T2K radioactive drainage treatment

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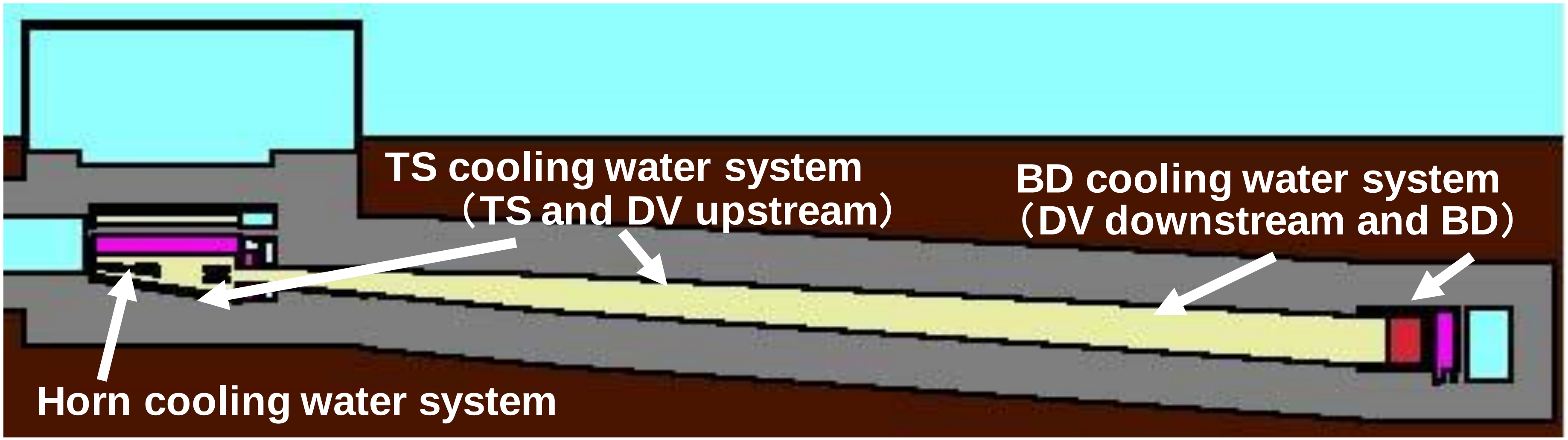
Overview

- **The last NBI workshop was held just after the commissioning of the T2K neutrino beam.**
  Disposal plan of radioactive cooling water was reported.
  See http://www-nu.kek.jp/~oyama/nbi2010.oyama.ppt

- **Three years of neutrino beam has been finished.**
  More realistic disposal scenario based on 3 years experience is reported. Prospect for beam power upgrade up to ~700kW is presented.

Cooling water systems in T2K neutrino beam line

- We have three independent cooling water systems



- Total water in the system are 2.7m^3 for Horn, 7.8m^3 for TS and 10.0m^3 for BD.

- In this talk, I will focus on cooling water from Horn and TS because their radio-activation is much higher.

Radionuclides in the cooling water

- **Neutrons from the beam with energy larger than ~20MeV break the $^{16}_{8}O$ nuclei in H_2O.**

- **Several kinds of radionuclides with Z ≦ 8 and N ≦ 8 are produced as spallation products.**
  The nominal production cross sections are ~30mb.
  The radionuclides include ^{3}H, ^{7}Be, ^{11}C, ^{13}N, ^{15}O, ^{14}O, ^{16}N, ^{14}C.

- **The radionuclides except ^{3}H and ^{7}Be decay within several ten minutes, or have extremely long life. Disposal scenario of only ^{3}H ($\tau_{1/2}$=12.3y) and ^{7}Be ($\tau_{1/2}$=53.3d) must be considered.**

- **Metal ions resolve from beamline components/pipes.**
  Radionuclides, mainly ^{22}Na ($\tau_{1/2}$=2.6y), from metal ions must be taken into consideration.

^3H

- ^3H cannot be removed by ion-exchangers.
  Dilution is only the way for disposal.

- There are two constraints from regulations.
  A) The concentration of ^3H in the disposal water should be less than 60Bq/cc.
  (JAEA requires 42Bq/cc for safety margin.)

  B) Total ^3H from J-PARC should be less than 5000GBq/year.

  More severe regulation is A).

- The capacity of the dilution tank is $84m^3$.
  Only $84m^3$ x 42Bq/cc = 3.5GBq ^3H can be disposed in one cycle.
  We must repeat dilution/disposal cycle.

