Fish rearing in ALPS treated water and tritium transfer from seawater into fish OBT.

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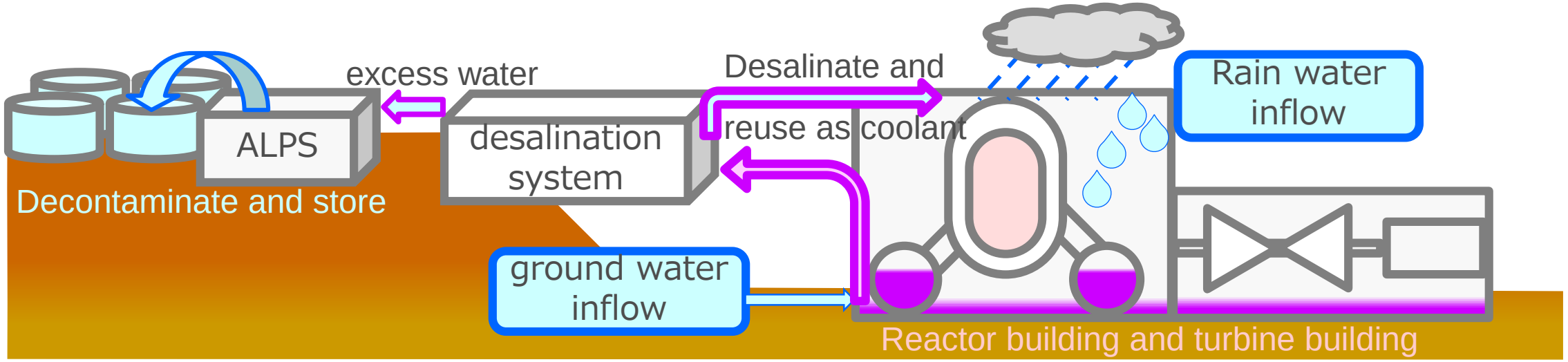
Contents

Introduction

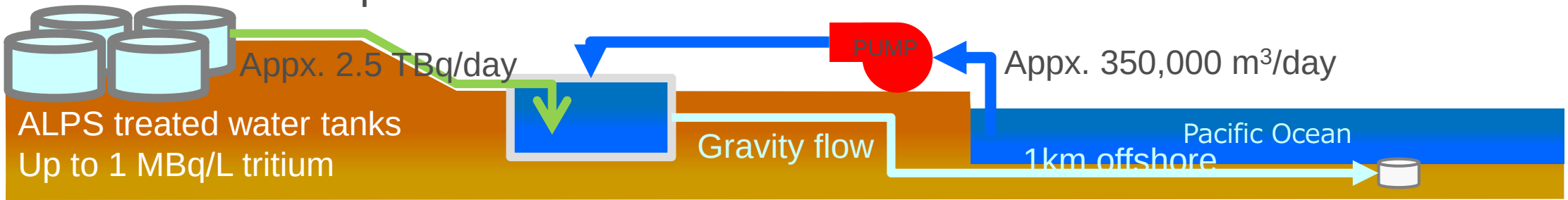
- Fukushima Dai-ichi Nuclear Power Plant accident caused radiation polluted water to cool and stabilize reactors. Polluted water amount is increased by rainwater and ground water inflow.
  - Polluted water is stagnated in reactor buildings. Stagnated water is decontaminated by Advanced Liquid Processing System (ALPS).
  - Radio nuclides except for tritium are removed by ALPS.
  - More than 1,000,000 m^3 ALPS treated water is stored in Fukushima Dai-ichi NPP.



Aerial photo of Fukushima dai-ichi

Ocean release of ALPS treated water.

- Stored ALPS treated water will fill all storage tanks in 2023 winter or 2024 spring.
- TEPCO would start ALPS treated water which contains tritium release into Pacific Ocean until summer, 2023.
  - In accordance with the policy of Japanese Government
  - Yearly tritium release ≤ 2.2×10^{14} Bq/year.
  - Tritium concentration in release water ≤ 1.5 kBq/L
    - Regal limit for ^{3}H liquid waste discharge in Japanese law = 60 kBq/L.
    - Tritium concentration in stored ALPS treated water ≒ 0.1~1 MBq/L.
    - ALPS treated water will be diluted by seawater.
    - Released point is 1 km offshore from Fukushima Dai-ichi NPP.



Radiation concentration in ALPS treated water

TEPCO

Nuclide	Radiation Conc. [Bq/L]	comment
H-3	1.9E+05	
C-14	1.5E+01	
Mn-54	<6.7E-03	
Fe-59	<1.7E-02	
Co-58	<8.0E-03	
Co-60	4.4E-01	
Ni-63	2.2E+00	
Zn-65	<1.5E-02	
Rb-86	<1.9E-01	
Sr-89	<1.0E-01	
Sr-90	2.2E-01	
Y-90	2.2E-01	equilibrium with Sr-90
Y-91	<2.2E+00	
Nb-95	<1.0E-02	
Tc-99	7.0E-01	
Ru-103	<1.0E-02	

Nuclide	Radiation Conc. [Bq/L]	comment
Ru-106	1.6E+00	
Rh-103m	<1.0E-02	equilibrium with Ru-103
Rh-106	1.6E+00	equilibrium with Ru-106
Ag-110m	<5.6E-03	
Cd-113m	<1.8E-02	
Cd-115m	<6.4E-01	
Sn-119m	<1.7E-01	estimated from Sn-123 conc.
Sn-123	<1.2E+00	
Sn-126	<2.7E-02	
Sb-124	<9.5E-03	
Sb-125	3.3E-01	
Te-123m	<9.2E-03	
Te-125m	3.3E-01	equilibrium with Sb-125
Te-127	<3.2E-01	
Te-127m	<3.2E-01	estimated from Te-127conc.
Te-129	<8.1E-02	

