MIXED INCINERATION SYSTEM FOR LLW RIAW AND LIQUID SCINTILLATOR WASTE AFTER STORAGE-FOR-DECAY

Katsumi Naba
Radiation Safety Laboratory
School of Medicine, Keio University
Tokyo 160, Japan

Kuniaki Imao
Chuwa Kiko Co.
Tokyo 103 Japan

ABSTRACT

Medical radioactive waste have short lived nuclide except for H-3, C-14 and have no α emitters. Therefore it becomes easy to incinerate after storage-for-decay. In Japan, medical LLW is managed separately from reactor waste. Most parts of medical radioactive waste are inflammable solid and organic liquid scintillator cocktail wastes (OLSW); Both radioactive wastes are combustible after decay. For OLSW, a newly developed bubbling vaporization apparatus (WDS 101B, Aloka Co., Tokyo) was used for the purpose of removing water from the gel scintillator. The results are a lower radioactivity of organic distillate and a higher residual neutral detergent that can be easily separated easily. The organic distillate was completely burned using a nozzle burner type incinerator (AFF-150, Sun Pot Co., Tokyo) equipped with a stainless steel electrostatic precipitator.

As for the inflammable solid of I-125 waste, radioimmunoassay tube (RIAW) wastes account for 80% of LLW. After about 2 years storage-for-decay, residual I-125 in a waste bag was directly measured by a newly developed Beryllium Window NaI Scintillation Survey Meter (S-1371, Ohyo Koken Kogyo Co., Tokyo). This waste is easily and completely burned under high temperature. A stainless steel furnace was cooled by water and removal of the I-125 from off gas was carried out by a centrifugal cyclone. From 1987 to 1991 test incineration by 60 kg/h capacity incinerator F-II was carried out after 2 years storage-for-decay under the auspices of the Japan Science and Technology Agency and the results were reported in 1989 Joint International Waste Management Conference held in Kyoto. Considering these results and experiences, a new large scale incinerator, 150 kg/h capacity AP-150 (Chuwa Kiko Co., Tokyo), has been developed and since March, 1992, practical application has been begun. This incinerator can be used not only for the LLW but also hospital biomedical waste. After over 480 days storage-for-decay, mixed RIAW with OLSW was incinerated and radioactivity in the off-gas was measured. Considering radiation safety for the public exposure, I-125 ALI for the public was estimated at 9 KBq according to 1990 ICRP recommendations. During this 15 days (under 8 hrs/day) incineration (RIAW 7,000 kg. OLSW 500 Kg) the estimation of the radiation exposure to the public was confirmed below 2.0% for ALI's.

Keio Universiyy Hospital, under private management, has 1,000 beds and is physically connected to the Keio School of Medicine. Seven-hundred researchers are registered as approved radioisotope users in the research and clinical laboratories. On site local waste disposal has many advantages shown as follows:

- Divide the RI and inflammable waste classes;
- Necessary incineration time is short (under 120 hours/year); for the remaining hours of the year, the incinerator can be used for hospital biomedical waste;
- The residual ash is small after incineration; the rate of volume reduction exceeds 99%;
- Savings: disposal total volume and expense during 3 years; RIAW: 50 L containers; 1, 500→4,500,000 RIA waste tubes→13,500 Kg ¥48,000,000→$384,000. OLSW: 1,000 liters.

INTRODUCTION

In Japan, incineration of medical LLW is carried out under the approval of the Japan Science and Technology Agency. This incineration system is mainly composed of the following two systems and shown in Fig. 1:

1. incineration of OLSW,
2. incineration of RIAW.

In Japan, OLSW incineration is carried out locally on the site of the user and RIAW is centrally carried out. Therefore, problems arise from these incineration systems. They are summarized as follows:

OLSW

1. Transport of inflammable radioactive organic liquid,
2. complete combustion,
3. removal of RI from hot temperature off-gas,
4. removal of water from gel waste,
5. radiation exposure to the public.