- In 2012, 44GBq ^3H are produced.
  We needed 14 dilution/disposal cycles.

^{7}Be

- ^{7}Be can be removed by ion-exchangers.

- There are two constraints from regulations.
  A) The concentration of ^{7}Be in the disposal water should be less than 30Bq/cc.

  B) Total ^{7}Be from neutrino facility should be less than 1.2GBq/year.

  Unlike ^{3}H, more severe regulation is B).

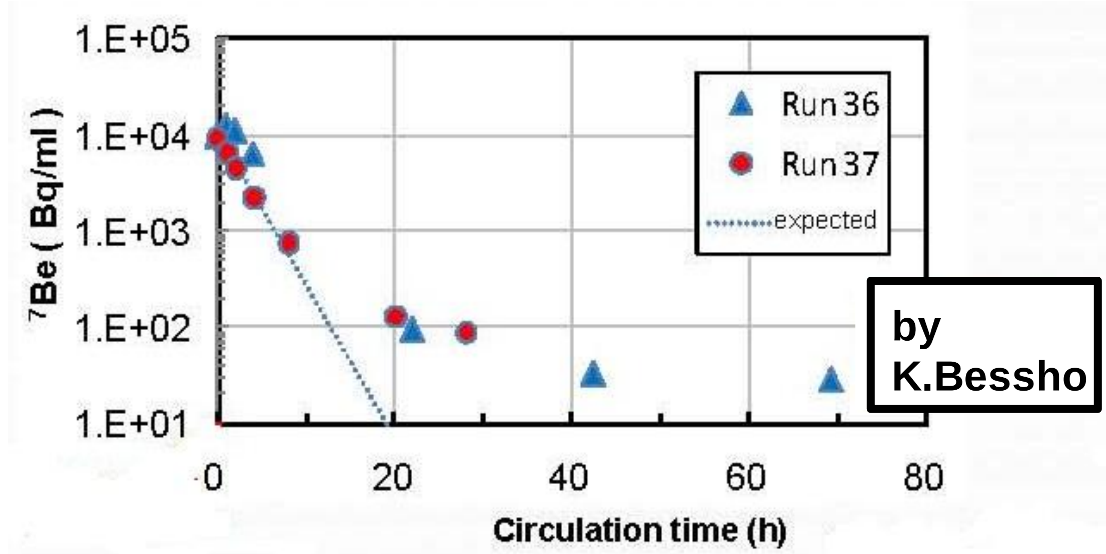
- In 2012, 83GBq ^{7}Be are reduced to be 0.21GBq.
  The reduction rate is 0.25%.
  For future upgrade of beam power, better reduction rate by ion-exchangers is needed.

- We have metal-oxide colloids problem which prevent effective removal of ^{7}Be.

The metal-oxide colloid problem

by K. Bessho (KEK Radiation Science Center)

- The concentration of ^{7}Be in the horn cooling water were measured many times during the ion-exchange. 0.1% ~ 1% of ^{7}Be cannot be removed by ion-exchangers.



- It is because ^{7}Be are sometimes adsorbed on **metal-oxide colloids** and become electrically neutral. Their adsorptivity on cation-exchange resins become low.

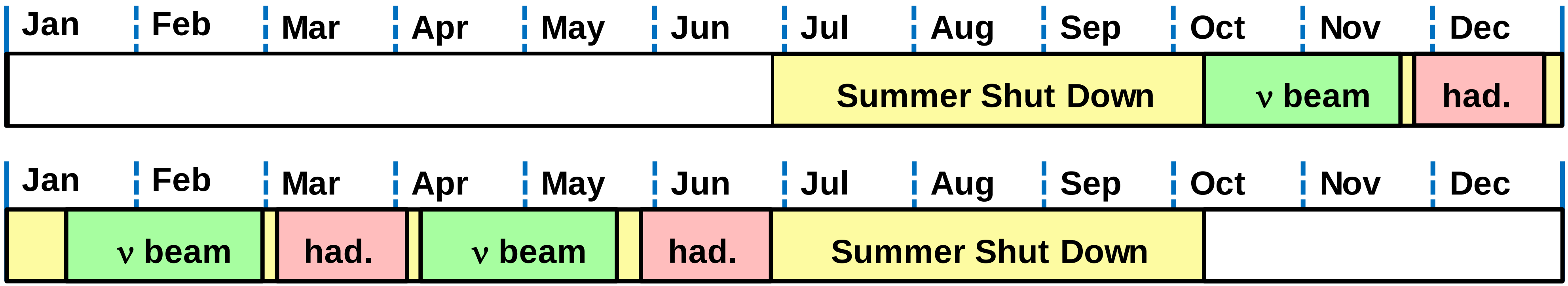
- If the cooling water become **acid**, the metal-oxide colloids return to soluble metal ions, and ^{7}Be also return to ions. It is recommended to change the water to **acid** for effective removal of ^{7}Be by the ion-exchanger.

