Tritium Focus Group (TFG) meeting

23-25 September 2014

Energy Innovation Laboratory (EIL)
Idaho Falls, ID

Tritium research at Kyushu Univ.

Percolation behavior of tritiated water into a soil packed bed

interdisciplinary Graduate School of Engineering Sciences IGSES Kyushu University

ECHE Fukada Lab.

Kazunari Katayama
（片山 一成）

Location

Kyushu Univ.
Fukuoka city

Hakozaki Campus

Tritium handling facility
(0.5Ci/y)

Ito Campus

Education for bachelor students

Chikushi Campus

"Karashi Mentaiko"
Spicy fish egg

"Tonkotsu ramen"

Pork-flavored Noodle

Interdisciplinary graduate school of Engineering Science

(Prof. Tanabe, Prof. Yoshida, Prof. Zushi, Prof. Handa)

Research Institute for Applied Mechanics (QUEST)

Introduction of laboratory

九州大学

Energy chemical engineering course

Prof. : Satoshi Fukada

Associate Prof. : Kazunari Katayama

Engineering Official : Toshiharu Takeishi

Prof.Fukada

Master Course Student 2: 5
Master Course Student 1 : 5
Bachelor Student : 5

EChE
Fukada Lab.

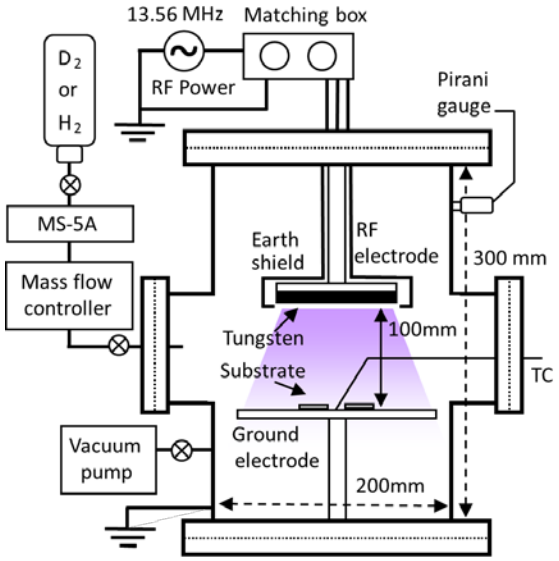
Katayama

Dr.Takeishi

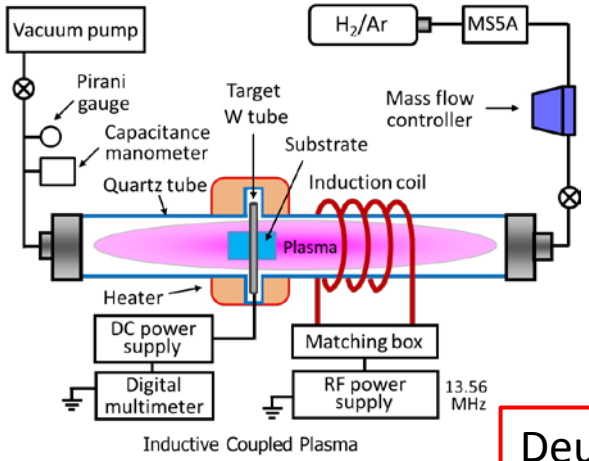
Recent Subject of Research

- Tritium behavior in Solid / liquid bleeder materials
- Plasma wall interaction (tritium retention)
- Tritium extraction by using plasma and permeator
- Tritium penetration in concrete materials
- Analysis of exhaust gas from cryogenic pump

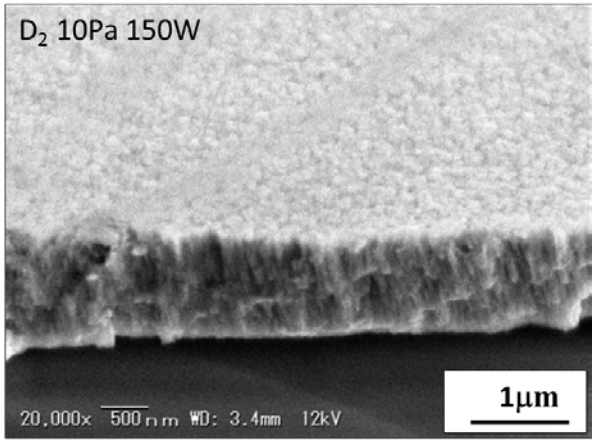
Plasma wall interaction



Capacitive Coupled Plasma

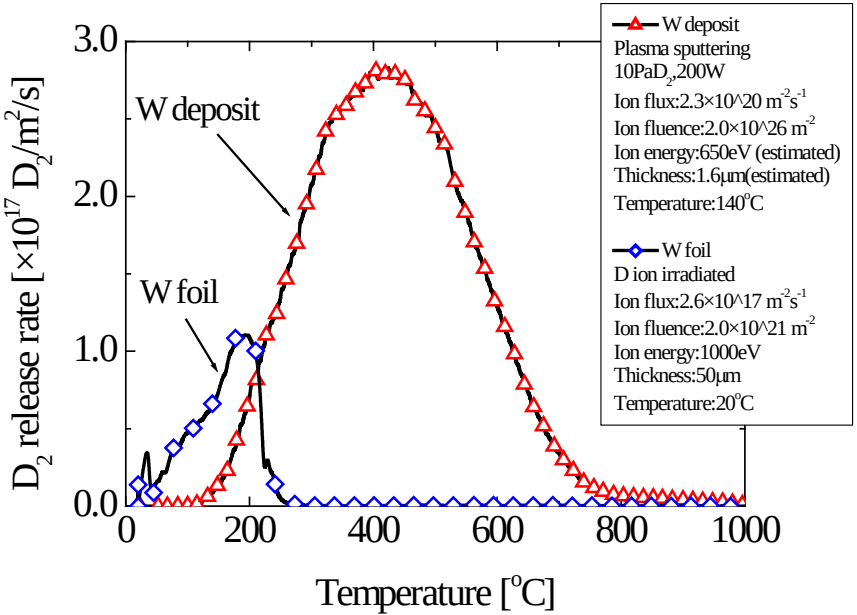


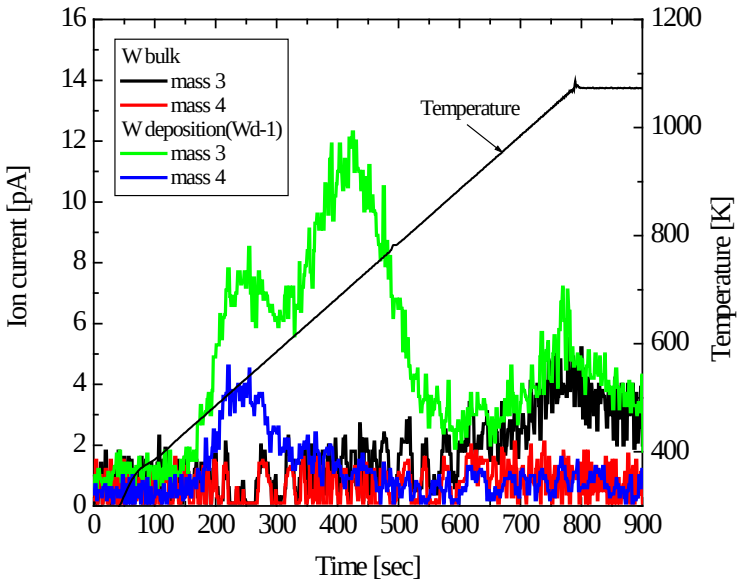
Inductive Coupled Plasma



(Deuterium Plasma 150W,10Pa,250h)

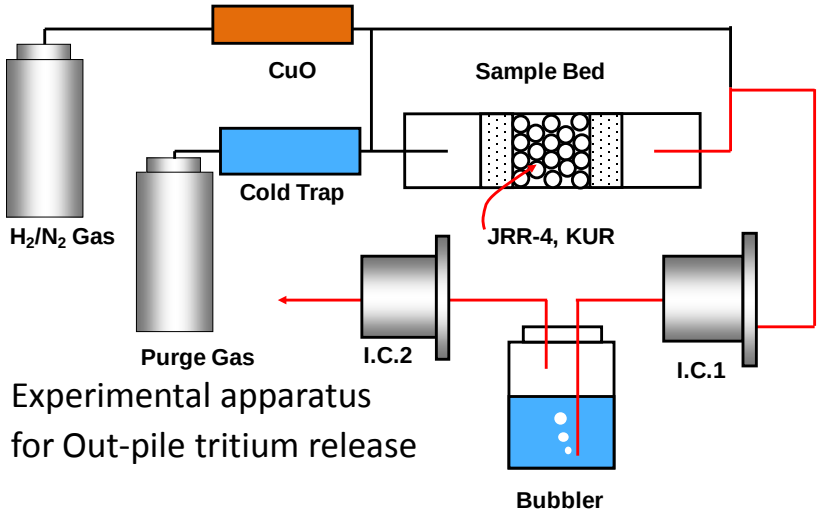
Deuterium release from W deposit
Exposed to EAST D plasma