RIAW

1. Radioactive decay of I-125,

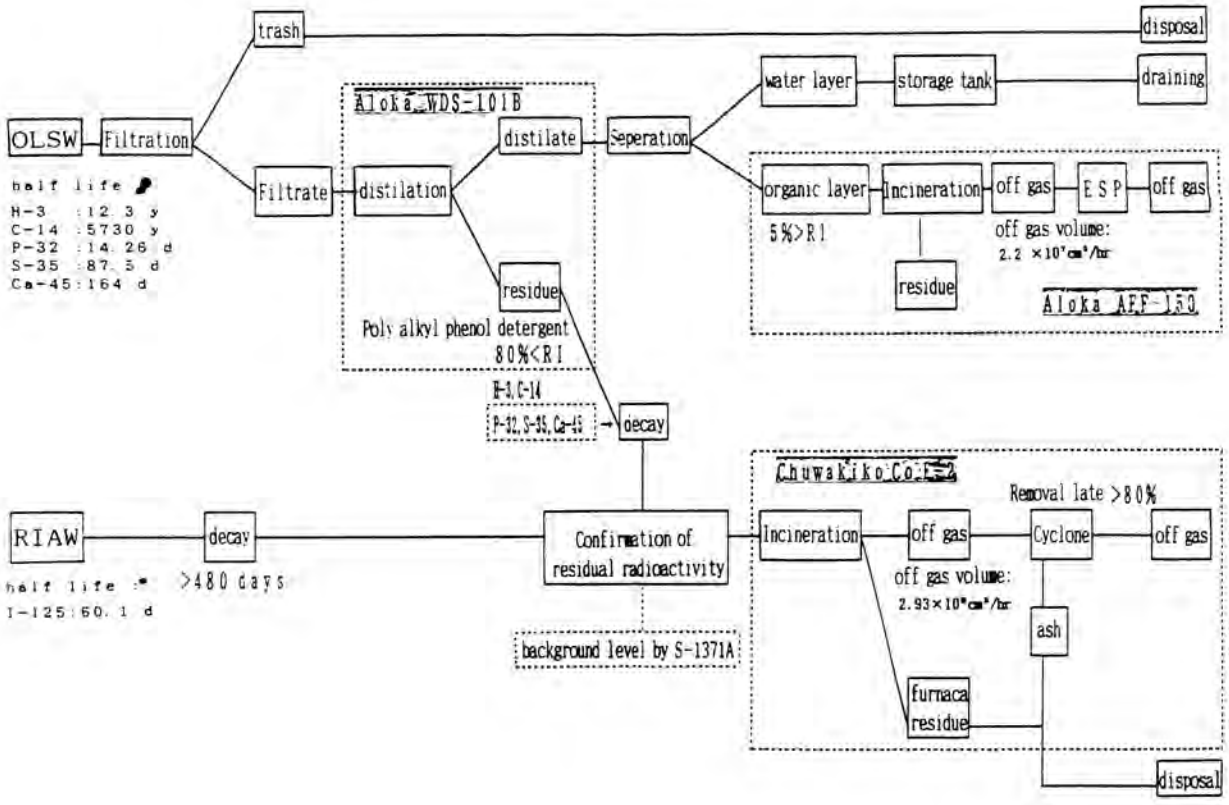


Fig. 1. Mixed incineration system for medical field LLW.

2. confirmation of residual I-125 activity before incineration,
3. removal of I-125 from hot off gas,
4. continuous measurement of RI concentration in off-gas,
5. radiation exposure for the public.

For the purpose of solving the above mentioned problems, two incinerators, one distillation apparatus, one computer controlled automatic gas sampling with spectroanalyzer and a I-125 survey meter were developed. As the result, incineration was carried out safely and easily for this medical field.

SYSTEM OF OLSW INCINERATION

This system is composed of the following processes and is shown in Fig. 2.

Filtration

Elimination of glass beads, filter paper, etc. The most important point is removing water from the gel scintillator.