Nuclide	Radiation Conc. [Bq/L]	comment
Te-129m	<3.2E-01	
I-129	2.1E+00	
Cs-134	4.5E-02	
Cs-135	2.5E-06	estimated from Cs-137 conc.
Cs-136	<3.0E-02	
Cs-137	4.2E-01	
Ba-137m	4.2E-01	equilibrium with Cs-137
Ba-140	<9.5E-02	
Ce-141	<2.5E-02	
Ce-144	<6.3E-02	
Pr-144	<6.3E-02	equilibrium with Ce-144
Pr-144m	<6.3E-02	equilibrium with Ce-144
Pm-146	<9.8E-02	
Pm-147	<1.9E-01	estimated by Eu-154 conc.
Pm-148	<5.0E-01	
Pm-148m	<8.4E-03	

Nuclide	Radiation Conc. [Bq/L]	comment
Sm-151	<9.0E-04	estimated by Eu-154 conc.
Eu-152	<2.8E-02	
Eu-154	<1.2E-02	
Eu-155	<3.3E-02	
Gd-153	<3.2E-02	
Tb-160	<2.8E-02	
Pu-238	<6.3E-04	estimated by total α conc.
Pu-239	<6.3E-04	estimated by total α conc.
Pu-240	<6.3E-04	estimated by total α conc.
Pu-241	<2.8E-02	estimated by Pu-238 conc.
Am-241	<6.3E-04	estimated by total α conc.
Am-242m	<3.9E-05	estimated by Am-241 conc.
Am-243	<6.3E-04	estimated by total α conc.
Cm-242	<6.3E-04	estimated by total α conc.
Cm-243	<6.3E-04	estimated by total α conc.
Cm-244	<6.3E-04	estimated by total α conc.

Radio concentration in K4 tank group. Measured in 2018.
Concentrations of all nuclides except for tritium are lower than legal limit for environmental release.

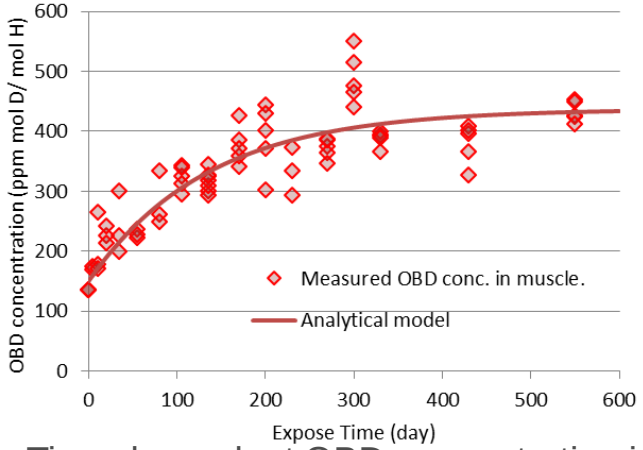
Objectives of Fish rearing Project.

- Tritium release amount and concentration is very low.
  - Almost equal to those from PWR plant.
  - It cannot be harmful.
- Tritium water release from Fukushima Dai-ichi causes unreasonable rumor.
  - Unreasonable rumor has negative impact on fishers' industry.

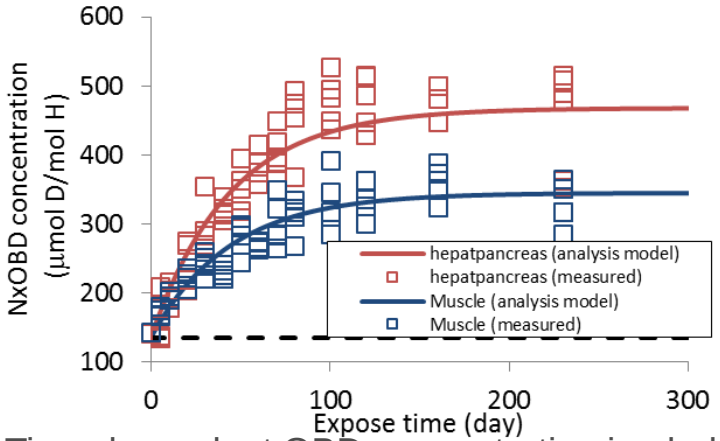
- Reducing uneasy feelings or unreasonable rumor is objective of this project.
  - Study of tritium behavior in the environment is already well established.
  - Fishers Cooperation and local government around Fukushima Dai-ichi required to perform demonstration.
- Perform rearing demonstration BEFOR ALPS treated water RELEASE START.
  - Started 3rd. Oct. 2022.

Previous Study

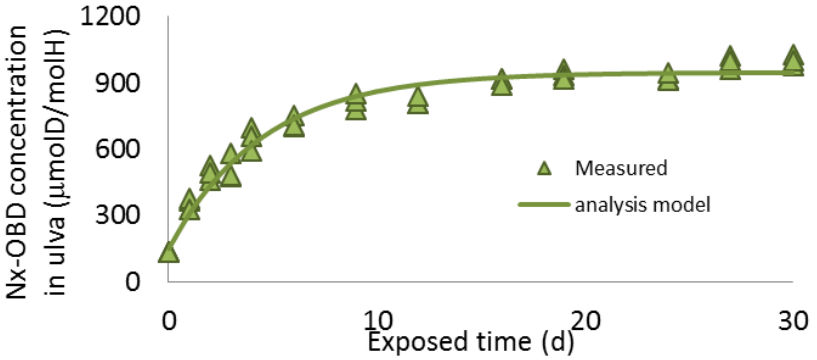
- Heavy water (DHO) exposure to flounder, abalone and sea lettuce (*ulva*) are already performed.
  - Performed by Institute for Environmental Science, Rokkasho, Aomori, Japan (https://www.ies.or.jp/)
  - Exposed to 0.2 % (mol D/mol H) heavy water (with Deuterium not enriched diet).
  - After appx. 1 year exposure, Organic Binding Deuterium (OBD) in flounder and abalone were saturated.
- Numerical tritium transfer models are already proposed.



Time dependent OBD concentration in flounder exposed to 2000 ppm heavy water.



Time dependent OBD concentration in abalone exposed to 2000 ppm heavy water.



Time dependent OBD concentration in sea lettuce cultivated in 2000ppm heavy water.