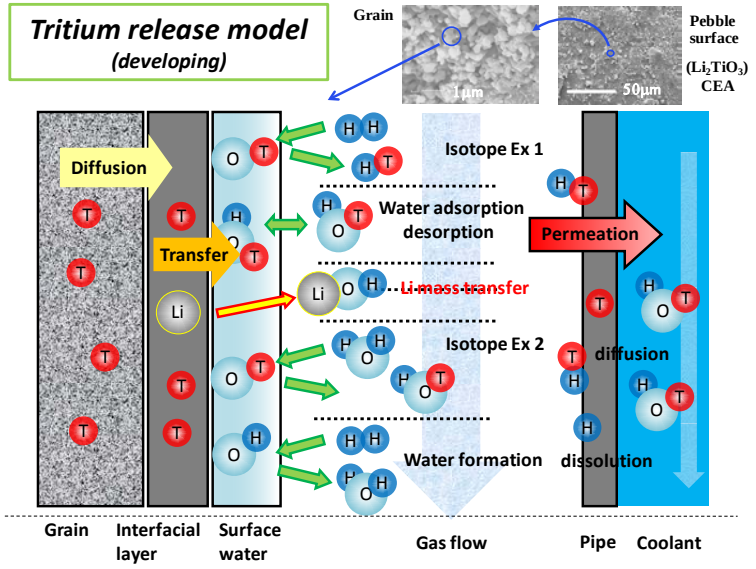
Solid Tritium Breeder

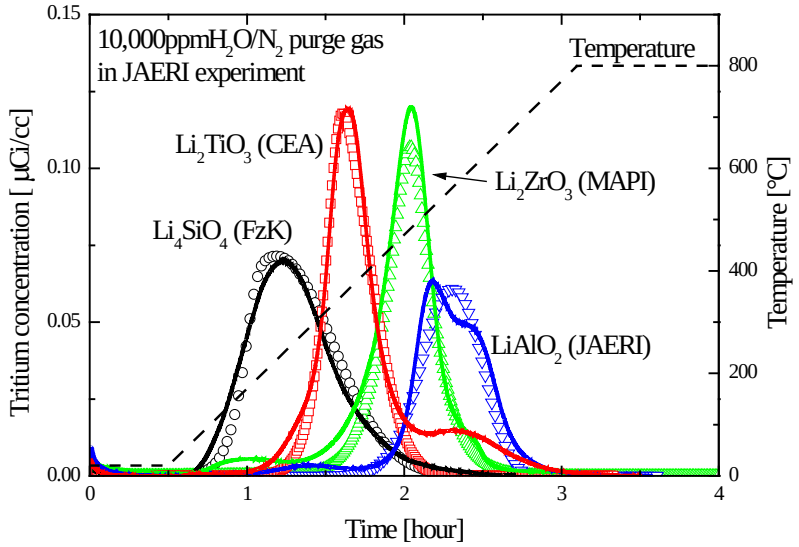
Neutron irradiation experiment



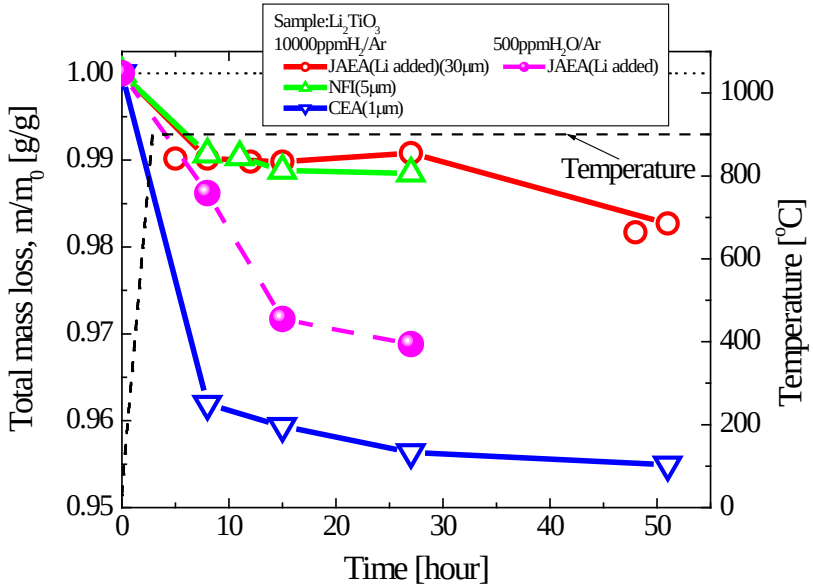
Experimental apparatus
for Out-pile tritium release

Tritium release model *(developing)*



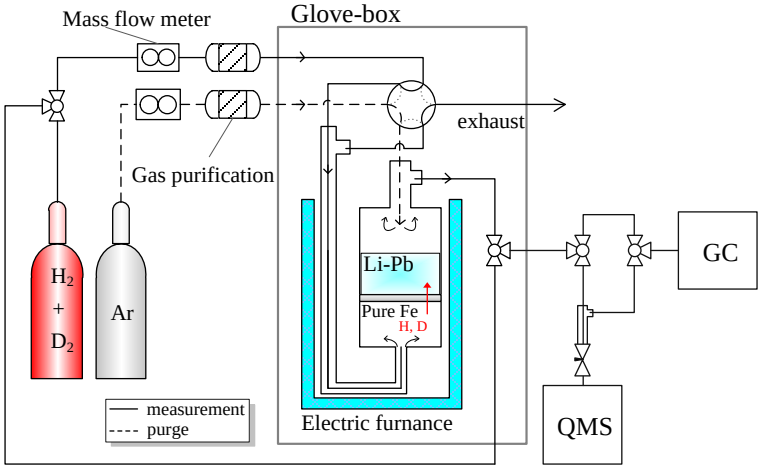


The release curves can be simulated well.

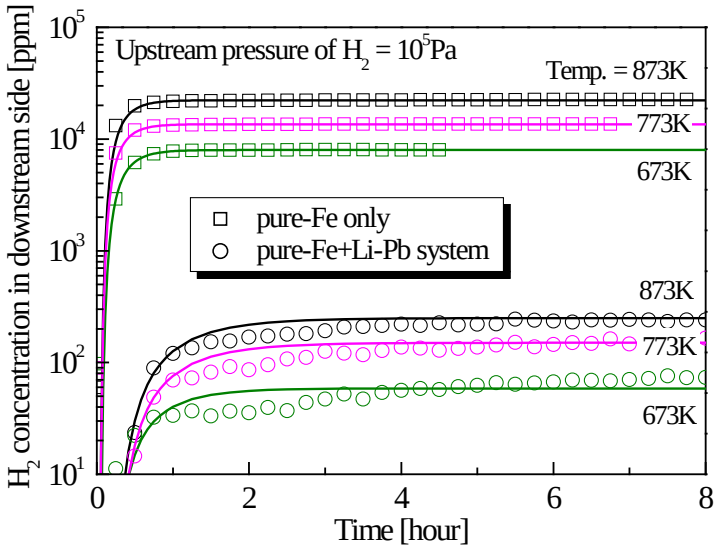


Study on lithium evaporation is ongoing.

