface of the *Chara braunii* , cell can be shortened by changing the light quantum quantity in 2-II, that the Sr crystals may grow on top of the Ca crystals by attaching the Ca crystals first and then feeding them into the Sr solution. From previous research and experiments, the possibility that photosynthesis is involved in the adsorption of the *Chara braunii* increased, so we tested it that changing the concentration of $NaHCO_3$aq in the agar medium would cause photosynthesis to be active and change the amount of adsorption.

【Experimental conditions】

Red LED (640nm) was irradiated at a distance of 10cm (photon quantity 16 $\mu mol m^{-2} s^{-1}$), and the cells were put into $CaCl_2$aq (10mM) + $NaHCO_3$aq (0.2mM) for observation. The irradiation time was 12 hours : 12 hours in the light phase and 12 hours : 12 hours in the dark phase.

【Experimental Methods】

(1) The tip of the *Chara braunii* was placed in agar medium containing $CaCl_2$aq (10mM) + $NaHCO_3$aq (1) 2.0mM, (2) 5.0mM.

(2) The first node of the *Chara braunii* was placed in the agar medium containing The *Chara braunii* was cut out with the agar.

(3) The *Chara braunii* in (2) were placed in $SrCl_2$aq (10mM) + $NaHCO_3$aq (① 2.0mM, ② 5.0mM.)

(4) Observations were carried out using a stereo microscope and an optical microscope.

【Results ・ Examination】

In both samples, it was not confirmed that the Ca crystals formed at the time of injection became larger (① Fig. 23, 24, 25) (② Fig. 26, 27, 28).

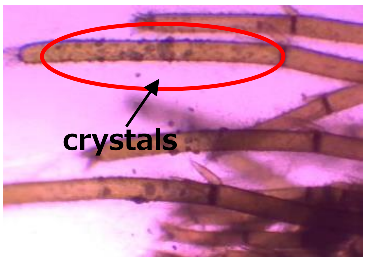


Fig 23.
cell state before input

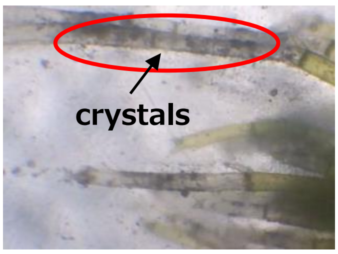


Fig 24.
cell state on 11th day

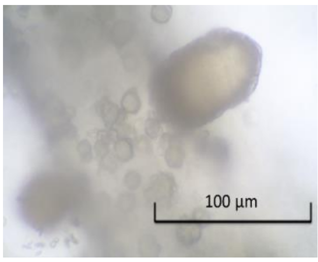


Fig 25.
crystal on day 16

However, in one of the samples in ②, the growth of cells was confirmed after fed into $SrCl_2$aq (Figs. 29,30,31). When the cells were taken out of the agar medium, no crystals were observed because the cells were not grown yet (Fig. 29), but after being put into $SrCl_2$aq, the cells grew toward the outside of the agar medium (Fig. 30), and crystal-like substances were observed at the part of the cells outside of the agar medium (Fig. 31, 32). This suggested that the simultaneous presence of Ca and Sr, rather than binding with Ca to the nucleus of a Ca-containing crystal, it might be important for Sr adsorption

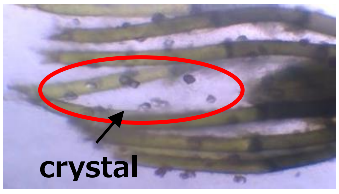


Fig 26.
cell state before input

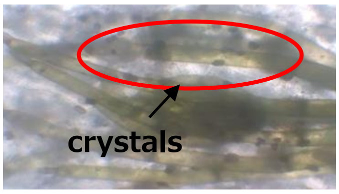


Fig 27.
cell state on 7th day

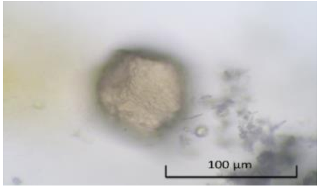


Fig 28.
crystal on day 16

Fig 29.
cell state before input

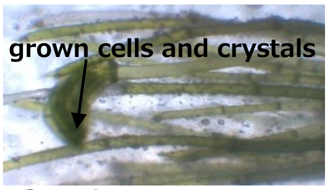


Fig 30.
cell state on 2nd day
(the ○part of Fig 29)

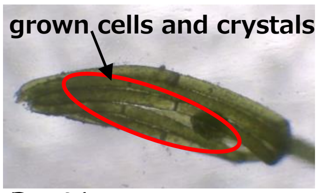


Fig 31.
cell state on 6th day
(the ○part of Fig 29)