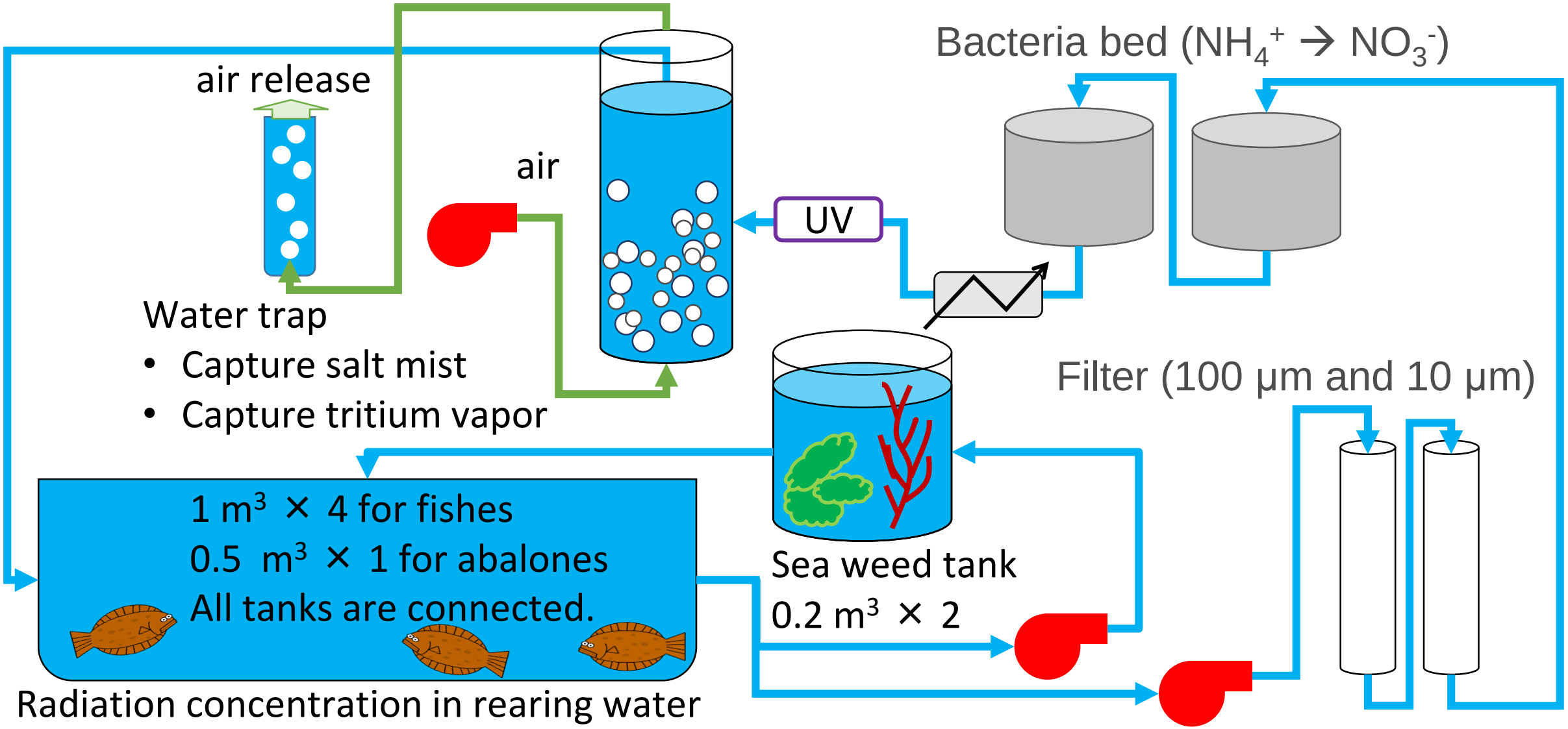
- Instate for Environmental Science, 2014 annual report "Transfer Parameters of Tritium from Seawater to Marine Organisms"

T.Shibata and Y. Ishikawa, "Deuterium transfer analysis including food chain from seawater into abalone", Radiation Protection Dosimetry (2022), Vol. 198, No. 13–15, pp. 1125–1130

Rearing condition

- Fish spices : Flat fish (large-tooth flounder, *Paralichthys olivaceus*)
  - abalone and seaweeds are cultivated in same tank
  (not reported in this presentation)
- Fish age : 0.5 years old (born in 2022 spring)
  - appx. 15 cm, 35 g at starting time.
- HTO conc. : 1.3 kBq/L
- Temp : 18 °C (constant)
- Diet : Commercial diet for cultivation(NOT tritium enriched)
- Feeding rate : 1 % of averaged body weight (appx.)
- Rearing time : 2.5~3 years.
- Fish rearing is performed in <u>closed system.</u>
  - ALPS treated water is regarded as nuclear fuel polluted material in Japanese law BEFORE release process is finished WITHOUT regard to its radiation concentration.
  - To reduce radiation liquid waist.

Fish rearing system (closed aquarium system)



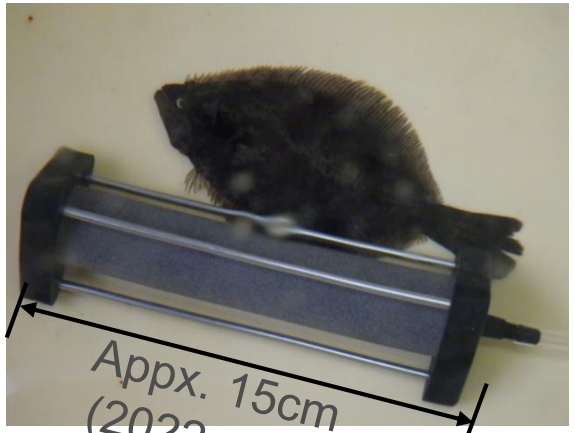
Radiation concentration in rearing water is measured 1 time/ month.

