A new fluorescence detection method with plastic scintillators using a conventional low back LSC -Organic waste less method

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Introduction: Pure beta emitters like ^{3}H, ^{14}C, ^{35}S and so on have been used for a long time to study metabolism. These radionuclides have been measured with a liquid scintillator using an liquid scintillation counter (LSC). An LSC is a superior device with high counting efficiency for low beta energies; however, organic liquid wastes are generated after measurement because the sample is dissolved in a liquid scintillator. We developed a new fluorescence detection method with plastic scintillators (PS), which are alternative materials of liquid scintillators, using a low back LSC-LB7 (Hitachi, Ltd., Japan).

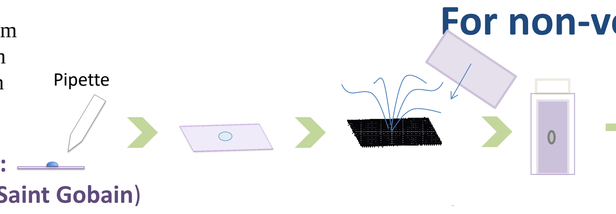
PS-sheets method

For non-volatile compounds

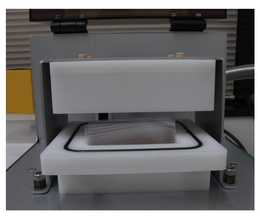
PS-sheet
L=45-50 mm
W= 13 mm
T= 0.5 mm
for 20 mL vial

Pipette

PS-sheet:
BC-400 (Saint Gobain)

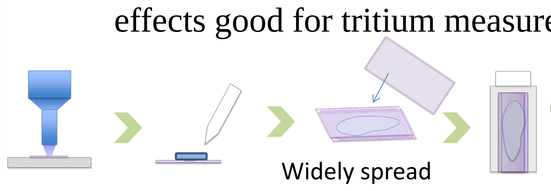


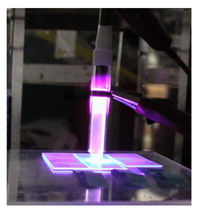
A sample solution was applied to a PS sheet, then the sample was dried on the PS sheet. After the sample was dried, another PS sheet was covered onto the sample, and then the assemblage was put in a 20mL glass vial and measured using an LSC.



Commercial Plasma treatment device: IP-220P (Izumikougyou co. Ltd.)

Plasma treatment of the surface for hydrophilicity effects good for tritium measurement.





DBD plasma with Ar gas

PS-sheet
L=~70 mm
W=~20 mm
T= 0.5 mm
for 100 mL vial
Utmost, 64 PS-sheets are available to put in a vial.

Because the limit of sample solution applied to the PS-sheet was small like utmost 50 μL for a 20 mL vial, a wide mouth Teflon vial was useful to increase the sample.
A large size PS-sheet is available to put 1 mL sample solution even when the sheet was treated with the plasma.

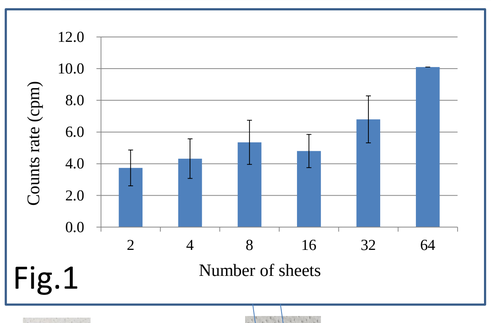
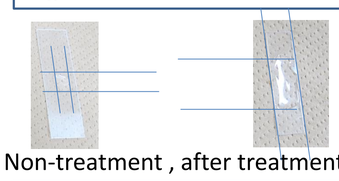


Fig.1

The background (BG) of the PS-sheets depending on the number of the sheets is shown in Fig.1.
The BG of 32 and 64 sheets were higher compared with those of 2 to 16 sheets, because static electricity occurred between the plural sheets, for a while.



Non-treatment , after treatment: 100 μL ^{3}H-methionine

After the plasma treatment, the surface area widened more than 4 times. This method is useful for tritium measurement because of its short range.