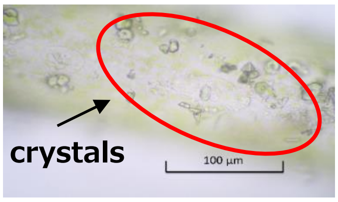


Fig 32.
crystals on day 16

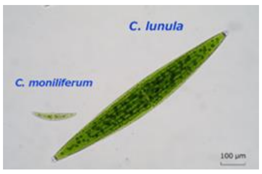
3. Sr absorption experiment using *Closterium moniliferum*

In this study, in order to clarify how and under what conditions of *Closterium moniliferum* bsorbs Sr^{2+} efficiently, I). Determination of Sr absorption using a Shimadzu AA-6300 Furnace atomic absorption spectrophotometer, II). High-resolution scanning electron microscopy (SEM-EDX) was used to observe the photosynthesis inhibitor (DCMU), and III). Comparison of the Sr absorption of *Closterium moniliferum* after immersion in Ba was verified.

【Previous study】

The seniors compared the Sr2+ absorption of different LED wavelengths using C. moniliferum and C. lunula (Fig. 33). C. moniliferum and C. lunula were each placed in SrCl2aq (10 mM) and incubated in a plant incubator (20°C ± 3 C.lunula and C.moniliferum were irradiated with red (640 nm), white, blue (450 nm), and green (525 nm) LEDs at different distances in a plant incubator (20 °C ± 3 °C) to determine which wavelengths absorb the most Sr (Fig. 34).

Fig 33.



C.moniliferum* and *C.lunula

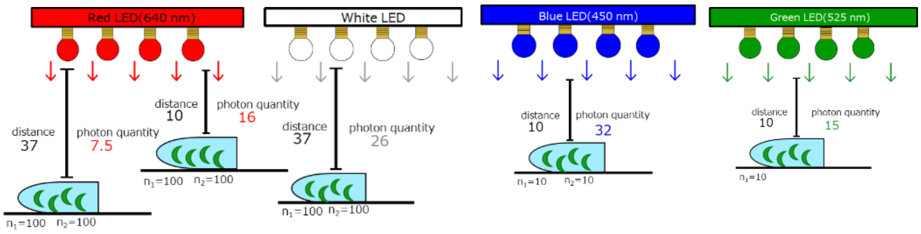


Fig 34. avelengths of irradiated LEDs, their irradiation distances (cm), and light quantum quantities (μ-molm^{-2}s^{-1})

n1 : Number of measurements for C.moniliferum n2 : Number of measurements for C.lunula

By comparing the absorption of C.lunula and C.moniliferum on the same scale graph, it was found that the absorption of C.lunula was higher than that of C.moniliferum in red LED and white LED (Graphs 1 and 2). C.lunula showed the maximum absorption of 279 ± 27ng/cell at 10cm in red LED at 24 hours (Graph 1), and C.moniliferum showed the maximum absorption of 16 ± 1.1ng/cell at 37cm in red LED at 48 hours (Graph 2). Therefore, the red wavelength is considered to be related to many Sr2+ absorptions.

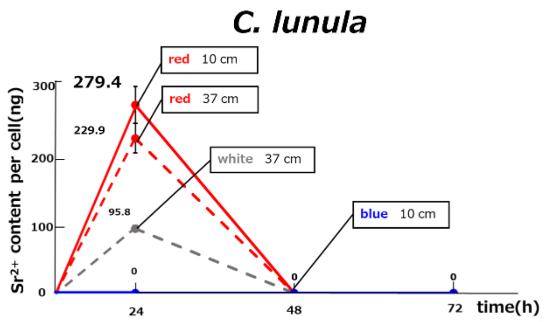


Fig 35. Sr^{2+} absorption quantity of C.lunula

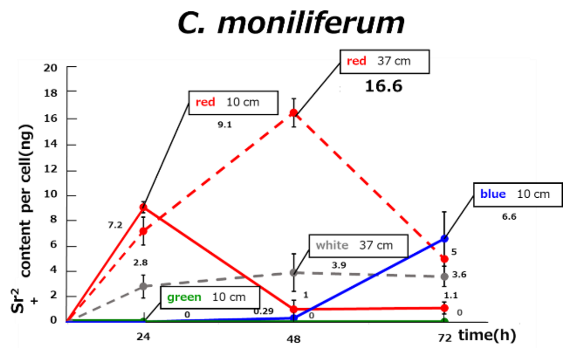


Fig 36. Sr^{2+} absorption quantity of C. moniliferum

(3)-I. High-resolution scanning electron microscopy (SEM-EDX) of C. moniliferum with photosynthesis inhibitor (DCMU)

In order to verify whether photosynthesis is involved in the efficient Sr2+ absorption of C. moniliferum, we prepare a sample (Fig. 18) using a photosynthesis inhibitor (DCMU) and observed C. moniliferum by high-resolution scanning electron microscope (SEM-EDX). and before the observation by high-resolution scanning electron microscope (SEM-EDX), the cells of C. moniliferum were observed by optical microscopy to verify whether the granules that were not stained by iodine solution could be identified.