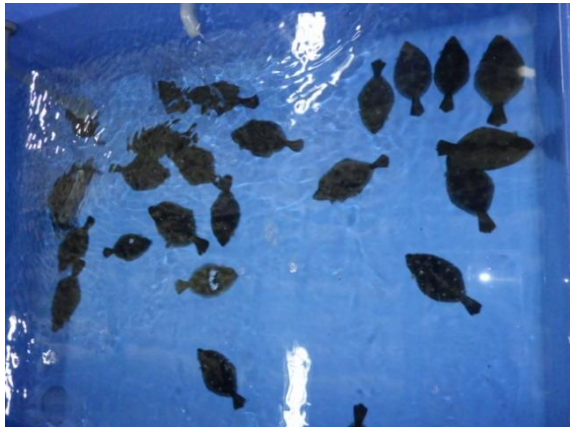
Pictures of rearing system

TEPCO

- Air dose rate around rearing system: appx. 1 μSv/h

- Yellow tanks: For ALPS treated water + seawater (HOT test)
- Blue tanks: For seawater (Cold test, negative control)





Exposure and Sampling plan

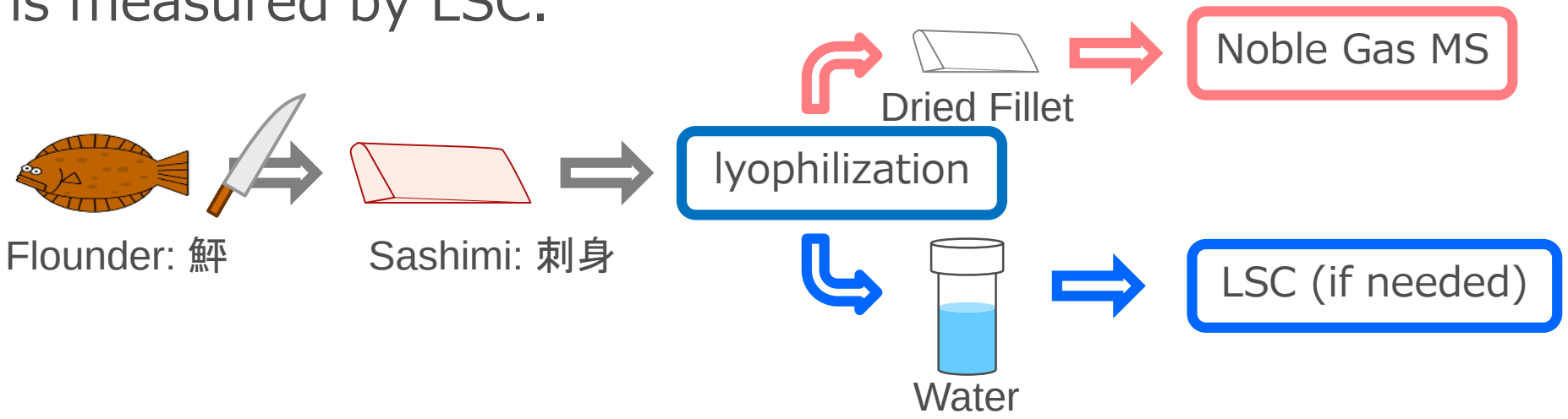
- 2 years exposure + 1 year egestion test for OBT measurement.
  - Exposure to 1.3 kBq/L tritiated seawater.
  - With normal (NOT tritium enriched) diet.
  - Measuring TFWT concentration and OBT concentration.

- Sampling will be performed 1-8 times per 2 months.
  - 1 sampling per a week in first 1 month for tritium (n=3).
  - Sampling span is expanded with expose period.

- 1 sampling per 6 months (3 in 1st 6 months) for the γ nuclides.
  - γ emitters concentration in ALPS treated water is very low. However, they must be monitored to reduce social impact.
  - Use 10~25 fishes for 1 batch measurement.

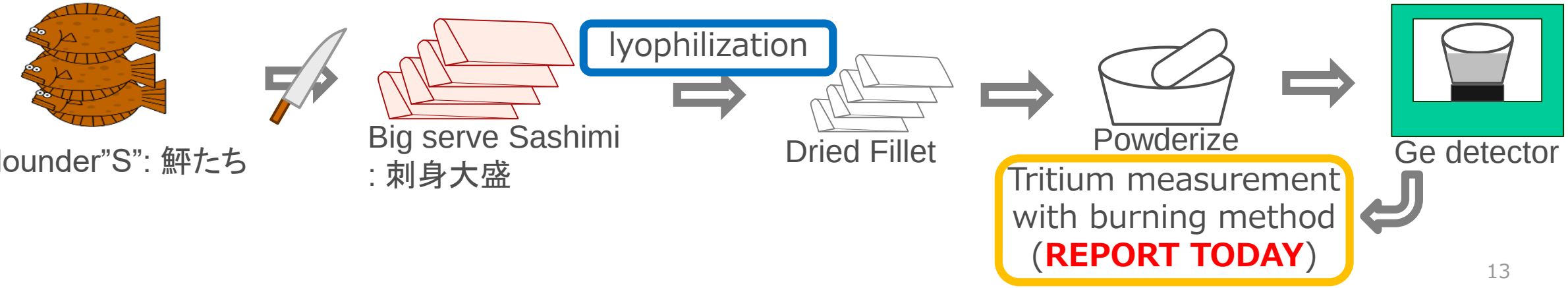
Measurement of Tritium concentration

- FWT and OBT concentration will be measured.
  - Tritium concentration in EACH sample will be measured.
- Because sample amount is limited, OBT measurement with combustion method will not be suitable.
  - To measure with combustion method, some fishes must be mixed.
- Noble gas MS system will be used (for this project and environment monitoring).
  - Noble gas MS delivery is delayed. → samples are stored in freezer.
  - FWT is measured by LSC.