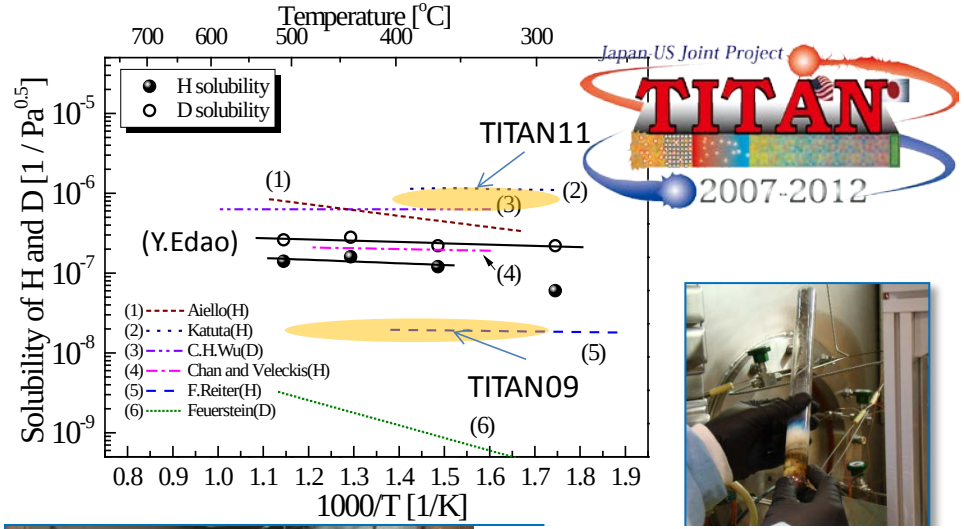
Liquid Tritium Breeder

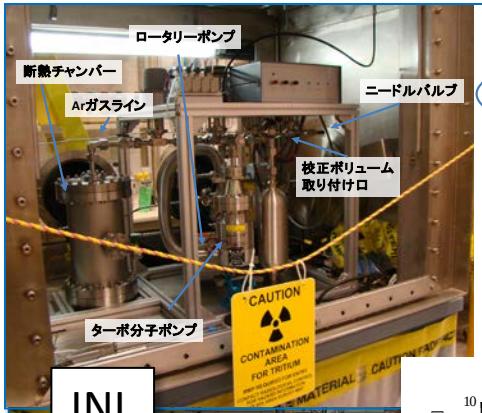


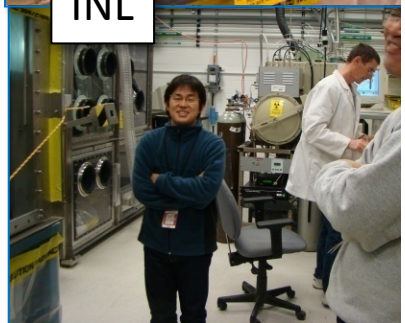
A schematic diagram of permeation apparatus.

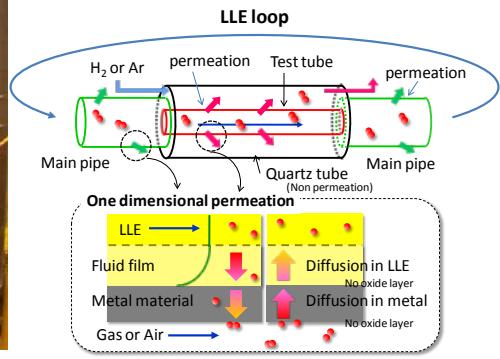


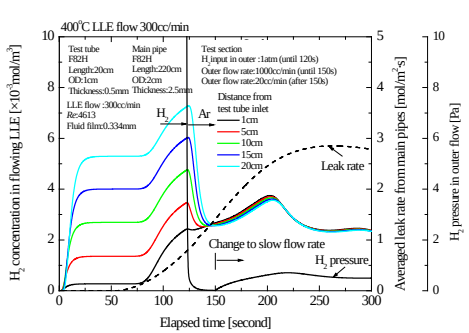
Comparison of the downstream H_2 concentration between α-Fe only and Li-Pb+α-Fe system.



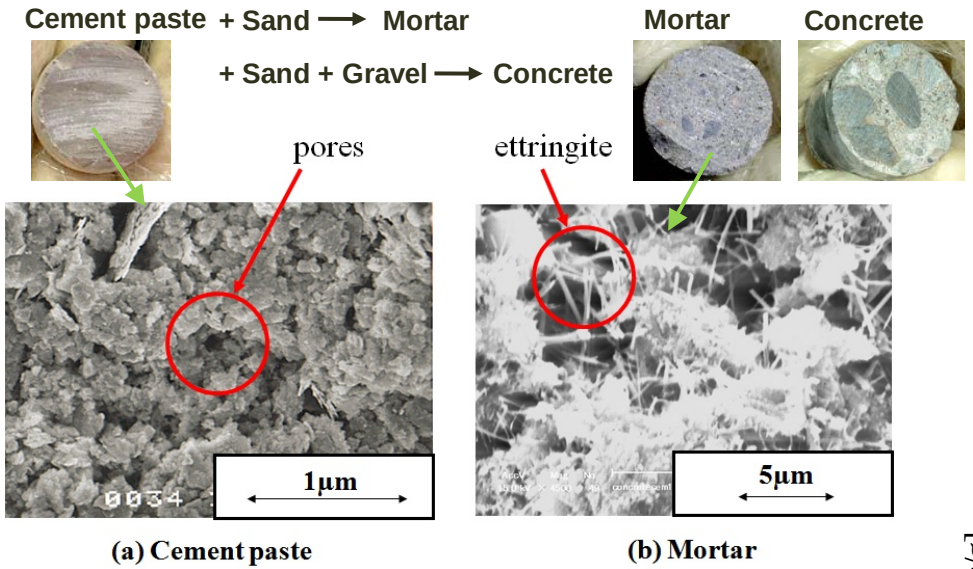




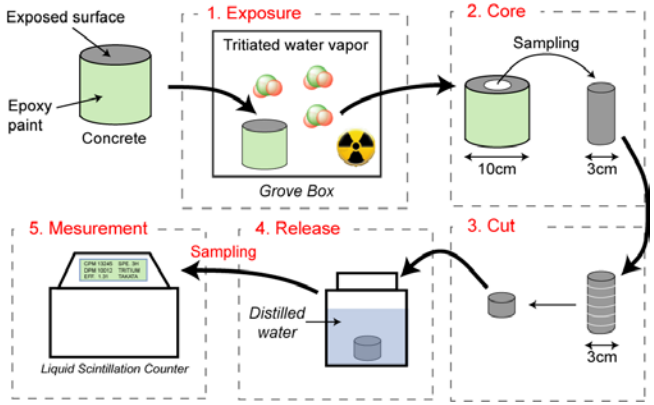


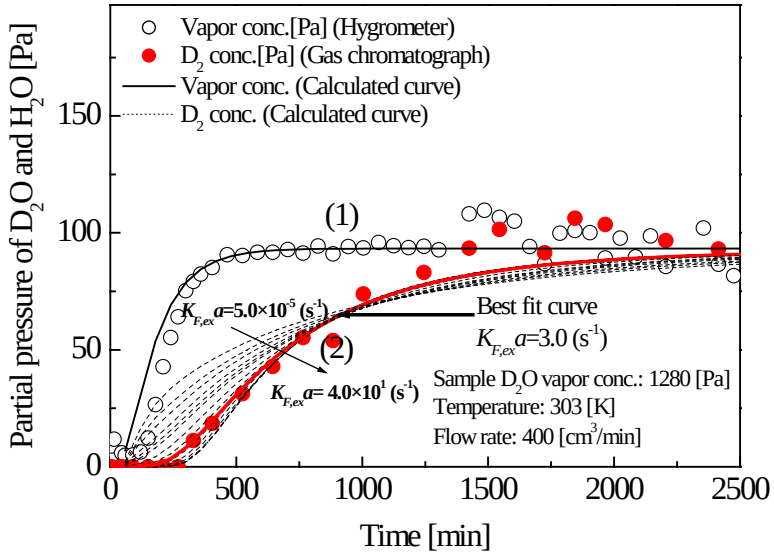


Tritium in Concrete materials

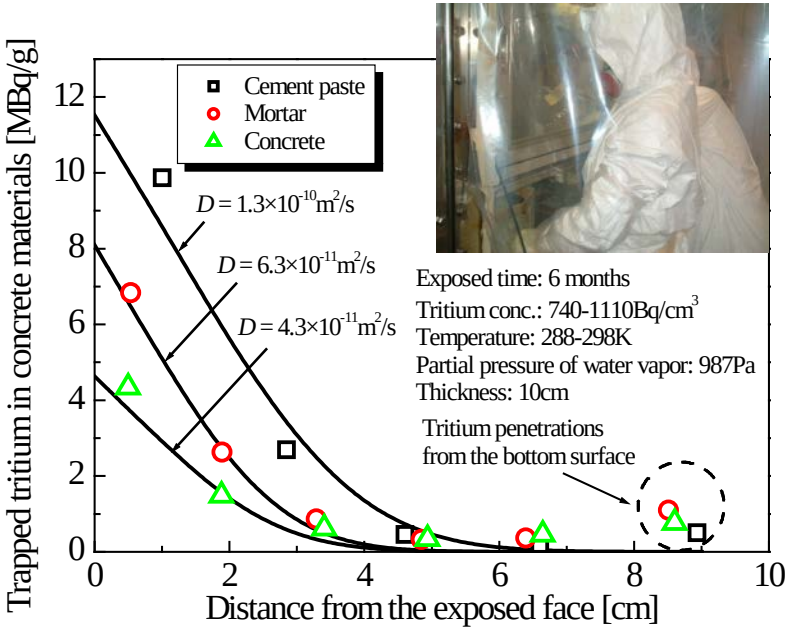


Collaboration with JAEA (TPL)