- sample① → put into CA medium
- sample② → $SrCl_2$aq only (DCMU-free)
- sample③ → $SrCl_2$aq with DCMU

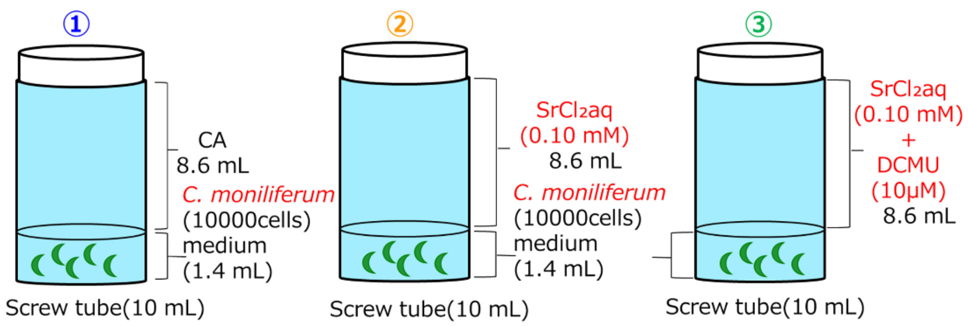


Fig 37. Samples used in the experiment and conditions to be fed into the control

【Experimental conditions】

Previous studies have raised the possibility that red wavelengths are effective for efficient Sr_2^{+} absorption in C. moniliferum. Based on this, we used the conditions under which C.moniliferum showed the highest amount of Sr_2^{+} absorption in the previous study. C. moniliferum was irradiated with a red LED (20° C±3° C, light and dark changing every 12 hours) (640nm, irradiation distance 37cm, photon quantity 7.5 $\mu \cdot molm^{-2}s^{-1}$) and placed in $SrCl_2aq$ for 48 hours (Figure 19).

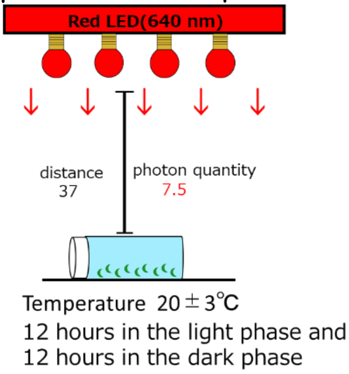


Fig 38. wavelength of the LED which irradiated and irradiation distance and quantity of photon

【Experiment and observation method】

① C.moniliferum was placed in $SrCl_2aq$ (0.10mM) for 48 hours.

② C.moniliferum was filtered through a membrane filter and washed several times with pure water.

③ The ② filters were placed on a watch plate, placed in a Petri dish, and dried thoroughly in a dryer (40-50 °C).

④ Coated with platinum and observed with a high-resolution scanning electron microscope (SEM-EDX) (Fig 20 and 21).

【Observation results】

①

Fig 39

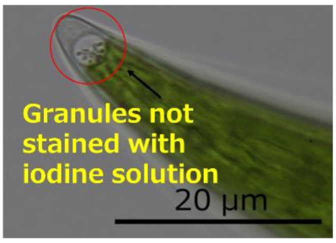


Fig 40

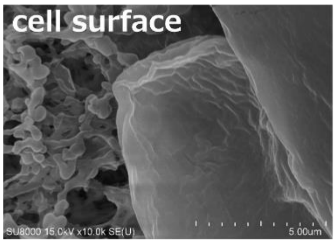
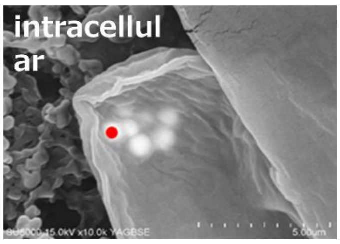