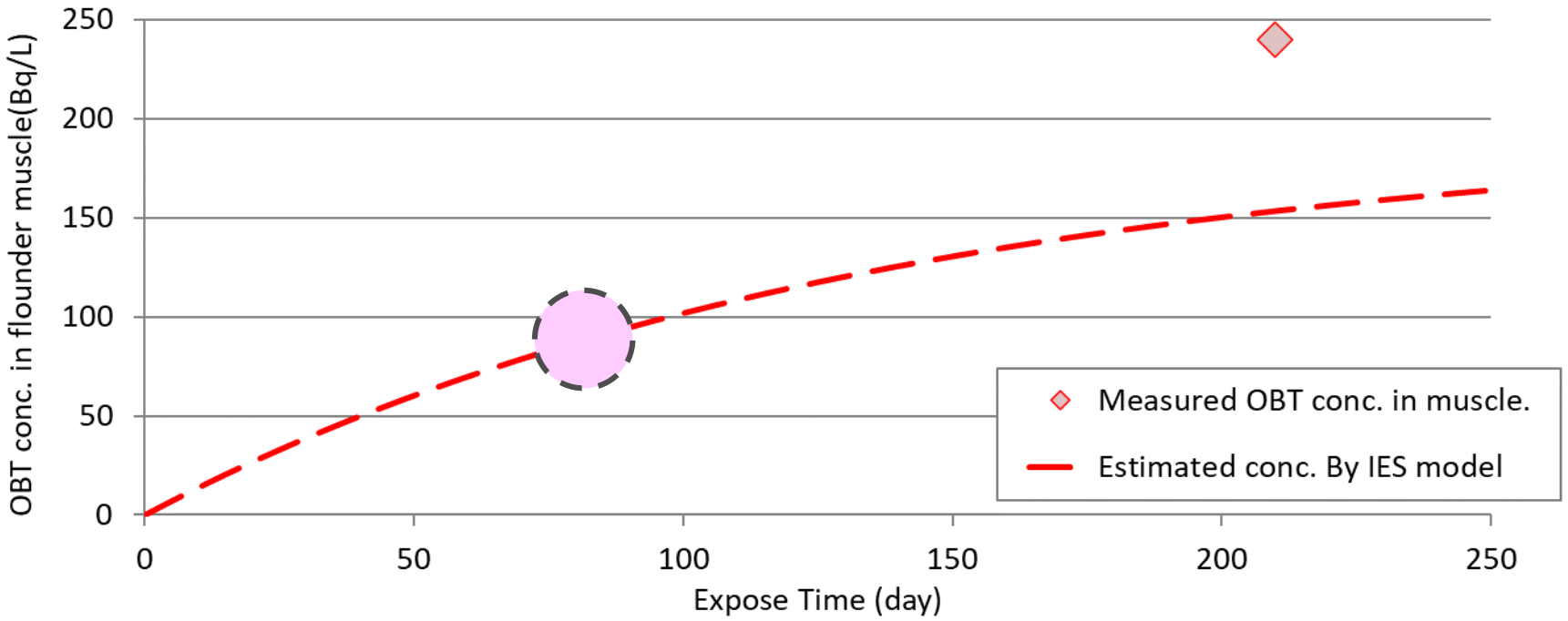
Measurement of The other nuclides (γ nuclides)

- Concentration of γ emitters is measured by Ge detector.
  -> Estimated concentration is very low
  = enrichment or long time measurement would be required.
  - Appx. 10 sample (depending on fish size, total appx. 0.5 kg-wet) will be used for 1 measurement.
  - Corrected samples will be lyophilized and powderized to reduce volume and to perform long term measurement.
- OBT concentration in this sample is measured with burning method.
  - Noble gas MS delivery is delayed -> To obtain data at an early point.



Result (1/2)

- Measured OBT concentration:
  ➔240 Bq/L after 7 months (210 days) exposure
  - Measured concentration are averaged value of some (appx. 10) samples.
- Measured tritium concentration were higher than estimated.
  - Estimated OBT concentration was calculated by numerical model proposed by IES.

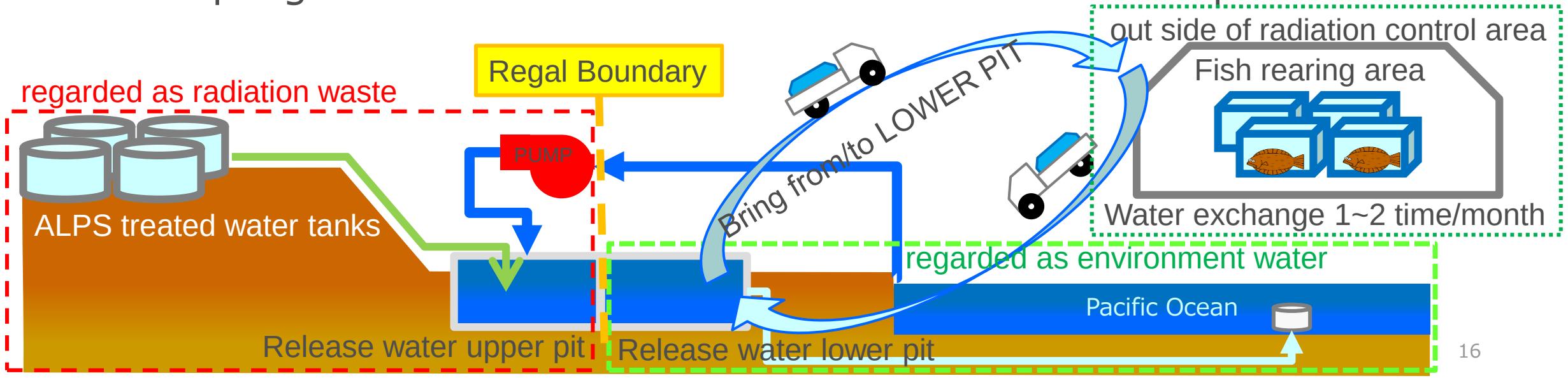


Result (2/2)

- Measured tritium concentration were higher than estimated.
  - Estimated OBT concentration was calculated by numerical model proposed by IES.
  - This can be because sample flounder age is different.
    IES experiment was started in May. = appx. 2-month-old.
    ←→TEPCO experiment was started in Oct. = appx. 6-month-old.
    - Younger flounder grows faster.
      → Absorption rate of diet would be higher.
      ≒ younger flounder OBT can be more diluted by ^{1}H in diet than older one.
  - This can be caused sample variability.

Fish rearing plan AFTER ocean release started.

- TEPCO will rear fish in RELEASED water.
  - RELEASED ALPS treated water is regarded as environmental water.
  - Semi-closed aquarium system will be used.
    - Rearing water can be discarded. Closed system is not required.
  - Rearing period is not determined (At least 2 years)
    - Will be determined by require from local government, society etc.
  - Sampling and Tritium measurement will be 1~2 times per month.