Bubbling Vaporization

The heating temperature of the OLSW inside the vessel is kept between 65°C-85°C and the solution is bubbled with nearly 0°C circulated air. After distillation, the water layer is separated from the organic chemical layer and put down the drain according to regulation. By this method, gel scintillator waste is able to be distilled without overflowing easily and safely. From the results of distillation, radioactivity distribution was found to be as follows (Table I):

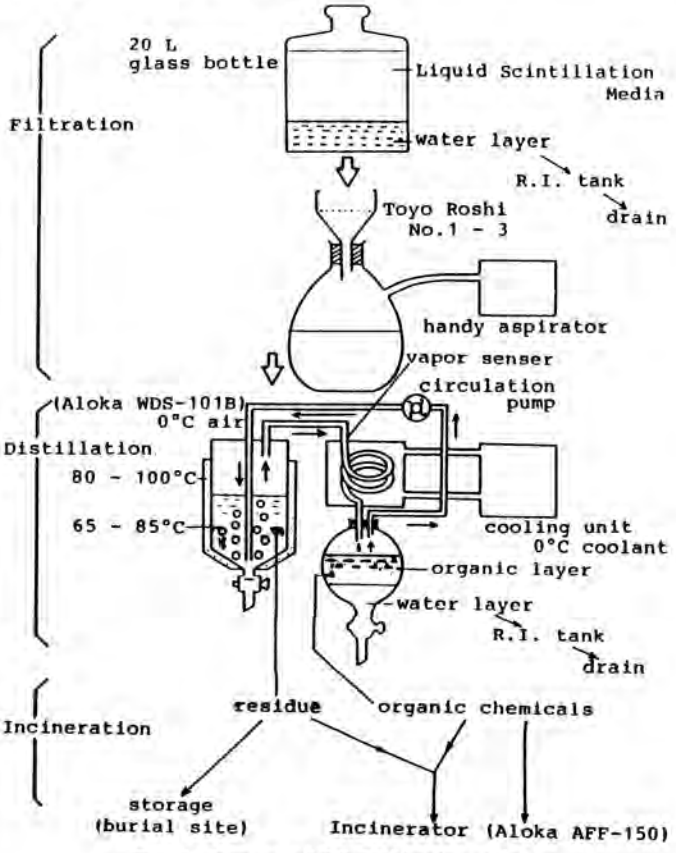


Fig. 2. System of OLSW incineration.

TABLE I
Radioactivity Distribution after Distillation

Portion	Distribution %
original	100
distilled organic layer	1
distillate water	10
residue	89

After bubbling vaporization, incineration for the organic layer was carried out due to low radioactive concentration. The main operation is as follows:

1. In order to obtain the distilled chemicals having a low radioactive concentration, early stage distillation is necessary. (After the long period storage, H-3 labeled compounds are easily self-decomposed to Tritiated water),
2. the lower the heating temperature, the lower the radioactivity of the distillate,
3. the higher the heating temperature, the shorter the required time for distillation.

Using this system, including continuous works for filtration, distillation and incineration, the disposal capacity of 8 hours per day will reach 10 liter/day. Owing to several automatic controls of this apparatus, the required working time for a single worker will be shortened by 1-2 hours per day. After radioactive decay, the residue will be burned with RIAW.

Incineration of OLSW

Incineration is carried out only for the organic distillate, not for the residue. The incinerator for the organic distillate is shown in Fig. 3.

The main performance of this incinerator is summarized below:

1. Burning capacity per hour: 1.63 liter/h.
2. Allowable environmental temperature: -10°C- +40°C.
3. Capacity of preheating and cleaning tank: 5 liter.
4. Capacity of OLSW distillate: 5 liter.
5. Off-Gas volume: $22 m^3/h$.
6. RI removal rate from hot off gas: >60%.

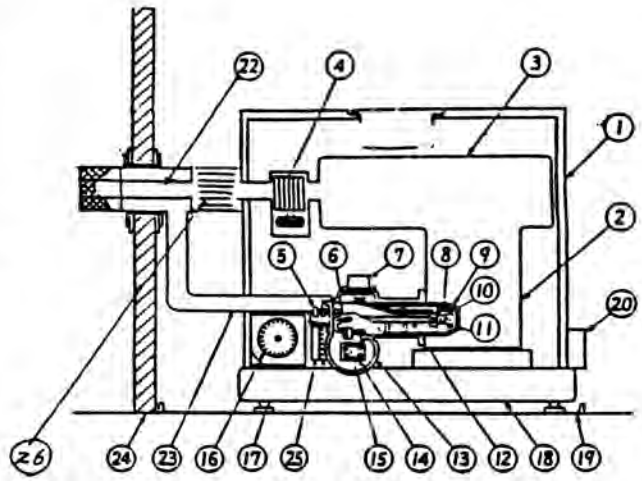
Corrosion of the nozzle was often found; the reason of this disturbance was caused by the corrosion of the garbage supply pipe and tank, therefore, all metallic materials used were stainless steel to avoid corrosion. Additionally automatic cleaning of the system was accomplished by the mixture of tungoil and N-butanol after each incineration run.