Fig 41



②

Fig 42

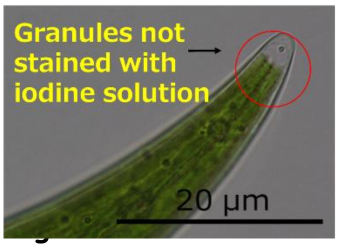


Fig 43

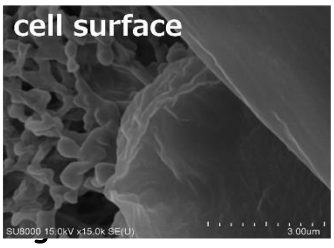
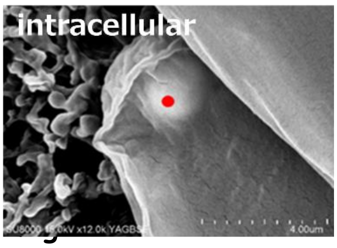
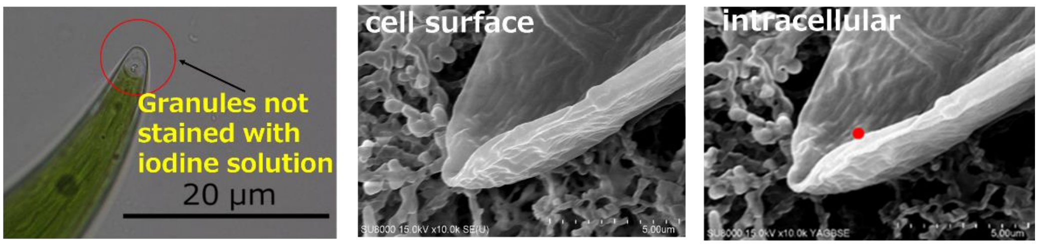
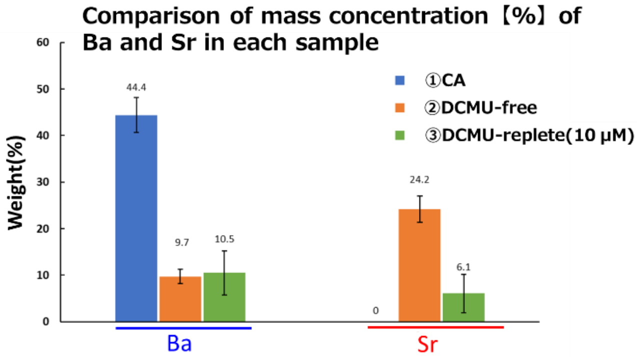


Fig 44



③





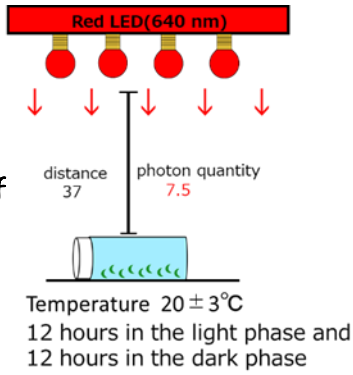
Element	Weight [%]		
	①	②	③
C	20.47	26.92	31.94
O	16.12	9.02	34.78
S	11.85	15.05	6.85
K	4.15	6.12	3.34
Cl	1.02	0	0.61
Sr	0	37.75	7.32
Ba	46.38	5.15	15.16
total	100.00	100.00	100.00

As a result of observation, Ba was found in the terminal vacuoles of sample 1 while Sr was found in the terminal vacuoles of sample 2 and sample 3. However, the percentage of Sr identified in sample (3) was lower than that in sample (2), and a higher percentage of Ba was identified in sample (3) This is probably because the photosynthesis inhibitor (DCMU) inhibits the transfer of electrons in the electron-transfer system that occurs in the thylakoid membrane within the chloroplast. Since the percentage of Sr identified in the DCMU-added samples from C. moniliferum was small, the absorption of Sr_2 may be related to photosynthesis.

3-II. Comparison of the Sr absorption of *C. moniliferum* dipped in BaCl2aq

Based on the observations in 3-I, the possibility that Ba is replaced by Sr was raised, so we immersed C. moniliferum in $BaCl_2$aq (0.17mM) for 2 hours and 24 hours, and then replaced it with $SrCl_2$aq (0.10mM) to see if the amount of Sr^{2+} absorption increased (Fig. 49).

Fig 49



【Experimental method】

① C. moniliferum were immersed in $BaCl_2$aq (0.17mM) for 2 hours and 24 hours.
② From the solution in ① above, we measured 5000μL of supernatant solution only.
③ 5000μL of $SrCl_2$aq (0.10mM) was added.
④ Steps ② and ③ were performed 10 times.
⑤ The solution of ④ was irradiated with red LED for 12 hours in the light phase and 12 hours in the dark phase.
⑥ The solution in ④ was measured using an absorption spectrophotometer.