Detail of rearing condition and expected OBT conc.

- Fish species : Flat fish (large-tooth flounder, *Paralichthys olivaceus*)
  - some the other spices could be reared.
- Fish age : 1 and 2 years old (born in 2022 and 2023 spring)
- HTO conc. : appx. 300~400 Bq/L (not precisely controlled)
- Temp : 18 °C (constant)
- Diet : Compounded diet for cultivation(NOT tritium enriched)
- Feeding rate : 1 % of averaged body weight (appx.)
- Rearing time : at least 2 years
- Fish rearing will be performed in semi-closed system.
  - rearing water will be changed 1~2 times/month.
- Sampling rate : 1~4 times/month

✓ Rearing equipment may not be changed from CLOSED rearing system.

✓ Maximum capacity is appx. 150~200 kg/batch.

Probability to sample supply for academics.

- Fishes reared in Released water are regarded as environmental samples.
  - Not regarded as radiation materials.
  - Samples can be EASYLY carried out from Fukushima dai-ichi site.
- TEPCO could provide reared fishes for researchers.
  - Because rearing capacity is limited, TEPCO cannot accommodate ALL request.
- TEPCO would be happy if many researchers and laboratories measure reared sample as an independent organization.
  - TEPCO's activities, especially radiation measurement are required to have transparency.

Conclusion

- TEPCO have started fish rearing in ALPS treated water project in Oct. 2022.
  - Flounder have been reared in seawater containing 1.3 kBq/L HTO.
  - OBT concentration was measured. TEPCO would start to release ALPS treated water into pacific ocean in Summer, 2023.
- TEPCO will rear fishes in released ALPS treated water.
  - Reared fishes are regarded as environment samples, not radiation materials.
  - Reared fishes could be provide for researchers.
  - TEPCO would be happy if many researchers measure reared fish sample.

- Thank you for listening.

  – TEPCO fish rearing HP: https://www.tepco.co.jp/en/decommission/progress/watertreatment/breedingtest/index-e.html

  – Rearing team Twitter(Japanese only): @TEPCOfishkeeper

  – Live camera:  https://www.youtube.com/channel/UCLEn8NHHX2WrMvn6ZYfAjJA

- Supporting information

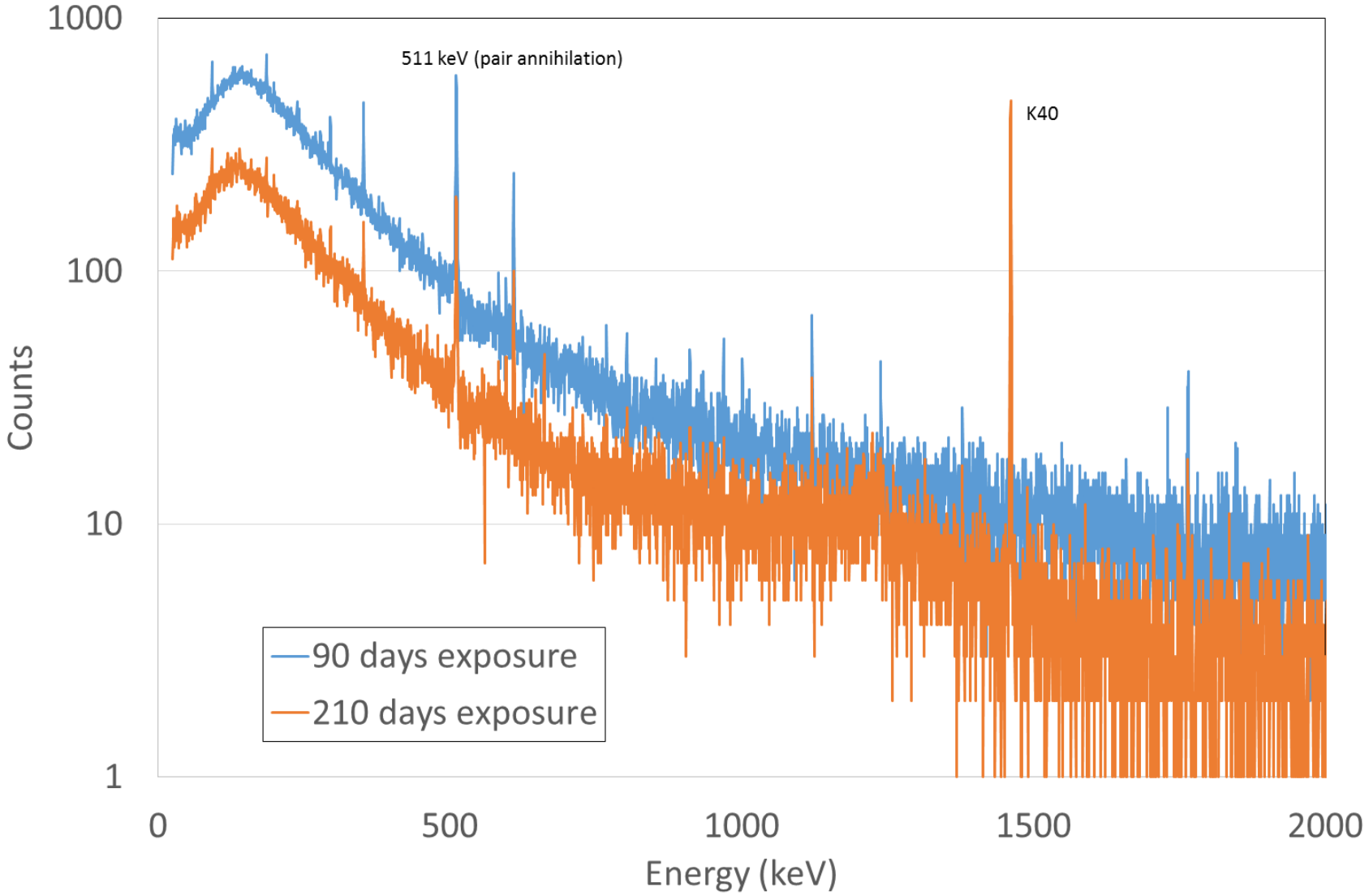
Result of water quality inspection

contents	Concentration
pH	8.7
BOD	<1.0 mg/L
COD	<0.5 mg/L
suspended solids (SS)	<1.0 mg/L
n-hexane extractable material (mineral oil)	<0.5 mg/L
n-hexane extractable material (animal or vegetable oil)	<1.0 mg/L
Phenolic component	<0.1 mg/L
Coliform bacteria count (CBC)	0.0 /mL