^{3}H and ^{7}Be from the Horn and the Target Station

	Beam power	p.o.t ($\times 10^{19}$)	^{3}H (GBq)	^{7}Be (GBq)
Jan 2010 - Jun 2010	< 60kW	3.2	8	18
Nov 2010 - Mar 2011	~150kW	11.1	27	60
Dec 2011 - Jun 2012	~170kW	15.8	44	83
Oct 2012 - Jun 2013	200kW	47	114	250
Oct 2013 - Jun 2014	250kW	60	146	320
Oct 2014 - Jun 2015	250kW	60	146	320
Oct 2015 - Jun 2016	300kW	70	170	380
Oct 2016 - Jun 2017	300kW	70	170	380
Oct 2017 - Jun 2018	300kW	70	170	380
Oct 2018 - Jun 2019	700kW	160	390	860

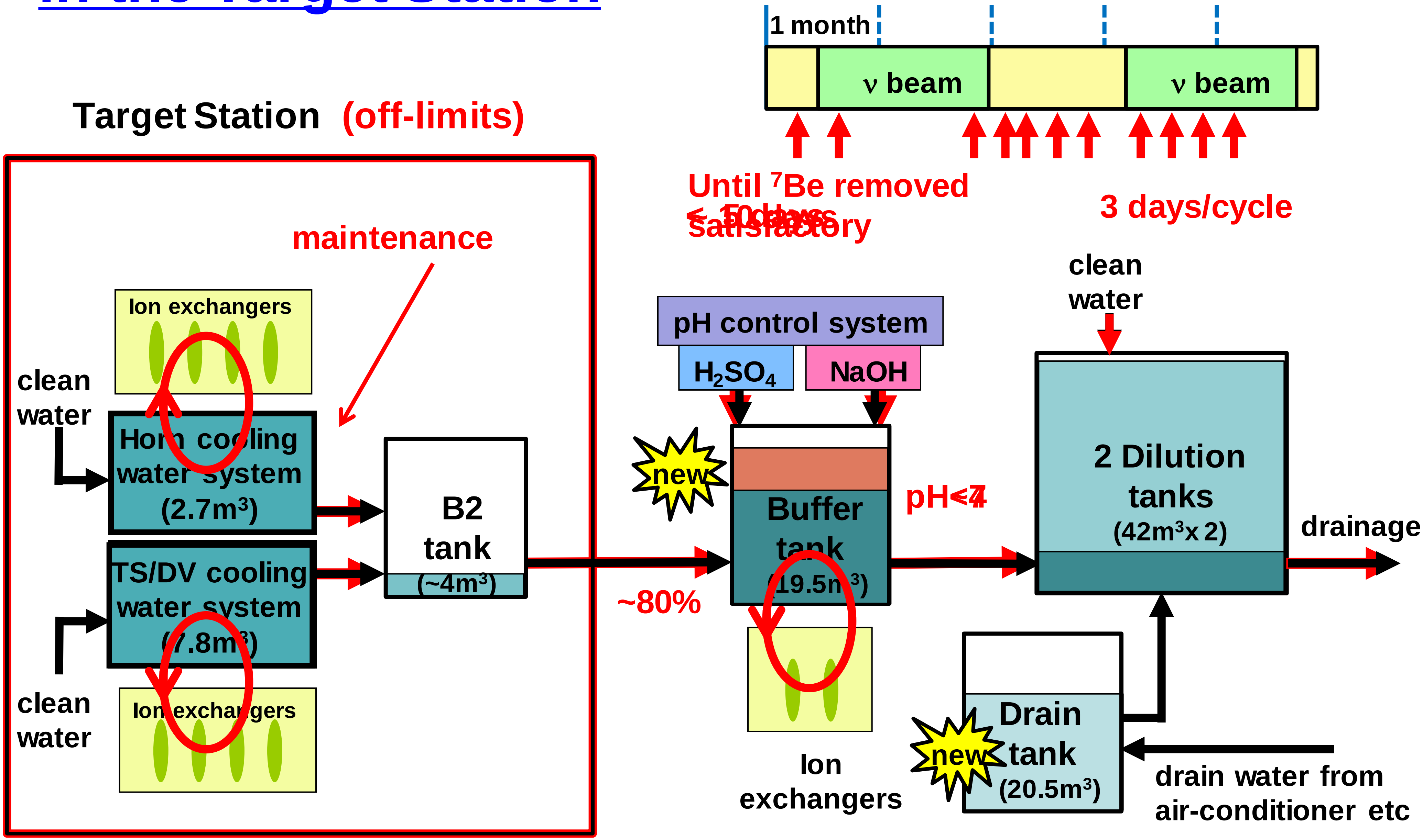
← We are here (Oct 2012 - Jun 2013)