Table 2　 Comparison of Sr absorption (ng/cell) and Sr recovery (%) of each sample

Immersion time of $BaCl_2aq$(0.17mM)	concentration of $SrCl_2aq$ (mM)	Sr absorption per cell (ng/cell)	Sr recovery rate (%) in solution
0	0.10	0.092	**2.1(48hrs.)**
2	0.10	0.30	**3.4(24hrs.)**
24	0.10	0.48	**5.5(24hrs.)**

The Sr^{2+} absorption of *C. moniliferum* immersed in $BaCl_2aq$ (0.17 mM) for 2 hours and 24 hours was compared. The absorption of *C. moniliferum* immersed in BaCl2aq for 2 hours was 0.39ng/cell and that of *C. moniliferum* immersed in $BaCl_2aq$ for 24 hours was 0.48 ng/cell. The results showed that the absorption of i *C. moniliferum* immersed in $BaCl_2aq$ (0.17mM) for 24 hours was higher (Table 2). The Sr recoveries in the solution were determined to be 3.4 % for immersed in *C. moniliferum* BaCl2aq for 2 hours and 5.5 % for *C. moniliferum* immersed in $BaCl_2aq$ for 24 hours. The results of 3-II atomic absorption spectrophotometer showed that both Sr^{2+} absorption and recovery were high. Therefore, the possibility of increasing the amount of Sr^{2+} absorption by replacing $SrCl_2aq$ with $BaCl_2aq$ after dipping *C. moniliferum* in $BaCl_2aq$ was increased.

4. water disappearance (evaporation) experiment utilizing the *Nostoc commune*

We added 30g of water to 1.0g of dried *Nostoc commune* to see if there was any difference in water loss (evaporation) between samples with and without *Nostoc commune*. As a result, all the water disappeared (evaporated) four days earlier in the sample with the *Nostoc commune* . Based on this result, we thought that use the *Nostoc commune* may be useful for the treatment of contaminated water (tritiated water)　in Fukushima by releasing it into the atmosphere.

4- I . Changes in the amount of water lost (evaporation) by the *Nostoc commune* due to different wavelengths of light

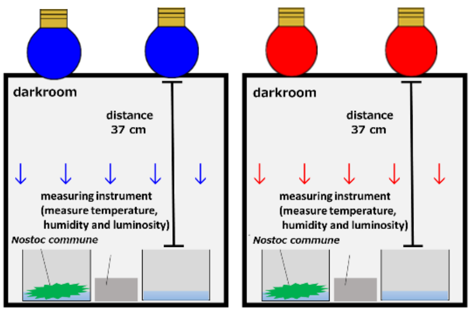
Since the amount of Sr absorption increased by changing the wavelength of light in our research on *C. moniliferum*, we thought that the wavelength of light was very important for algae.

【Experimental method】

(1) We added 15.0g of tap water to 0.1g of dried ***Nostoc commune***.

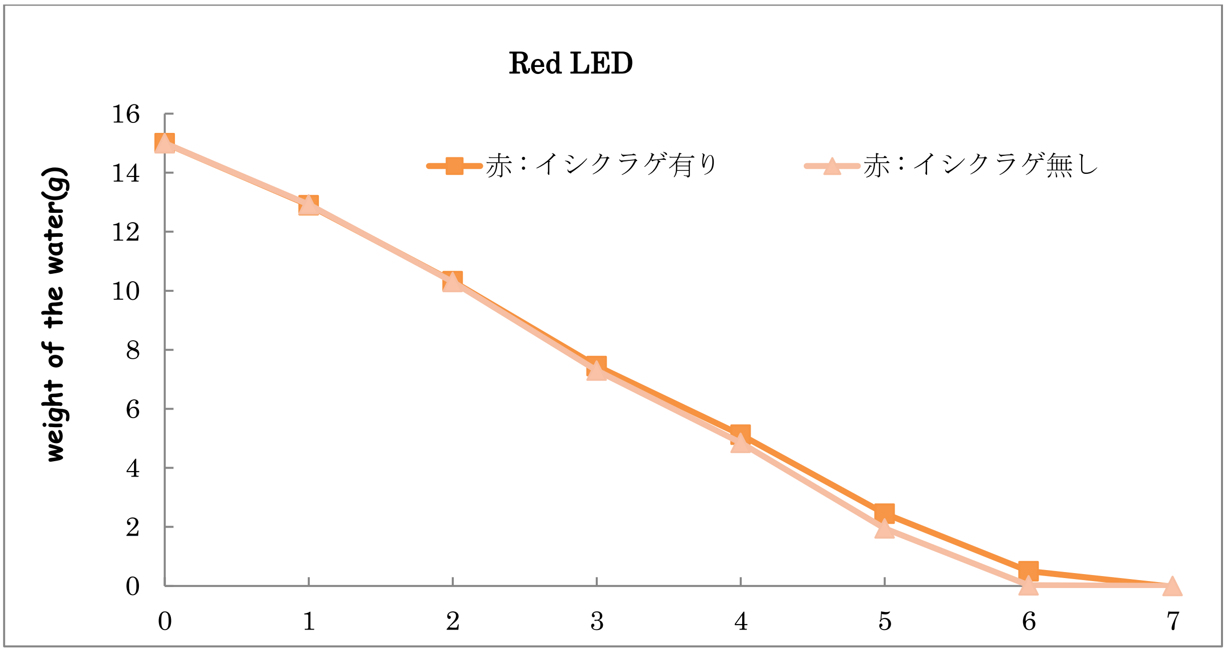
(2) The weight was measured every day and compared with the weight of the previous day to determine the amount of water lost (amount of evaporation).