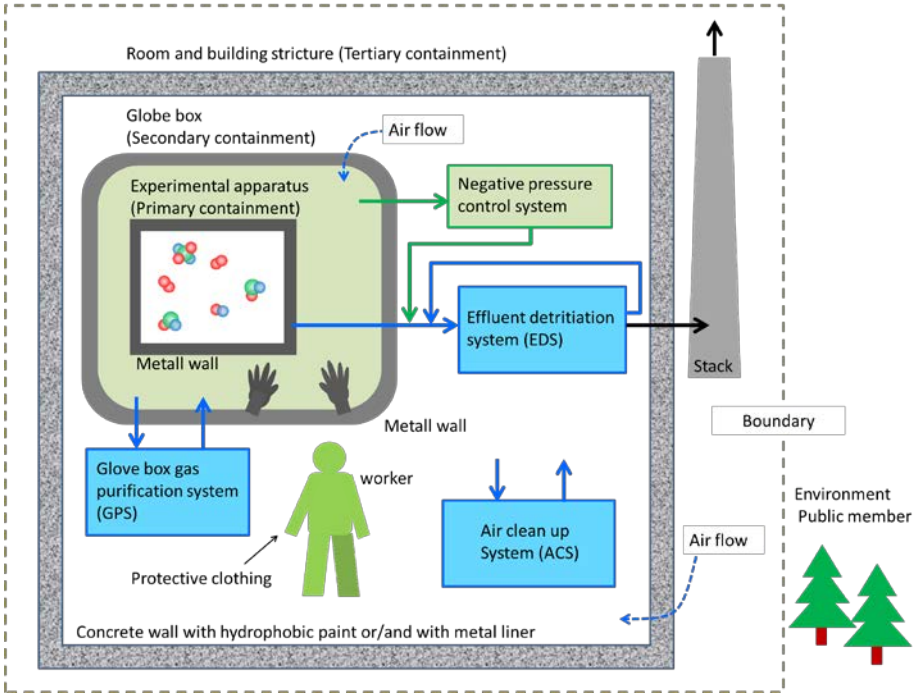
D2O permeation in cement paste.



Diffusion coefficient
Cement paste > Mortar > Concrete

Study on T in Soil

Development of tritium confinement system

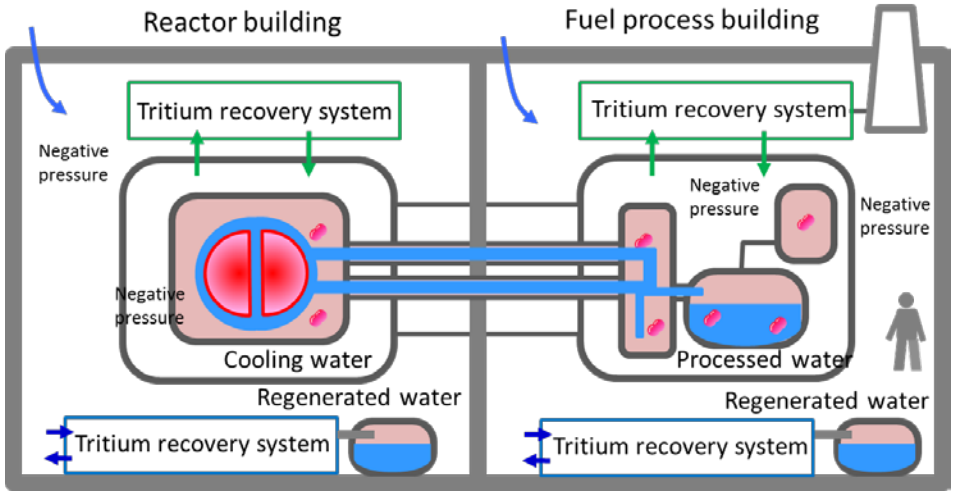


In tritium handling facility, tritium is confined by multiple confinement system.

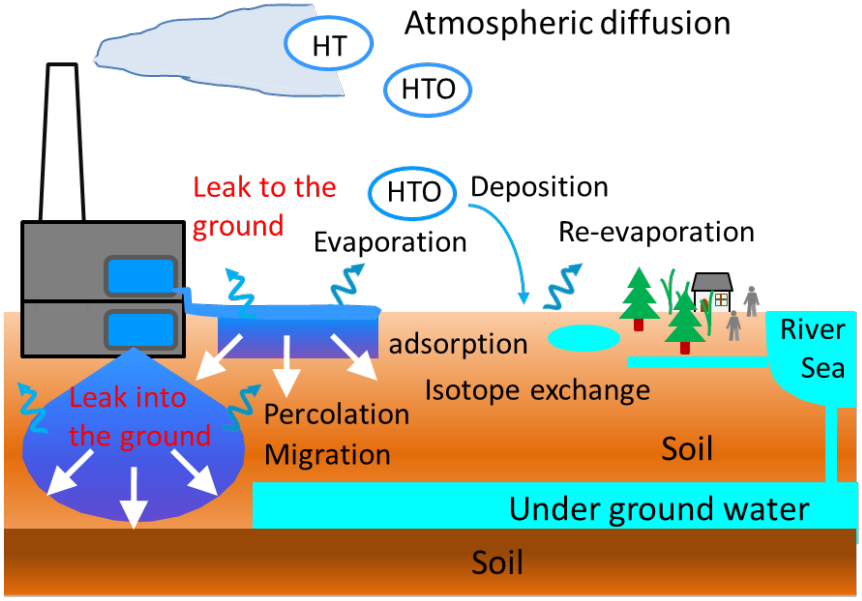
Under the concept of Defense in Depth,
Research and Development of high-reliable confinement system has been performed in the past.

In addition, it is important to assume an severe accident including tritium leak to the environment.

Introduction-II



Fusion facility has huge tritiated water.



A large amount of cooling water is used in a D-T fusion reactor.

The cooling water will contain tritium with high concentration because tritium permeates metal walls easily at high temperature.

Many Air Clean-up System are installed.

A large amount of tritiated water is generated by the re-generation process of adsorption bed.

Studies on tritium behavior in the air and the surface of ground have been done in the past.

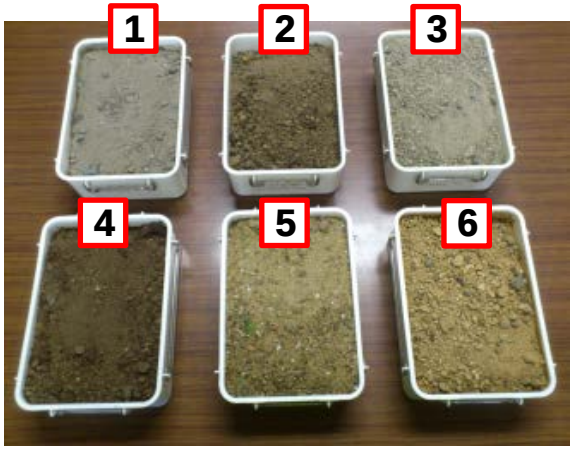
TRIDOSE(JAERI) TRIMOD(France) ETMOD(Canada) UFOTRI(Germany)

In this study, we focused on trtium behavior in soil. Tritium penetration behavior was investigated.

