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SHORT COMMUNICATION

Dental & Craniofacial Research

# Development of liquid flexible radiation detectors

**Kiyoshi Nomura***

Radioisotopes Center, Tokyo Metropolitan University, Japan

The accident of TEPCO's Fukushima Daiichi Nuclear Power Plant, resulting from the Great East Japan Earthquake (11th, March, 2011), brought radioactive contamination widely to soils, forests, roofs of houses and so on. It was difficult to identify contaminated spots in narrow spaces such as side grooves, drainage grooves and drain pipes, using conventional radiation counters. In case of emergencies such as nuclear accidents and disasters, new measurement equipment is required, capable of handling wide-area radioactive contamination and non-uniform radiation fields [1].

There was not so much idea to make the detector itself flexible except for position detector using plastic scintillation fibers (PSF) [2]. The PSF detector connects two photomultiplier tubes (PMT) to both ends of the PSF, and specifies the position of the radiation according to the time difference or the emission amount ratio of the arriving light. The flexible PSF itself is bundled with fine fibers [3]. Liquid light guide (LLG) can enlarge easily scale of the tube. The position detector due to Cherenkov light of LLG was studied mainly for neutron measurement [4]. The light transmission loss was hardly observed even when irradiating $^{60}$Co γ rays of $1.5\times10^4$ Gy to liquid scintillation light guide [5], whereas the light loss rate of the PSF was over 90% at $2.5\times10^3$ Gy [4] .

On the other hand, a liquid scintillation system for measuring β particle emitting nuclides is popular as a dedicated apparatus for β particle measurement. The coincidence counting system with two PMTs is used to reduce the influence of external radiation background. A liquid scintillation is considered to be sensitive to the external radiation, but liquid flexible detectors have not been enough developed for γ ray radiation.

We have developed a flexible radiation detector using a liquid scintillation light guide (LSLG) and a single PMT. We found a linear relationship between irradiation positions and count ratios of two divided regions in pulse height analyzed spectra because of light attenuation depending on distance of irradiation point from PMT head and further clarified that the integral count rates are proportional to those of a conventional NaI scintillation counter [6].

A detector with many allied flexible tubes or with a small mat could be realized easily. The flexible detector enables us to measure body surface of human being, living and wild animals. A vest-type flexible surface detector would be able to estimate the state of internal contamination by a coincidence technique between front and back counters while wearing it (called a wearable detector). The burden on human beings would be smaller than a conventional whole body counter. In addition, when working at uneven high dose places, a more secure feeling should be obtained compared to a small personal dose meter. The characteristics and applications of a flexible liquid detector are shown in Table 1.

***Table 1.*** *Characteristics and applications of liquid scintillation light guide (LSLG)*

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|---|
| Fluorescence lifetime (several nano-seconds) → Absorbed dose rate meter with a wide range |
| Detection of irradiation position by analysis of energy spectrum. → Position sensitive detector. |
| A flexible LSLG matched for the object to be measured. → Easy measurement of radioactivity |
| Identification of nuclides is hard. (disadvantage) → Hybrid detector and phoswitch scintillation detector. |
| A flexible surface detector with aligned tubes or a small mat. → Wearable detector |

Since emission lifetime of liquid scintillator is several nanoseconds, a LSLG detector can cope with a high counting rate and a wide dynamic range. The scintillator concentration of the core liquid and the scale of the tube can be easily adjusted according to the intended usage. A liquid scintillator is unsuitable for nuclide analysis, but its drawback would be compensated as follows; a hybrid detector or a sandwich type phoswitch detector would be easily realized by equipping a solid scintillator such as CsI crystal to the tip of fibers because solid and liquid scintillators have different characteristics (lifetime and wavelength of light emission), of which each signal could be separated.

A liquid detector that is equivalent to human tissue (including ca. 65% water) could directly measure body-equivalent absorbed dose for evaluating radiation effects although almost all solid state detectors are necessary to calibrate because of large dependency on radiation energy.

In particular, in order to evaluate influence of radiation irradiation for diagnosis and therapy in medical institutions, medical applications of flexible detectors would be greatly expected although the further study is necessary.

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***Correspondence:*** Kiyoshi Nomura, Radioisotopes Center, Tokyo Metropolitan University, Minami-Osawa 1-1, Hachioji, Tokyo, 192-0364, Japan, E-mail: k-nomura@t-adm.t.u-tokyo.ac.jp



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