Fig 50



【Experimental conditions】

(1) A sample with and a control without ***Nostoc commune*** were prepared, and the LED irradiation distance was 37cm. The distance of the LED was 37cm, and the experiment was conducted in the light period of 24 hours (Figure 50).



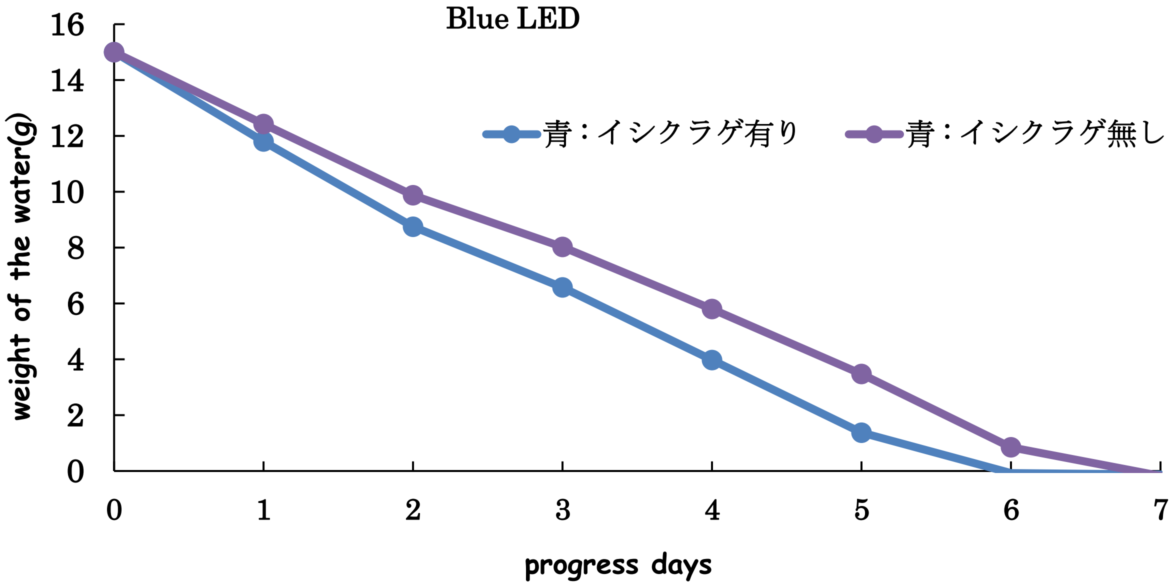


Fig 51:　Amount of water lost (evaporation) due to different wavelengths of light.

As a result, all the water disappeared the fastest in the sample with the blue LED

(Figure 51). As a consideration, we thought that the amount of water loss **(evaporation)** increased due to the active photosynthesis.

4-II. Change in the amount of water loss (evaporation) in the *Nostoc commune* due to different irradiation distances

Since it was found during the study of C. moniliferum that the amount of Sr absorption changes with the amount of light quanta, we measured the amount of water loss (evaporation) by increasing the amount of light quanta. In addition, based on the daily increase of contaminated water, a mixture of $SrCl_2aq$ and CsClaq was added every day.

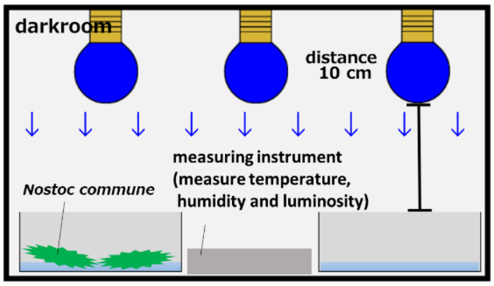
【Experimental method】

(1) A mixed solution of $SrCl_2aq$ (0.1mM) and $CsCl_2aq$ (0.1mM) was prepared.
(2) Add 3g of the solution of (1) every day to 0.1g of dried ***Nostoc commune***
(3) The weight was measured every day, and the difference from the previous day was used as the daily loss.

【Experimental conditions】

The irradiation distance was set at 10cm, and the irradiation time was set at 12 hours in the light period and 12 hours in the dark period (Fig. 52).