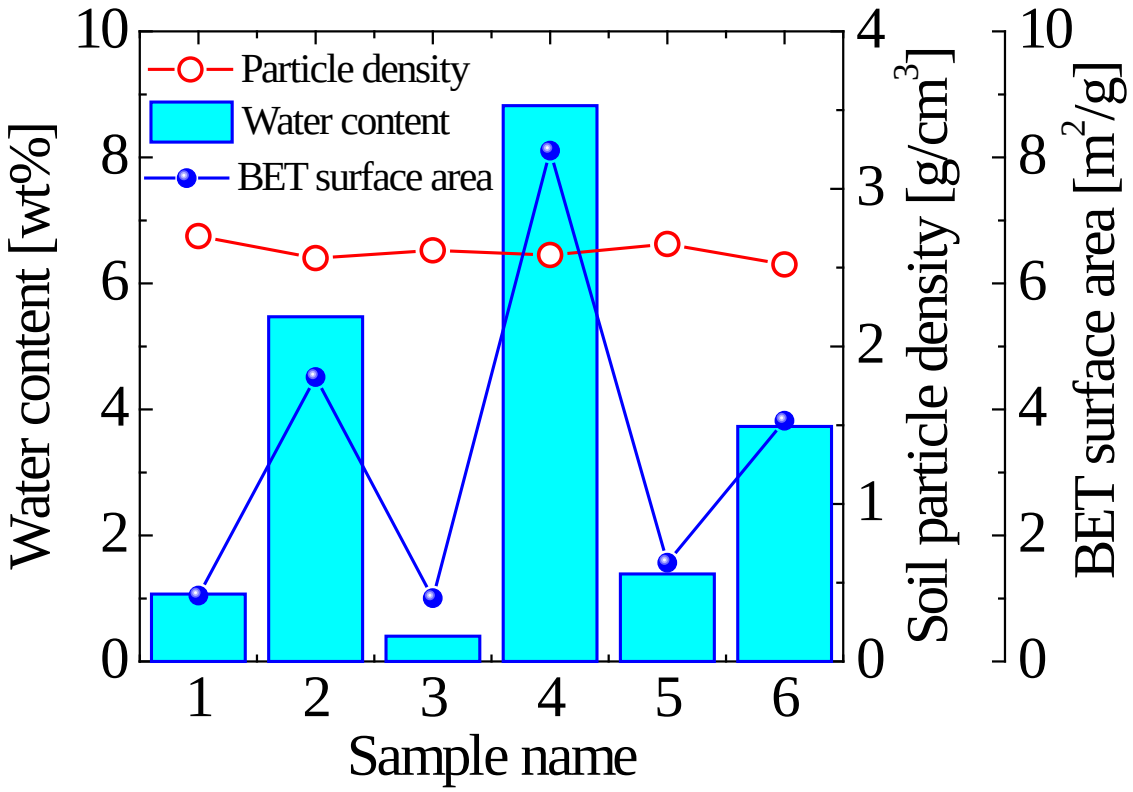
Sample soils

Sample soils were picked up at 6 locations
in the HAKOZAKI-Campus of Kyushu University.

1 : Dirt walkway (near pool)
2 : Trees near main gate
3 : Dirt walkway (near IR center)
4 : Pine trees (Dep.Agri)
5 : Trees near (Dep.Arts)
6 : Sports ground



Comparison



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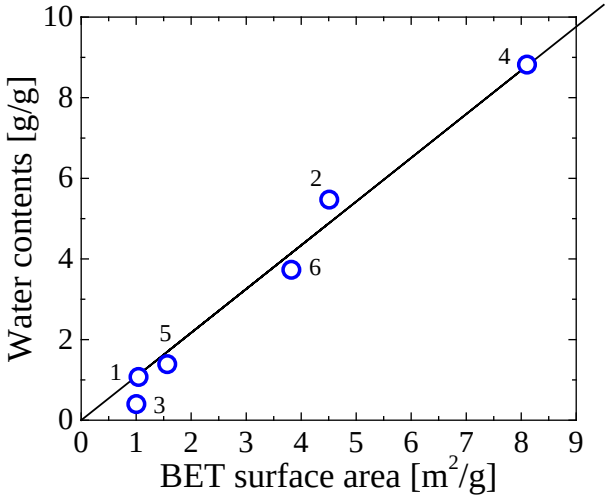
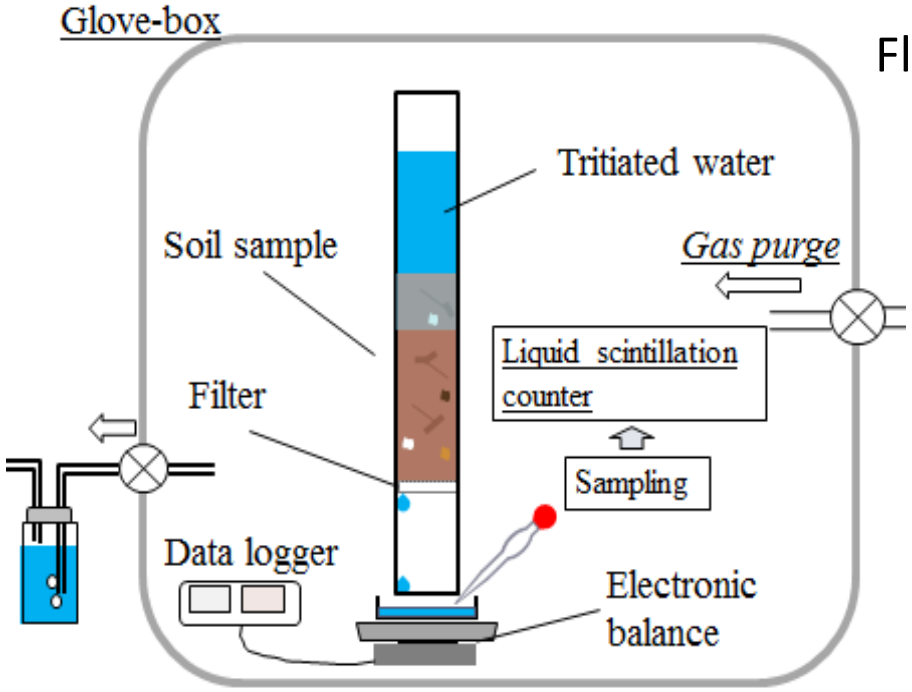
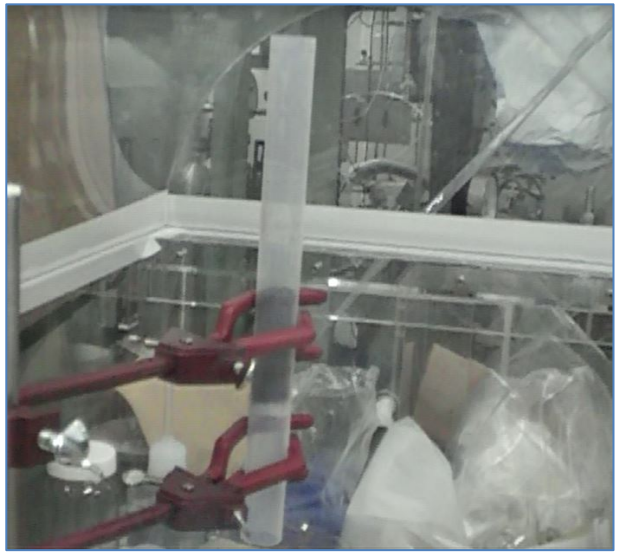


- Obtained particle densities were in the range of normal soil density, 2.5～2.8g/cm^3.
- Water content in atmosphere was approximately proportional to BET surface area.