Electrostatic Precipitator (ESP)

Using a flat electrode, experiments were carried out on Tc-99m and P-32 air contamination at room temperature. The method is shown in Fig. 4.

1. Applied voltage: 6 Kv-9 Kv,
2. flow velocity: 1.1 m/sec-1.55 m/sec,
3. the maximum removal ratio at room temperature reached 80% in the case of 1.1 m/sec-1.55 m/sec at 9 Kv.

In the case of hot off-gas environment, using the stainless steel flat electrode, the removal ratio was lowered to 60% at the condition 1.1 m/sec, 8 Kv. A periodic cleaning cycle of 2 weeks had been initiated to remove ash from electrode.



1. out side pannel
2. combustion chamber
3. heat exchange
4. exhaust fan
5. holder of fire sensenser
6. fire senser set
7. ignition transformer
8. ignition plug
9. guide hole
10. stabilizer
11. nozzle
12. nozzle pipe
13. burner casing
14. oil filter
15. magnetic valve
16. circulate fan
17. balancing foot
18. steel dish
19. spacer
20. automatic stop for earthquake
21. off gas pipe
22. supply air pipe
23. room wall
24. air control damper
25. magnetic pump
26. ESP

Size : 952(H) x 1,200(L) x 823(W) mm

Fig. 3. Incinerator of OLSW.

INCINERATION SYSTEM FOR RIAW

RIAW tubes consist mainly of polyethylene or polypropyrene. These materials are easily combustible under high temperature conditions. The main problems of RIAW incineration are summarized below.

Development of Low E.C. Energy Survey Meter (S-1371)

The counting efficiency for I-125 is always very low with a traditional survey meter because of the low response for I-125, 35 Kev E.C. energy. A new survey meter called S-1371 was developed. Its main components are:

1. NaI(Tl) scintillator: diameter 25.4 mm, thickness 2 mm.
2. Window: Beryllium thin layer 200 μm.
3. Size: 303 (length) x 136 (width) x 97 (height) mm.
4. Weight: 2.7 Kg.