Chemical components concentration

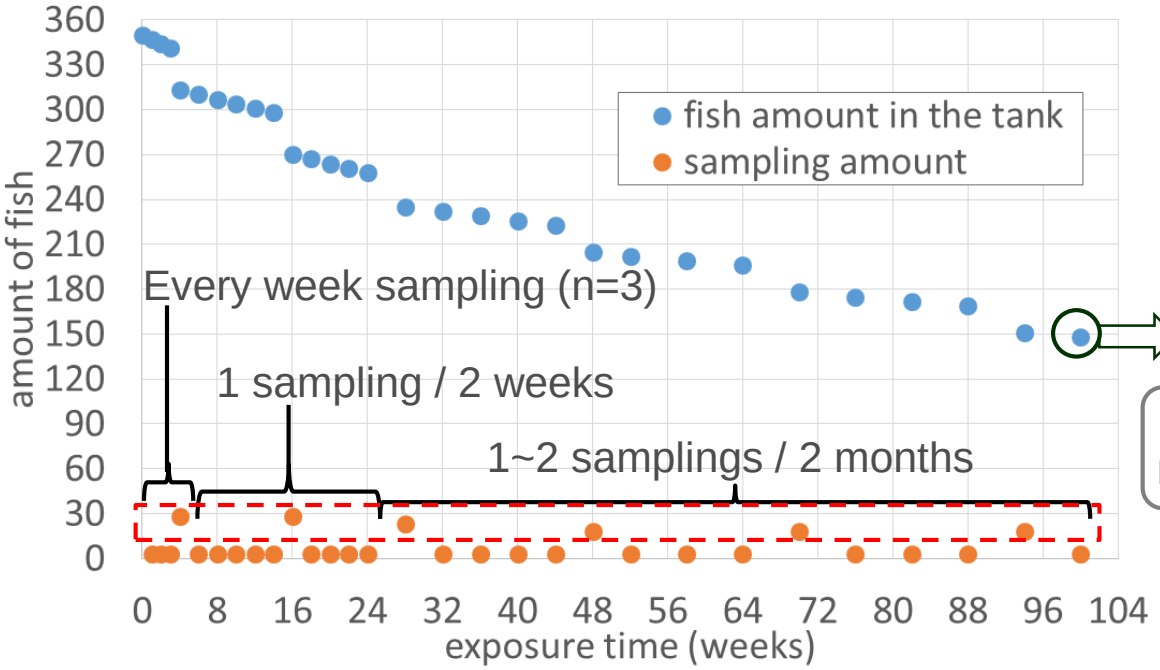
Component	Conc. (mg/L)	component	Conc. (mg/L)	component	Conc. (mg/L)
Cadmium (Cd)	<0.01	Total nitrogen (N)	3.7	Cupper (Cu^{2+})	<0.1
Cyanide (CN^-)	<0.05	Total phosphorus (P)	<0.05	Zinc (Zn^{2+})	<0.1
Organic phosphorus	<0.1	PCBs	<5.0E-4	Dissolved iron (Fe)	<1.0
Lead (Pb)	<0.01	Trichrolo ethylene	<0.03	Dissolved manganese (Mn)	<1.0
Chromium (Cr (VI))	<0.05	Tetrachrolo ethylene	<0.01	Total chromium (Cr)	<0.1
Arsenics (As)	<0.01	Dichrolo methane	<0.02	Total Nickel (Ni)	<0.1
Total marcury (Hg)	<5.0E-4	Tetrachrolo methan	<0.002	Thiuram (agrichemical)	<0.006
Alkyl mercury	<5.0E-4	1,2- dichrolo ethane	<0.004	Simazine (weedkiller)	<0.003
Selenium and its compounds (Se)	<0.01	1,1- dichrolo ethane	<0.1	Thiobencarb (weedkiller)	<0.02
Boron and its compounds (B)	0.4	*cis*-1,2- dichrolo ethylene	<0.04	component	<0.003
Fluoric anion and fluoric compounds (F)	<0.5	1,1,1- trichrolo ethane	<0.3	Benzene	<0.01
Ammonia and ammonium ion (NH_3, NH_4^+)	<1.0	1,1,2- trichrolo ethane	<0.006	1,4- dioxane	<0.005
Nitrous acid and nitric acid (NO_2^-, NO_3^-)	3.0	1,3- dichrolo propene	<0.002		

Gamma measurement result



Radio nuclide accumulation was not observed.

Sampling plan (for OBT and the other nuclides)



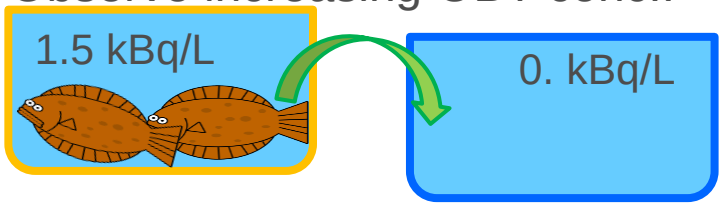
Remains will be used for egestion test

Including γ nuclide measurement (n=3+10~25)