HTO percolation experiment



Fluororesin Tube（ID:2.2cm,L:30cm）



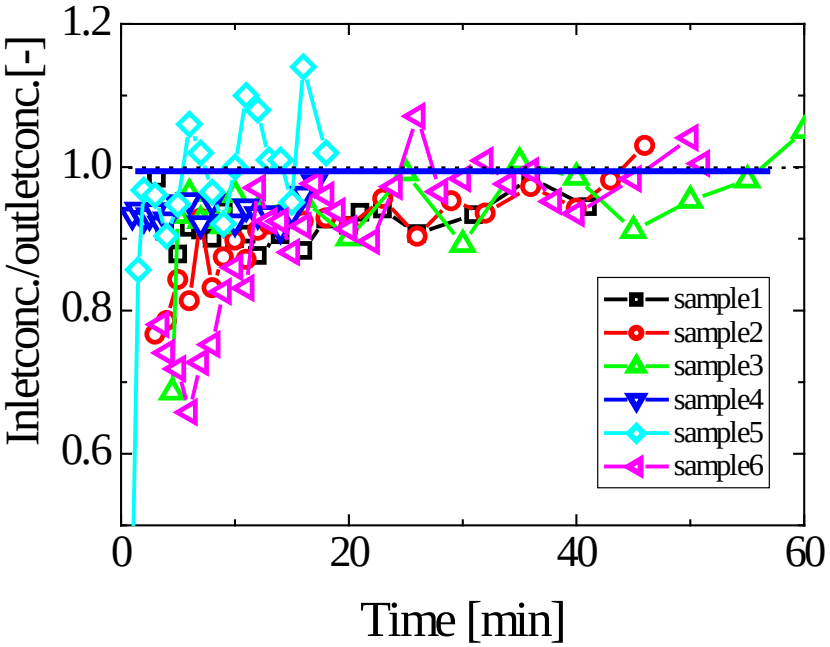
Sample	1	2	3	4	5	6
Weight[g]	49.3	28.5	19.1	25.6	29.5	38.3
Porosity [-]	0.31	0.51	0.35	0.6	0.35	0.4
Tritium [MBq/cc]	0.87	0.58	0.27	1.15	0.45	0.55

T concentration in effluent water was measured by LSC

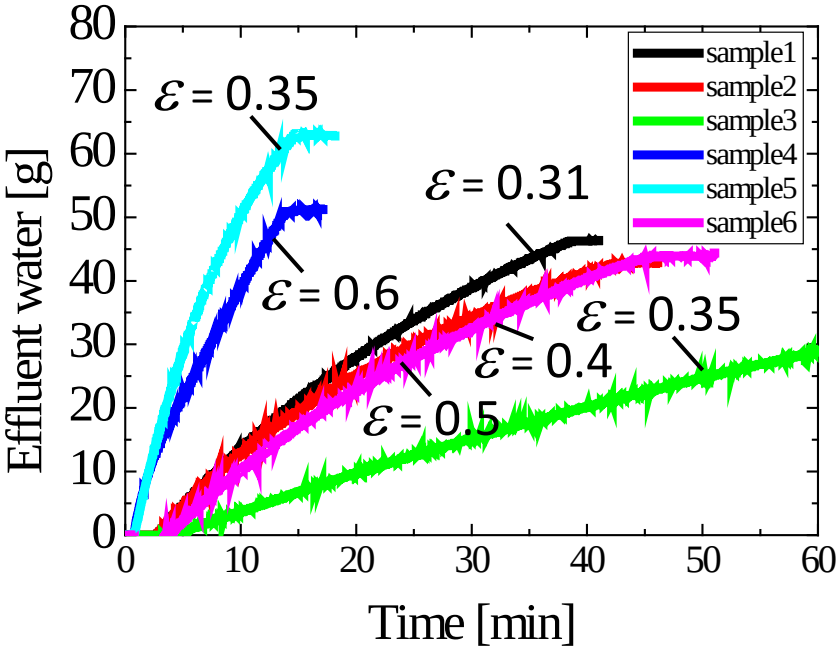
HTO percolation experiment

Kyushu University

Tritium conc. In the effluent



Weight of effluent water



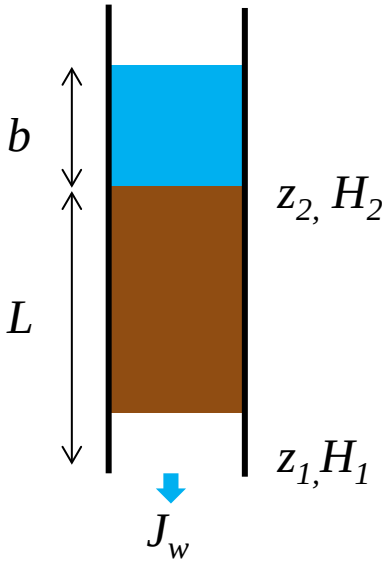
- T concentration in the effluent water is lower than input one.
  - ⇨ Tritium was retained in the soil packed bed.
- Percolation rate differed with samples.
  - ⇨ Percolation rate depends on soil particle property.

Percolation rate

Water flow in saturated soil →Darcy's law

$$J_w = -Ks\frac{H_2 - H_1}{z_1 - z_2}$$

$$Ks = -\frac{L}{(t_1 - t_0)}\ln\frac{b_0 - L}{b_1 - L}$$



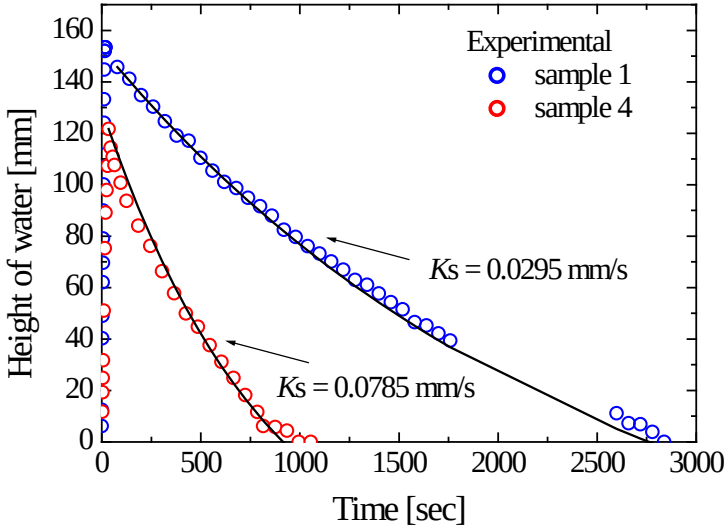
J_w:flux [mm/s]
Ks: saturated hydraulic conductivity[mm/s]
H_1: total head at z_1[mm]
H_2: total head at z_2[mm]
b: water height [mm]
L: bed height[mm]

Change of water height was monitored by video camera.

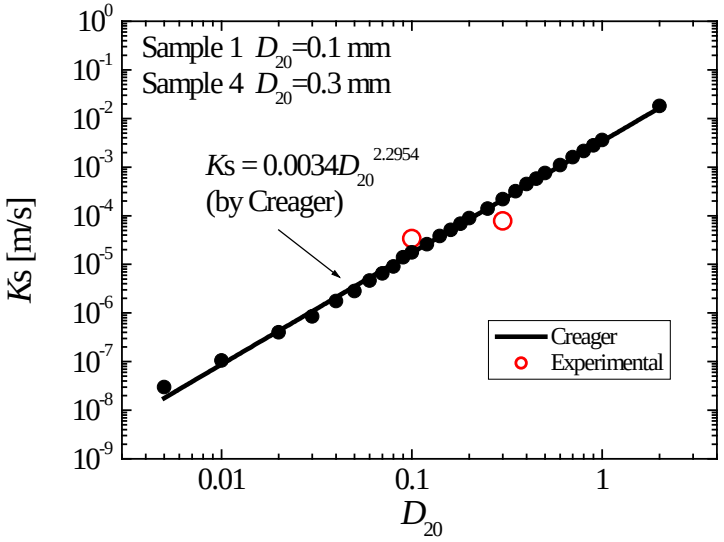
Time variation of water height

$$b_{(t)} = (b_0 + L)\exp(-\frac{Ks}{L}t) - L$$

Fitting curve



Comparison with Creager's estimation



Water & Tritium balance

Sample 1 as an example

	Water balance [g]	Tritium balance [MBq]
Input	58.2	50.7
Effluent	36.9	31.0
Sampling	9.5	2.66
Retention in bed	11.8	17.1
Retention/Input [%]	**20.3**	**33.7**

Water and Tritium Retention ratio

sample	1	2	3	4	5	6
W retention ratio [%]	20.3	15.5	8.44	14.3	16.2	22.4
T retention ratio [%]	33.7	17.1	12.1	18.2	17.3	27.2
T/W	**1.66**	**1.36**	**1.27**	**1.21**	**1.66**	**1.36**

Tritium retention ratio is larger than water retention ratio.

⇨ Tritium sorption via isotope exchange reaction.

Isotope exchange capacity

HT ratio of the water trapped in the soil is assumed to be balanced with HT ratio of the supplied water.