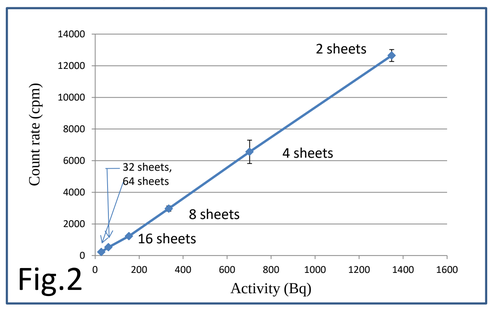


Fig.2

Fig.2 shows the relationship between the count rate and the total activity. 500 μL sample was put on each PS-sheet. Both of the 2 PS-sheets (1 assemblage) for different activities and/or 2 to 64 PS-sheets (1-32 assemblages) with same activity showed good linearity like Fig.2. It means the PS-sheets method is suitable for quantitative analysis.

Fig.3 shows the detection limit calculated by the below equations.

$$n_D = \frac{k^2}{2}\left[\frac{1}{t_S} + \sqrt{\frac{1}{{t_S}^2} + \frac{4n_B}{k^2}\left(\frac{1}{t_S} + \frac{1}{t_B}\right)}\right], \quad A_D = \frac{n_D}{\alpha \cdot \epsilon}, \quad k=2$$

8mL sample were detectable **0.3 Bq/L** with 1 d measurement.
When 1 mL sample puts on each sheet, the detction limit will be **0.15 Bq/L**.

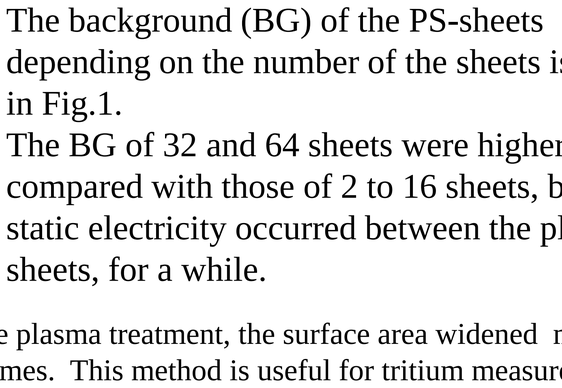


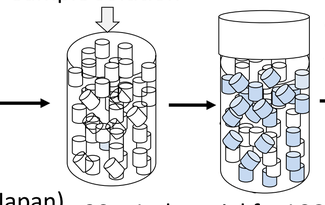
Fig.3

LSC-LB7

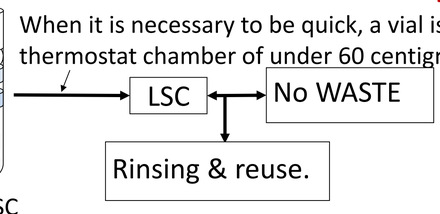
PS-pellets method

For volatile compounds

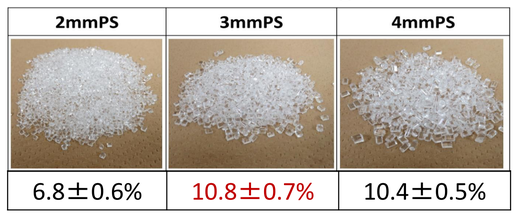
PS-pellets:EJ-200 (G-tech, Japan)
3 mm both in diameter and length



When it is necessary to be quick, a vial is put in a thermostat chamber of under 60 centigrade.



For large scale { to get high counting efficiency
to use a radiation & nuclear monitoring post



Small size PS-pellets showed low counting efficiency (cpm/dpm × 100), and middle and large PS-pellets showed higher counting efficiency. The middle size was commercial one, so the middle size was used ever afterward.