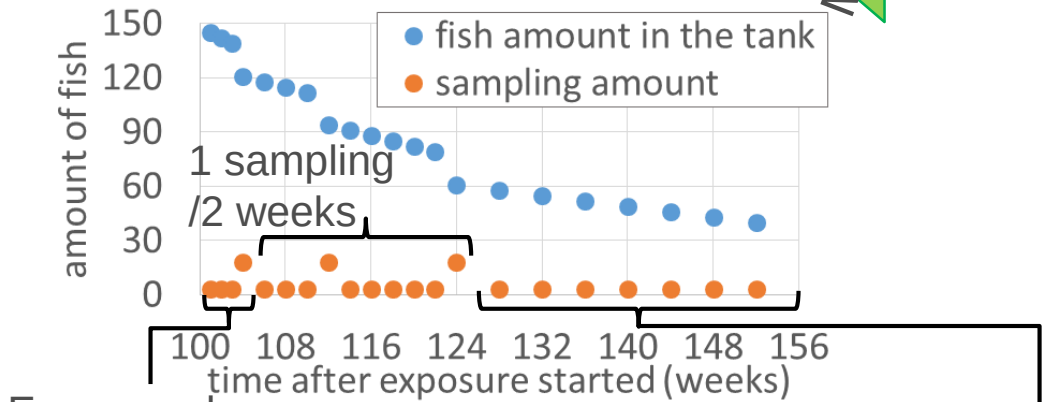
Move to COLD seawater

Planned fish amount in the tank (long term HTO exposure)

Rearing 2 years in HTO.
Observe increasing OBT conc..



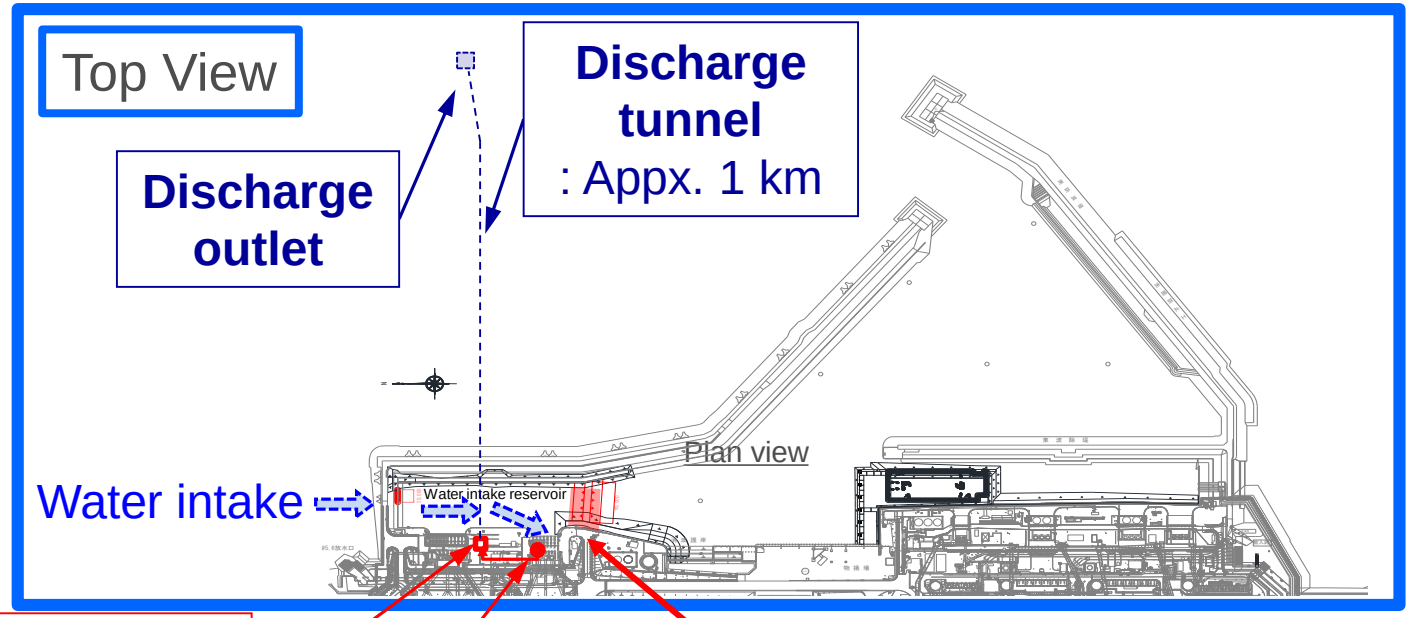
Rearing 1 years without HTO.
Observe decreasing OBT conc..

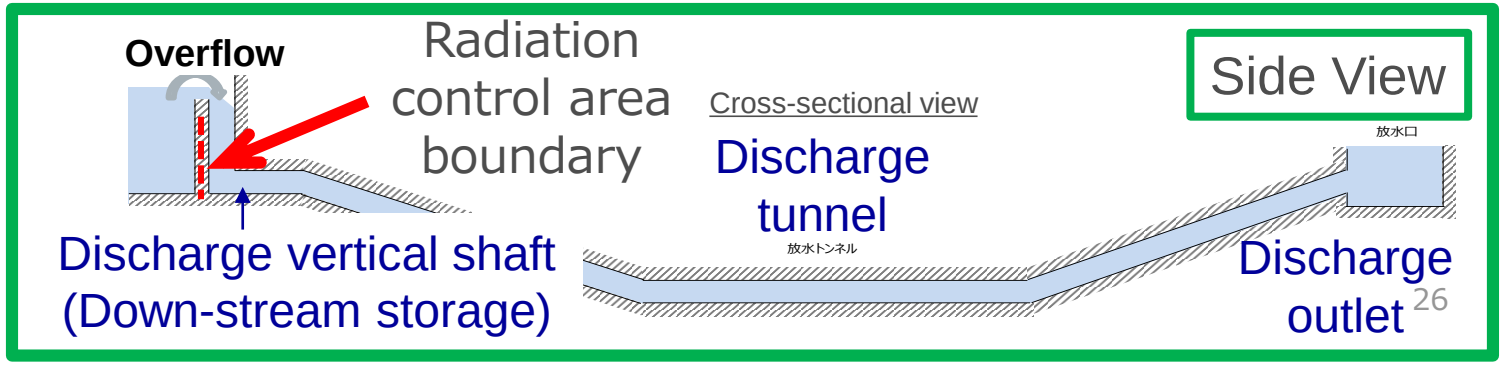


Planned fish amount in the tank (egestion test)

Overview of the Discharge Facility (1/2)

- Discharging water will flow out over the partition wall in the discharge vertical shaft to the outlet.
- Outlet is approximately 1 km away from the shore





Overview of the Discharge Facility (2/2)