Nominal 1-year beam schedule in J-PARC MR



- (~2 months ν + ~1 month hadron) x 3 cycles in one year.
- 1×10^7 sec/(3 cycles) ~ 38 days ν beam in one cycle.
- Disposal scenario of radioactive water should be arranged to match this schedule.

Disposal Scenario of Radioactive Cooling Water in the Target Station



Disposal of ^3H after dilution

	Beam power	p.o.t (x 10^{19})	^3H (GBq)	Effective volume of DP(m^3)	1 cycle (GBq)	Number of dilution cycles
Jan 2010 - Jun 2010	< 60kW	3.2	8	32	1.34	12
Nov 2010 - Mar 2011	~150kW	11.1	27	36	1.51	22
Dec 2011 - Jun 2012	~170kW	15.8	44	84	3.53	14

Oct 2018 - Jun 2019	700kW	160	390	84	3.53	110

- **With present (3 business day/cycle) operation, 110 dilution cycle/year is impossible. Present limit is ~500kW.**
- **Possible solutions are:**
  1. **3 days/cycle -> 2 days/cycle**
  2. **Work even on holidays (at least on Saturday…..)**
  3. **Ask a tank truck service by JAEA (16GBq/month)**

Reduction of ^{7}Be by ion-exchangers

	Beam power	p.o.t (x 10^{19})	^{7}Be (GBq)	After TS (GBq)	After BT (GBq)	Reduc. Rate
Jan 2010 - Jun 2010	< 60kW	3.2	18	0.52	------	2.9%
Nov 2010 - Mar 2011	~150kW	11.1	60	1.9	0.54	0.90%
Dec 2011 - Jun 2012	~170kW	15.8	83	0.58	0.21	0.25%

Oct 2018 - Jun 2019	700kW	160	860		1.2	0.14%

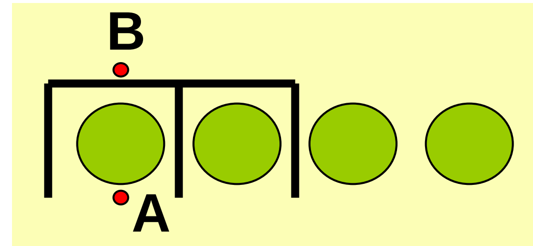
- **Long circulation in the ion-exchangers with pH control works well.**
- **With an improvement of reduction rate by another factor 2, we can reach our goal.**

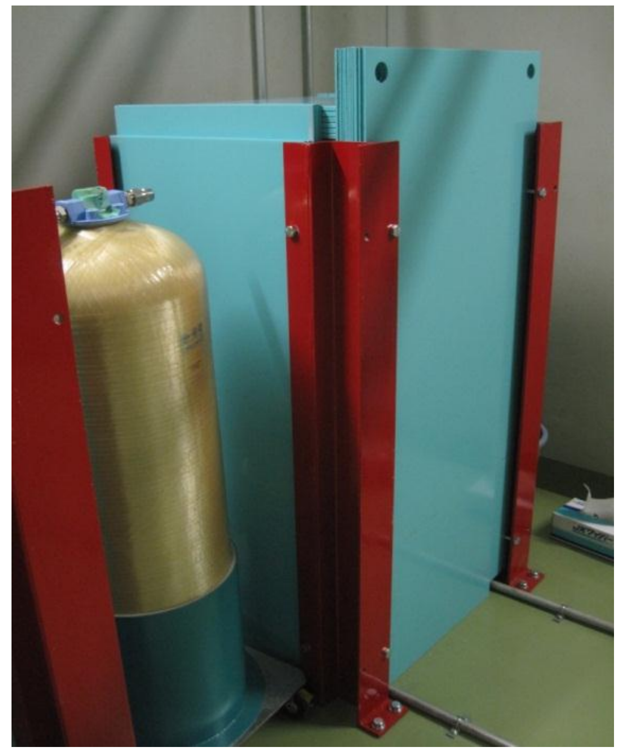
^{7}Be and ^{22}Na in the ion-exchangers