Sample 1

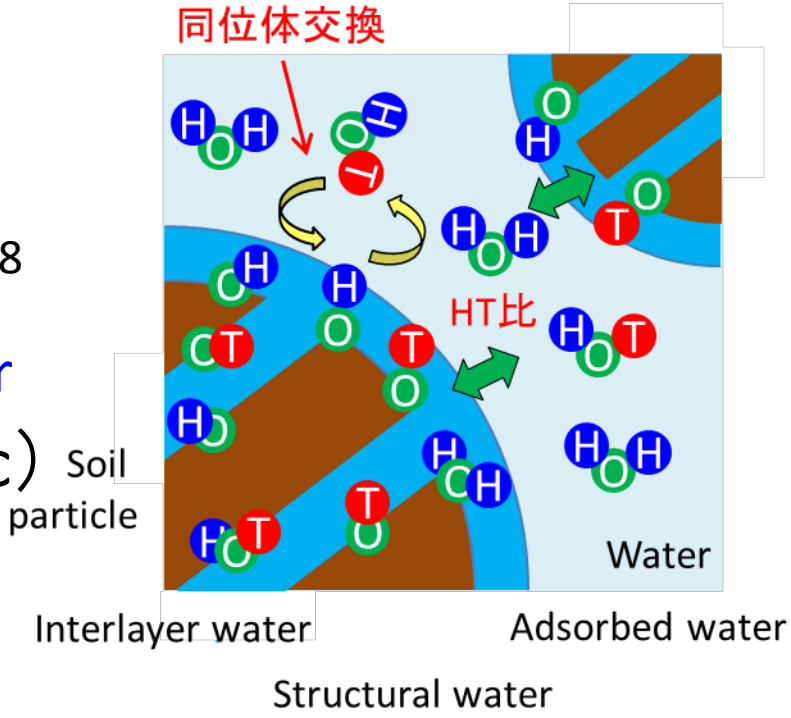
T conc. in the supplied water

0.87MBq/cc → HT ratio:1.37×10^{8}

T total retention　T in the retained water

17.07MBq－（0.87MBq/cc×11.8cc）

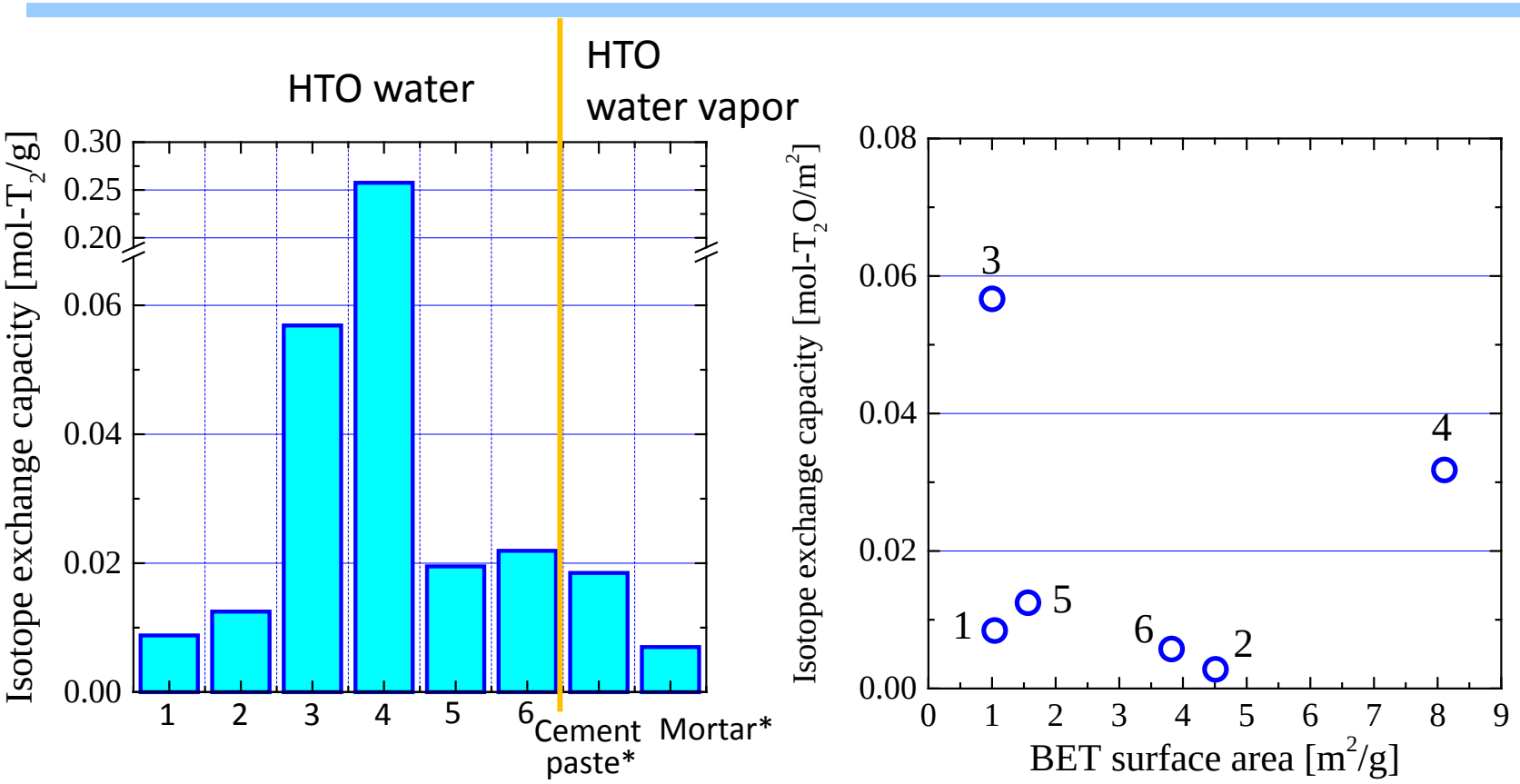
=6.80MBq　T in soil particle



Sample weight：49.3g　BET surface area：1.044m^2/g

Isotope exchange capacity : 8.79×10^{-3} mol-T_2O/g

IE capacity in soil

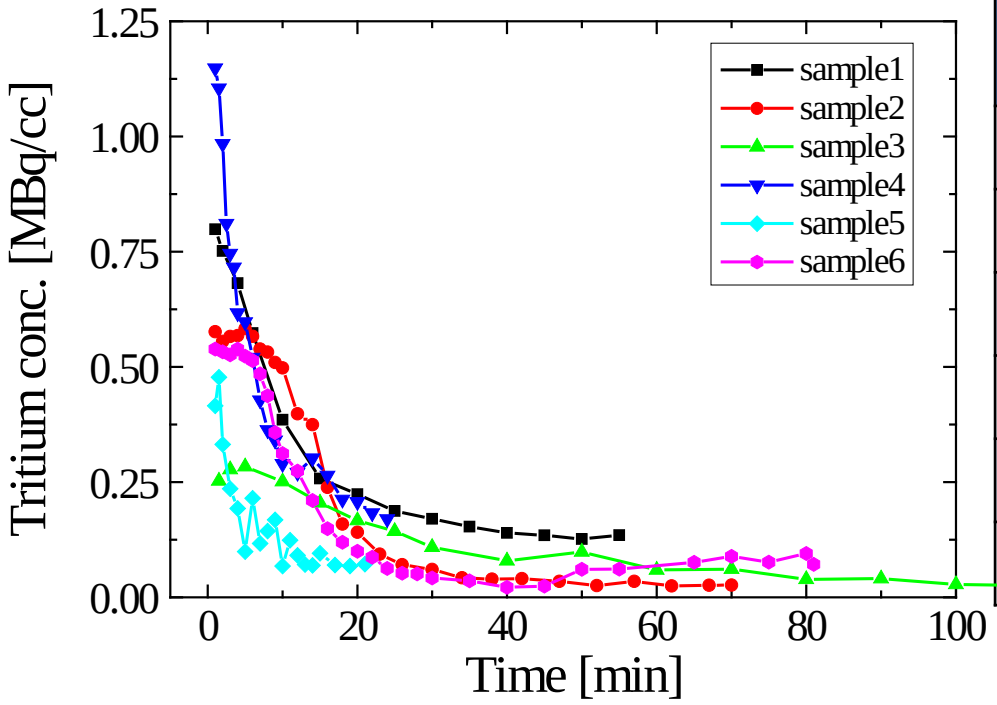


- Each sample soil has different isotope exchange capacity which is independent of BET surface area.
- Isotope exchange capacity in soil is comparable with concrete materials or more.

*Furuich, et al.,J .Nucl.Mater. 367-370(2007)1243-1247

Water purge

After the outflow of tritiated water stopped, distilled water was supplied to the soil packed bed.



Sample	Tritium removal ratio [%] (residual)
1	79 (21)
2	40 (60)
3	66 (34)
4	96 (4)
5	91 (9)
6	90 (10)

$$\frac{\text{T released}}{\text{T before purge}}$$

- Tritium removal ratio is greatly different in each sample soil.