Fig 52



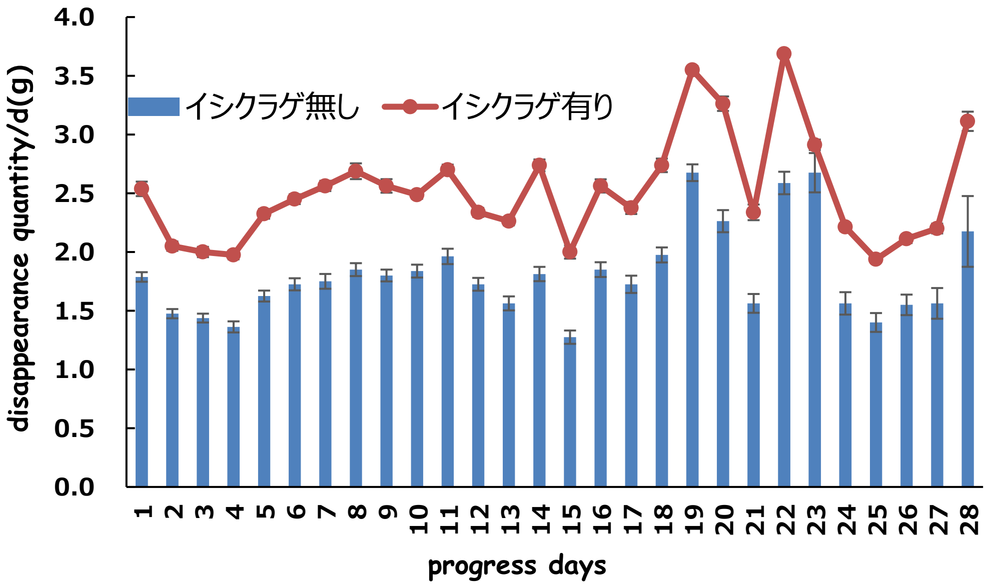
【Results】

Fig. 53 Amount of evaporation depending on the amount of light quantum

As a result, the amount of water lost (amount of evaporation) in the sample with ***Nostoc commune*** exceeded the amount lost (amount of evaporation) .
and in the sample without ***Nostoc commune*** on all days for 4 weeks (Fig. 53). As a result, the amount of water loss (evaporation) increased due to the active photosynthesis caused by the increase in the amount of photons.

Based on Table 3, which summarizes the results of the experiment, we considered the treatment of contaminated water, assuming that all the currently remaining contaminated water in the nuclear power plant site would be converted into steam using the. ***Nostoc commune***

Fig 53



→ 70.7 g (per 0.1g of ***Nostoc commune***).
From this, the amount of water lost (evaporation) per day was calculated to be
The amount of water lost (evaporation) per day was calculated to be: → 23.6 t (per 1.0 t of ***Nostoc commune***).
The amount of ***Nostoc commune*** needed to treat 500 tons of contaminated water per day is

500t ÷ 23.6t = 21.2t of ***Nostoc commune*** are needed.

180t of contaminated water increase per day (330t of contaminated water per day can be reduced)

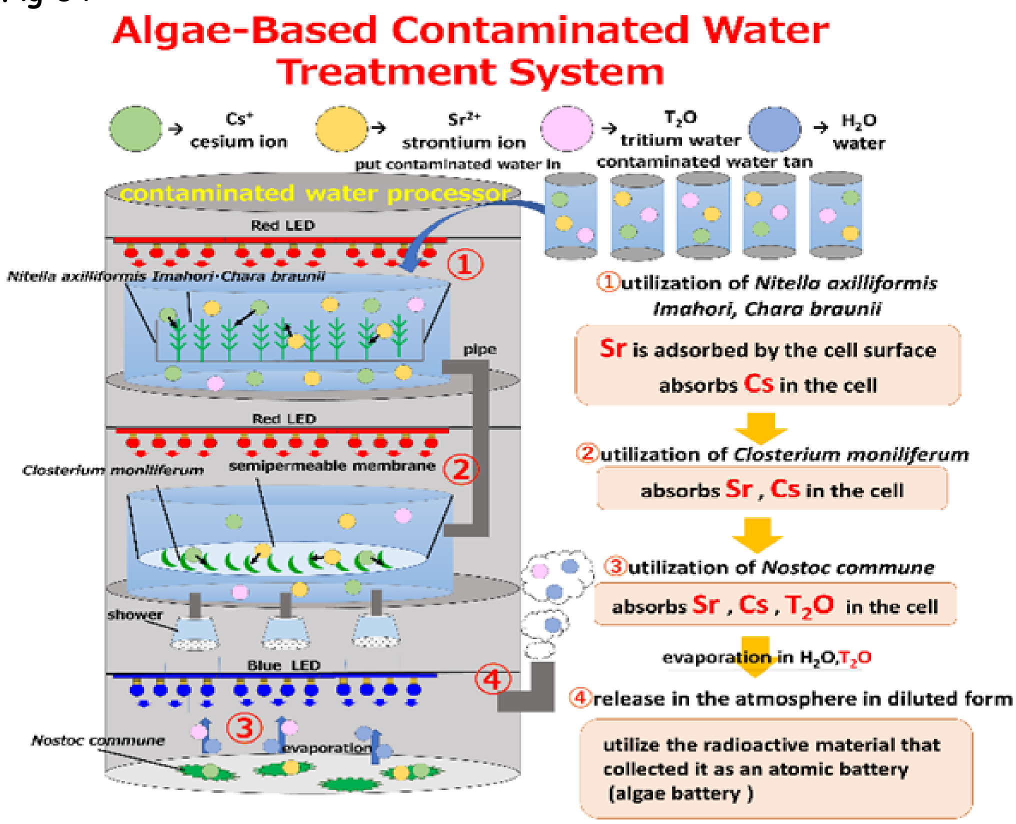
1,220,000 t (total amount of contaminated water that remains today) ÷ 330t = 3,697 days (= 10.3 years)