TABLE II
Comparing this S-1371 with other Survey Meters

Kind	Counting Efficiency (%)
GM survey meter	0.1
2 π gas flow	1.0
S-1371	24.0

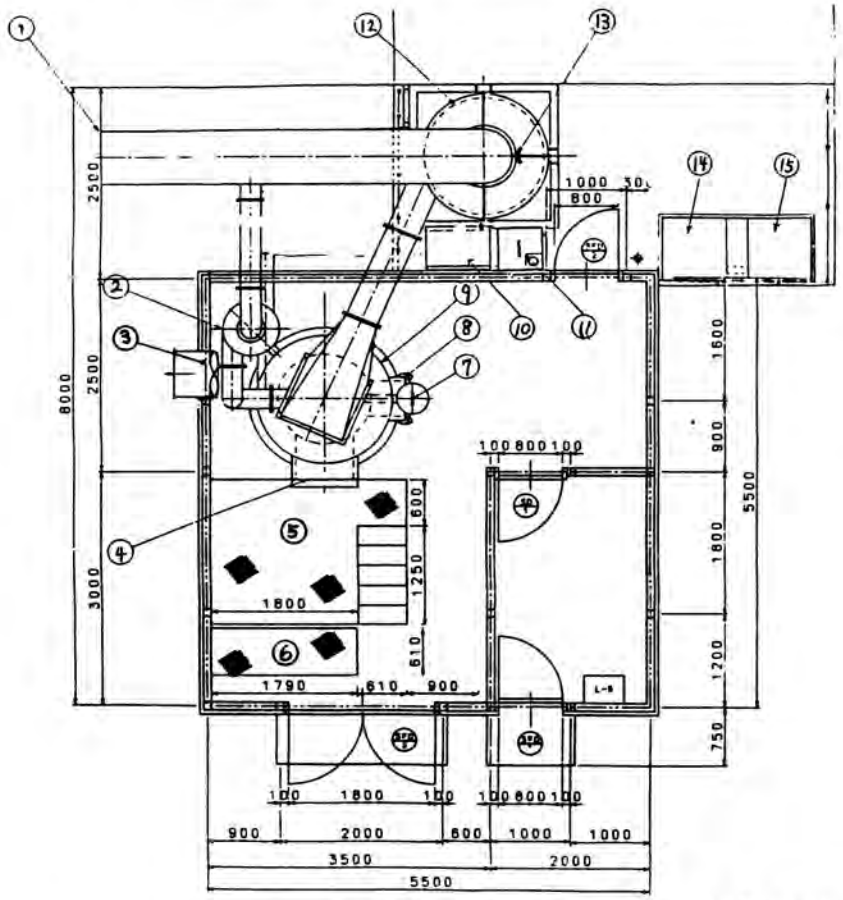


Fig. 4. A plane figure of the mixed incinerator AP-150.

Comparing this S-1371 with other survey meters in relation to the counting efficiency for I-125 is shown in Table II.

The minimum detectable level for I-125 is 3.7 Bq. The horizontal and vertical response ratio is 28/1.

Confirmation of Residual Radioactivity in RIAW Before Incineration

1. I-125 in RIAW

   Using the above mentioned S-1371 survey meter, surface cpm of about 150 bags were monitored and simulated experiments were done. As the results, the relationship between surface cpm and residual Bq were clearly found to be:

   12,000 cpm = 357.5 KBq

   From this relationship, residual I-125 was easily, correctly and quickly measured by the S-1371 before incineration.

2. H-3, C-14, P-32, S-35

   These nuclides are easily measured separately by a computer controlled Liquid and Well Scintillation Analyzer.

MIXED INCINERATION RIAW WITH OLSW

Incinerator (AP-150)

The incinerator is shown in Figs. 4, 5 and 6. Forced air supply into the furnace by a high pressure tubo fan provides sufficient surplus air and keeps the combustion gases in contact with air. Due to this method, this incinerator succeeds in completely preventing smoke. A comparison of the AP-150 and the F-II incinerators is in Table III.

A description of the AP-150 parts is as follows:

1. Water cooled jacket

   The furnace is fully covered with a water jacket.

Fig. 5. An outside view of AP-150; left: furnace; right: cyclone.

TABLE III
Comparison AP-150 (Final) with the F-II Incinerator

Chuwa Kiko	F-II (Trial)	AP-150 (Final)
Disposal capacity	60 kg/h	150 kg/h
Height	6,350 mm	10,300 mm
Inner furnace diameter mm	780 mm	1,150 mm
Inside Volume	0.6 m^3	2.50 m^3
Bottom Area	0.48 m^2	1.04 m^2
Weight	3,000 kg	13,860 kg
Electric Power	1.5 Kw	7.5 Kw
Wind Pressure	250 mmH_2O	600 mmH_2O
Off Gas volume	1,170 m^3/h	2,925 m^3/h

Fig. 6. Automatic sampling and measuring RI from off-gas.

2. Multi-nozzls are located at proper positions to ensure complete burning without smoke.
3. Cooling method by air supply:

   The air supply method which is very important for a smokeless system is protected by a water jacket system so that it is not destroyed.
4. Heated air vertical system:

   An air supply, heated through the hot water jacket into the furnace ensures a high degree of burning efficiency. There are special nozzles in the furnace lined up to make it as compact as possible.
5. RI removal from off-gas:

   A cyclone dust collector is also effective for I-125 removal from high temperature off-gas. Ducts and parts, except the furnace itself, are aluminized.
6. Automatic detection and stop firing for over 5 Gal earthquake.
7. Automatic sampling and measuring RI from off-gas.

Estimation of RI Concentration in Off-Gas Before Incineration

1. OLSW mixed combustion volume 15 kg/h. Off gas volume is $2.92 \times 10^9 cm^3$/150 kg/h. The degree of safety for off-gas RI limits is shown in Table IV.
2. RIAW combustion volume is 150 kg/h; 1 drum contains a 3,000 RIAW tube: weight = 10 kg/drum. Immediately after disposal, residual I-125 per 1 drum

   $357.5\ KBq = 3.575 \times 10^8\ Bq$

The estimation of the degree of safety for off-gases is in Table V.