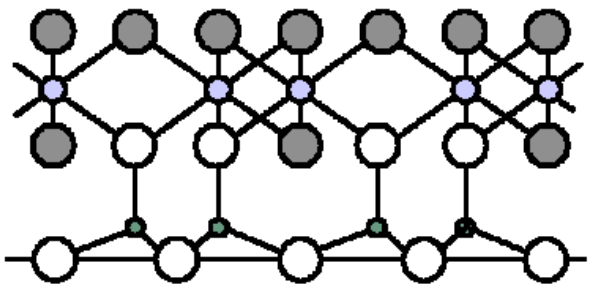
Water in Soil

Majority of clay mineral consists of sheet silicate.

(1) Adsorbed water（H_2O）released@100-300°C

(2) Interlayer water（H_2O）released@100-300°C

(3) Structural water（OH）released over 500°C

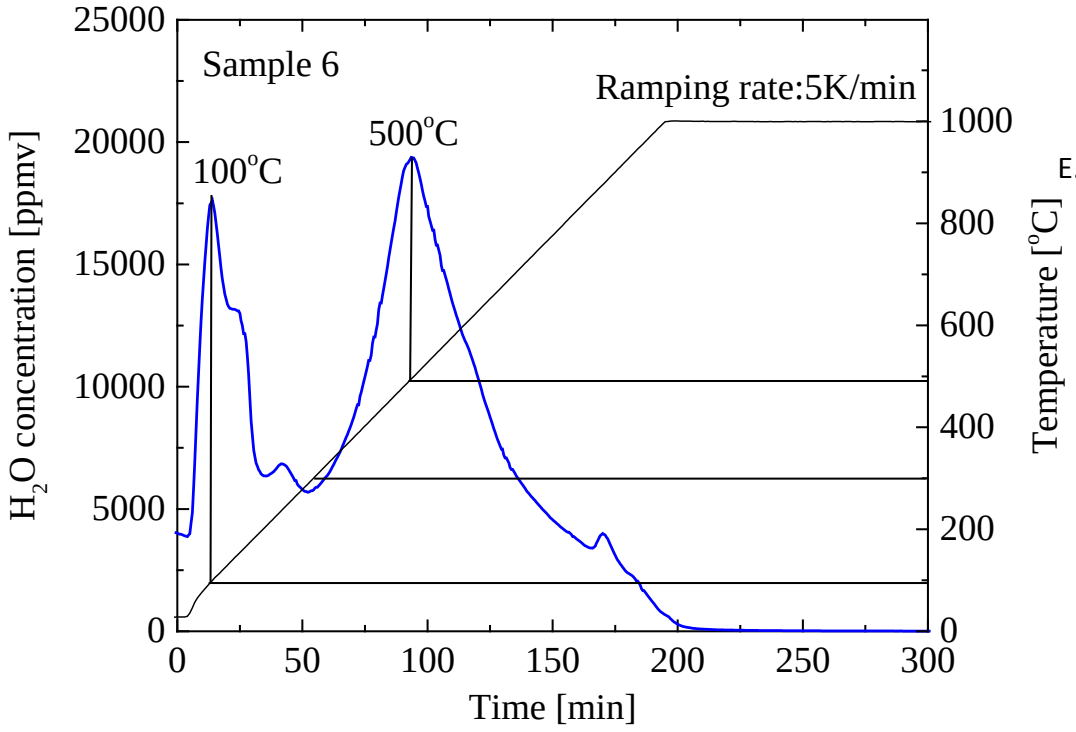


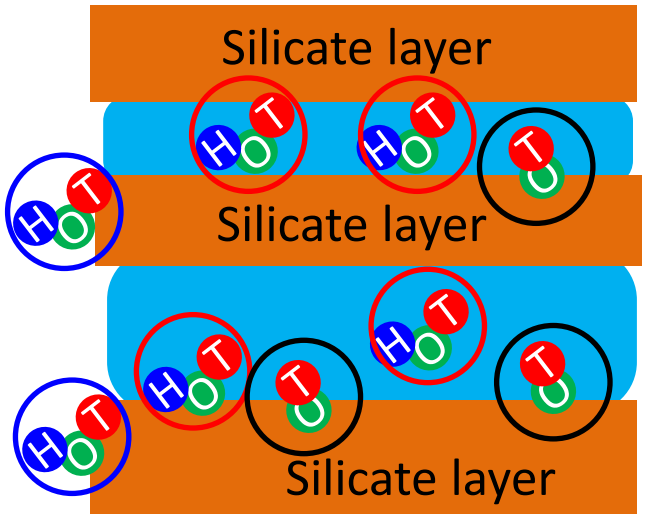
Kaolinite

Si^{4+} O^{2-}

Mg^{2+}, Al^{3+} OH^-

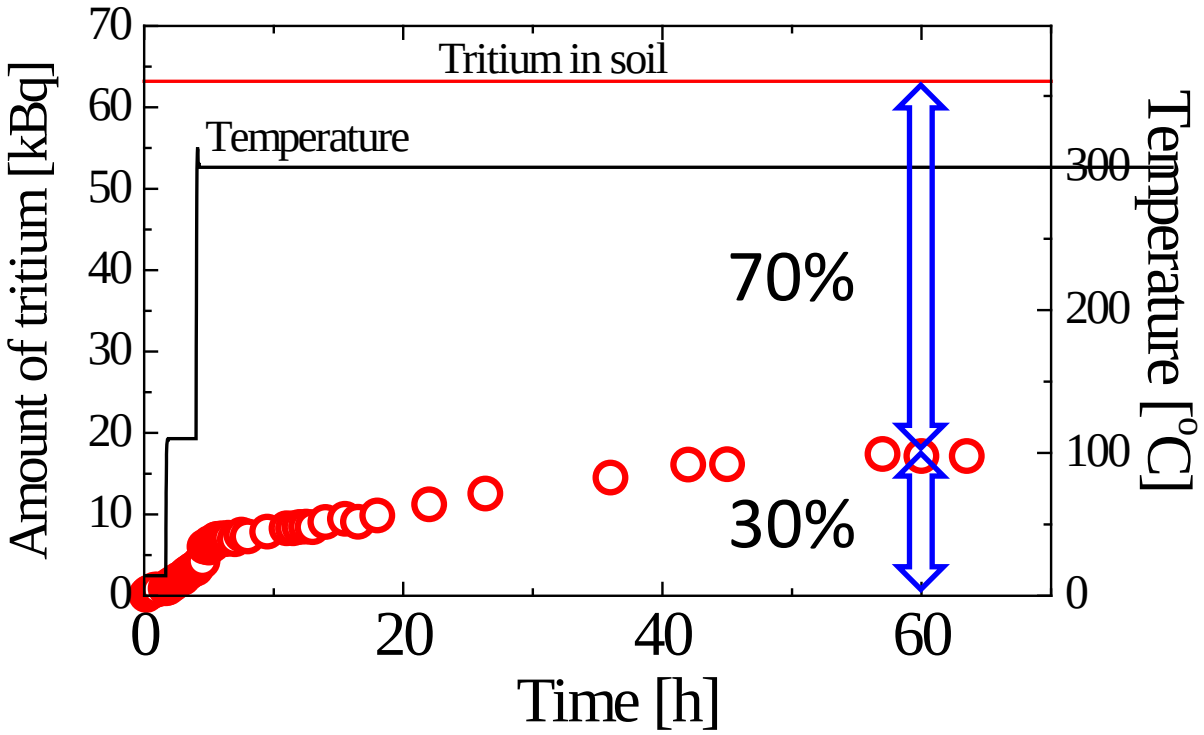
E.A. Kalinichenko, et al.,Clay Minerals, 37 (202) 497-508





Heating at 300°C

Soil sample 6 containing T was heated in wet argon to 300°C.



- Tritium was gradually released from soil by heating.
- Only 30% of the estimated tritium amount in the soil was released.
- The released tritium would be trapped as adsorbed water and interlayer water. The higher temperature is necessary to remove T.

Summary

For 6 soil samples in campus of Kyushu University, percolation behavior of tritiated water in soil packed bed was observed.

- Retention ratio of tritium in soil is larger than that of water because of isotope exchange reaction with supplied T and H in soil.
- Each sample soil has different isotope exchange capacity which is independent of BET surface area.
- Tritium retained in soil was not completely removed only by water purge. Heating is needed to remove tritium left in soil.

Thank you for your attention!