- **When radionuclei are accumulated in the resin, radiation dose around the ion-exchangers become high. Ion-exchangers are surrounded by iron shield.**

Radiation dose around the ion-exchanger

750kW, expectation Unit : μSv/h	A		B	
	^{7}Be	^{22}Na	^{7}Be	^{22}Na
After 6 months beam	49000	730	1020	31
After 2 years cooling	4	190	0.08	8
After 3 years cooling	---	95	---	4

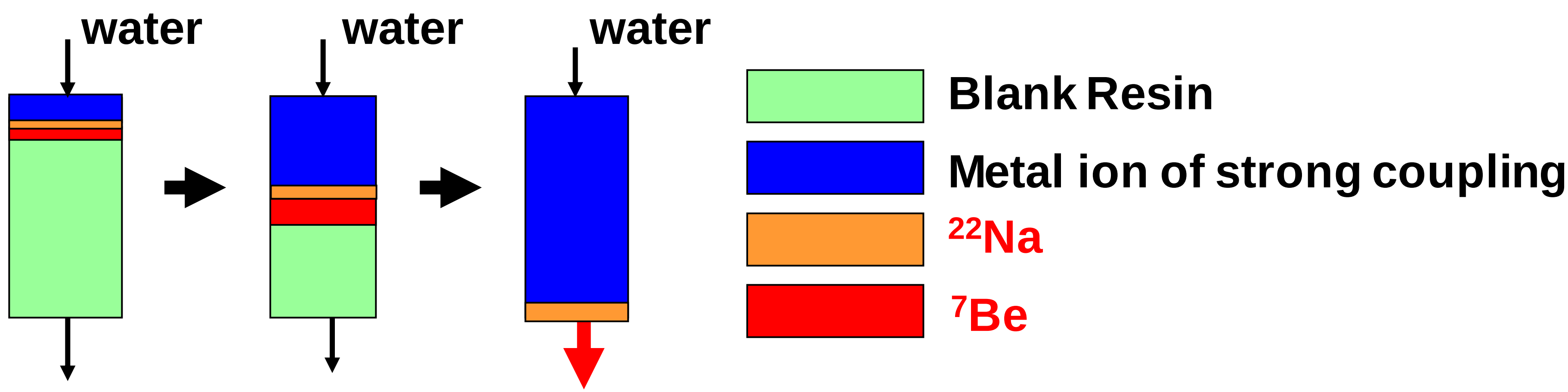




- **Since lifetime of ^{22}Na ($\tau_{1/2}$=2.6y) is longer than the that of ^{7}Be ($\tau_{1/2}$=53.3d), the contribution of ^{22}Na is more serious when we replace the ion-exchangers.**

Lifetime and replacement of the ion-exchangers

- The strength of coupling to resin is : metal ion > ^{22}Na > ^{7}Be. Radionuclei are gradually pushed out to downstream by metal ions, and finally may overflow from the ion-exchangers.



- Concentration of metal ions does not depend on beam power. From our experience in K2K, the lifetime of the ion-exchanger will be longer than the lifetime of ^{22}Na.
- We have multiple ion-exchanger slots.
- We hope that the radio-activation by ^{22}Na will cool down before replacement of ion-exchangers. We must keep watching.

Summary

- **Realistic radioactive disposal scenario is established considering annual beam schedule.**
- **The buffer tank and the drain tank were newly constructed in the radioactive-water disposal system.**
  1: long circulation in the ion-exchangers with pH control.
  2: disposal can be possible even in the neutrino beam period.
  3: volume of disposal water in one cycle became about twice.
- **The present limit of ^{3}H disposal corresponds to ~500kW beam.**
  Change of dilution/disposal cycle and/or tank truck are needed.
- **We have succeeded to reduce the concentration of ^{7}Be to be 0.25% in the buffer tank. A reduction rate of ~0.14% which is required in the ~700kW beam is not difficult.**
- **Replacement of the ion-exchangers and radiation dose from ^{22}Na may become a serious problem.**

End