During incineration, the measured value in off-gas was (6×10^{-6} Bq/cm^3). This data was the detectable limit of the analyzer for air concentration. The above result showed a good agreement with the Table IV.

AN EFFECT OF LLW INCINERATION UPON PUBLIC EXPOSURE

Annual Limit of I-125 Intake for Public Exposure

The I-125 off-gas concentration did not to exceed 6×10^{-6} Bq/cm^3. Considering the 1990 ICRP recommendation, the ALIs public exposure concerning thyroid burden were estimated as below:

$$\frac{ALIs \times (H_T\ (thyroid) \times W_T\ (thyroid))}{Intake\ Bq} =$$

Effective Dose Equivalent Limit

W_T : 0.03 −>−> 0.05 (1990*ICRP*)

As the result public ALIs was confirmed at 90 KBq/y.

Comparison of On Site Intake with I-125 ALI for the Public

On site disposal incineration, the scale of disposal are shown as follows:

1. incineration capacity: 150 Kg/h,
2. incineration time: <8hrs/day,
3. incineration period: 15 days/year.

Estimation of public on site I-125 exposure were carried out with the following condition,

TABLE IV
Safety Degree for Off-Gas RI Limit (16 Mar. 1992)

Drum No.	H-3	P-32	S-35	Total
R-1	0.711	0.0240	2.8×10^{-10}	0.7351
R-2	0.1062	0.0103	1.2×10^{-11}	0.1165
R-3	0.1300	0.0036	1.8×10^{-9}	0.1336
R-4	0.0057	0.0100	3.1×10^{-12}	0.0157
R-5	0.0423	0.0412	3.4×10^{-12}	0.0835

TABLE V
Estimation of Safety Degree for Off Gas Limit after Storage-for-Decay (* Bq/cm^3)

Elapse Days	Residual I-125 in 15 Drums	Concentration in Off-Gas*	Safety Degree for Off-Gas Limit
0	5.3625 MBq	1.33×10^{-3}	91.51
480	81.83 Bq	2.8×10^{-5}	0.3569
730	0.255 Bq	3.98×10^{-7}	0.0199

1. Person inhalation volume per day: 2×10^7 cm^3/day,
2. inhalation I-125 air concentration: 6×10^{-6} Bq/cm^3.

As the result public exposure was under 2% for ALIs.

RESULTS

The special properties of this LLW incineration system have important advantages shown as follows:

1. From the view point of public radiation exposure, the on site disposal is more suitable than a central waste management and also transportation problems are reduced,
2. the medical field LLW mostly contain short-lived nuclides; therefore, after 2 years of decay, incineration could be done easily, correctly and safely.
3. the most difficult point of LLW incineration is how to remove RI from the hot off-gas. This system has many important advantages as follows:
   a. no cloggin of the filter by ash dust---cyclone, ESP,
   b. no secondary waste production after use---cyclone ESP, and no filter.
   c. cyclone and ESP have durability for hot off-gas and humidity,
   d. durable furnace for hot temperature incineration---water cooled furnace,
   e. few maintenance and operations costs.

Reduction in the Costs

1. Reduction in the working personnel expenses,
2. reduction in the payment for the outside vendors,

RIAW 1,500 drums/3 years→4,500,000 RIAW tubes →13,500 kg; ¥48,000,000 = $384,000

Relief of Hard Tasks

The difficult task of waste disposal work became easier and safer due to the following reasons:

1. storage-for-decay.
2. complete combustion.
3. automatic control burning and RI measurement.
4. safety device for the accident.
5. reduced maintenance.

Durable Furnace for Hot Temperatures

Water cooled furnace achieved good durability for 1,200°C temperatures, especially for plastics burning.

Radiation Safety of the Waste Management

This incineration system will make the radiation risk for the medical field LLW disposal decrease by 20%.

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NOMENCLATURE

LLW: Low level Radioactive waste
OLSW: Organic Liquid scintillator waste
RIAW: Radioiimmunoassay Tube Waste

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