From the calculation, it is possible to treat the water in about 10 years. This indicates that it is possible to treat all the contaminated water in 1/4 of the time compared to the government's plan to treat it by releasing it into the ocean (about 40 years)

4. Prospects and Future Issues

In order to prevent contaminated water from being discharged into the sea of Fukushima, we are currently considering a contaminated water treatment system that utilizes algae. By dividing the treatment into multiple stages, we are able to provide the best conditions for the algae (Figure 54).

Fig 54



Stage 1

The first step is to remove $^{90}Sr_2^+$ and $^{137}Cs+$ from the contaminated water tank using the *Chara braunii* and *Nitella axilliformis*. In the future, we would like to determine the conditions under which *Chara braunii* and *Nitella axilliformis* can absorb and adsorb more Cs.

Stage 2

Using C. moniliferum, we will remove thin concentrations of Sr and Cs that could not be removed by *Chara braunii* and *Nitella axilliformis*. In the future, we would like to observe the inside of the cells using an optical microscope to verify if the cells absorb Cs. In addition, we would like to further examine how photosynthesis works in relation to the absorption of Sr_2^+

.

Stage 3

We will absorb tritium-containing contaminated water using ***Nostoc commune***, evaporate it, dilute it to a safe concentration, and release it into the atmosphere. We would like to remove the $^{90}Sr_2^+$ and $^{137}Cs+$ that could not be removed by C. moniliferum by absorbing them into the ***Nostoc commune***,. In order to achieve this, we would like to further examine the conditions under which the water in the ***Nostoc commune***, is converted to evaporation. In addition, we would like to study the method of mass cultivation of the ***Nostoc commune***, since it will require a large amount of ***Nostoc commune*** for practical use.

Stage4

The steam containing the tritiated water generated in the third step is diluted to a safe concentration and released into the atmosphere. All other radioactive materials will remain in the algae from the first three steps and will not be released into the environment. We would like to utilize the algae that has absorbed the radioactive materials as an algae battery using the principle of a nuclear battery.

Finally

It is said that the amount of contaminated water from Fukushima, which is still increasing, will run out of places to put it in the next two years, and there is a high possibility that it will be released into the ocean for disposal. If the contaminated water were to flow into the sea of Fukushima, it would cause harmful rumors and cause serious damage to farmers and fishermen. In order to prevent this from happening, I would like to contribute to the recovery of Fukushima in any way I can by conducting research on contaminated water treatment using this algae that I have inherited from my predecessors.

5. References

1) Masumi Yamamuro: Research on the development of technology to reduce eutrophication by promoting the calcification of axillary algae River Fund Grant No.: 21-1211-007

2) Keerthi SSenartahna Atapaththu et al Bull Environ Contam Toxicol(2016)96:347-353

3) Krejci et al.J.Struc.Biol.176,192(2011)

4) Hideaki SASAKI et al Algal Resources(2016)9:87-92

5) Megumi OKAZAKI et al Jpn.J.Phycol.(So(^)rui) 36: 193-201,September 20,1988

6) Annual Report of Niigata Prefectural Radiation Monitoring Center, Vol. 5, 2007 "Comparative Study of Stable Strontium Measurement Methods".

【評語】200024

There are three purposes of this project: 1. verification of Sr adsorption onto Chara Braunii, 2. Verification of Sr2+ absorption by C. moniliferum, 3. Obtain the amount pf using Nostoc commune, and predict treatment period of tritiated water on the premises. From experimental results, some useful adsorption capacities and short treatment period were recommended. Thus, it is a quite good research project for the high school student.