Table 1 Counting efficiency (%) of tritiated water in a large vial using LSC-LB7

HTO volume	Counting efficiency (%) of a liquid scintillator	Counting efficiency (%) of the PS-pellets filled full in a vial: Polyethylene vial 145 mL	Teflon vial 100 mL: a normal cap	Teflon vial 100 mL in a bag: a normal cap	Teflon vial 100 mL in a bag: a special cap
5 μL		38.92 ± 3.53		44.89 ±0.82	69.00 ±3.34
25 μL		36.25 ± 0.27		44.37± 0.32	62.48 ±0.76
50 μL		35.78 ± 0.13	46.42 ± 0.90	43.80 ±0.42	38.91 ±0.51
100 μL	44.67 ± 0.11	32.09 ± 0.37		37.11 ± 0.28	32.35 ± 0.55
500 μL		7.43 ± 0.11		20.28± 0.43	10.08± 0.24
1 mL	38.94±0.18	6.54± 0.090	5.79± 0.020	11.08± 0.12	5.88± 0.082
3 mL	38.75±0.17	2.55 ± 0.020	2.34± 0.083	3.74± 0.044	1.87 ± 0.031
5 mL	37.54±0.13	1.62 ± 0.030		1.26 ± 0.020	1.71 ± 0.027
7 mL		1.18 ± 0.019		0.96 ± 0.0056	1.66± 0.010
10 mL		0.80 ± 0.025		0.64 ± 0.011	0.64 ± 0.0061
Full*	-	0.14±0.0035	0.18±0.0047	-	-
ave. pellets weight (g)		96.9	117	72.5	

*full: 52 mL in a polyethlylene vial and 46 mL in a Teflon vial.

Table 1 shows counting efficiency depending on sample volume, liquid scintillator/ PS-pellets, and vials, which contained different amount of pellets.
When the sample volume was extremely small, the counting efficiency was higher compared with that of liquid scintillator. Additionally, the PS-pellets method showed very low counting efficiency when the vial was filled full with the sample solution.

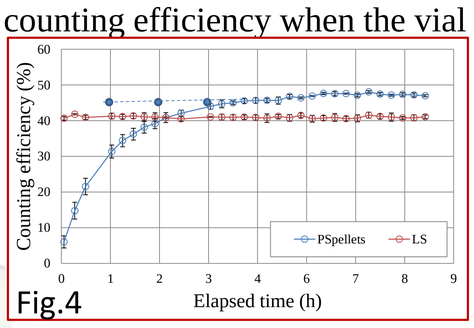


Fig.4

Fig.4 shows the relationship between the elapsed time and counting efficiency (%) of 5 μL tritiated water. When a thermostat chamber (HB-80, TAITEC) was used to heat the vial for 45 min, the counting efficiency was stable from the first time ( ). These data were in the case of using 20mL glass vial.

Fig.5 shows the relationship between the count rate and the activity in the case of 1 mL sample solution in each vial. The inclination of the linearity was different with amounts of sample, so the same condition is necessary.

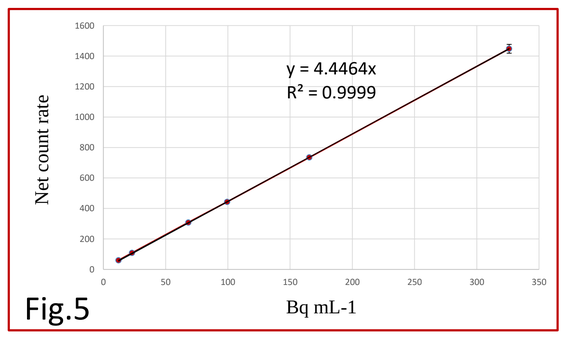


Fig.5

The detection limit with a 100 mL Teflon vial was **35.3 Bq/L** when the HTO and BG were measured 1 d. It is enough to measure regulation limit; however, it is still not used for environmental radioactivity check, directly.

Summary: A plastic scintillator (PS) is useful to measure low energy beta-emitters.

For metabolism study, a sheet type PS was available for non-volatile compounds and a pellet type PS was available for volatile compounds.
[For examples, non-volatile compounds are methionine and arginine, and volatile compounds are tritiated water and acetic acid sodium salt.]

With a low background liquid scintillation counter of LSC-LB7, a 100 mL Teflon vial with a wide mouth was able to use multiple sheets; maximum 64 sheets (in the case of 70 mm in height and 20 mm in width), and able to make 2 sockets for connection with a vacuum pump to reduce inner pressure and to get higher counting efficiency.

Unfortunately, use of PS-pellets and more than 32 sheets have an issue to generate static electricity; however, it is avoidable by preparing the vial in advance.

The PS sheets and pellets are reusable and no organic wastes are generated after measurement.