Use of ubiquitous materials for the estimation of accidental exposures

Incidents involving unexpected radiation exposure do take place due to human error, equipment failure or other reasons in spite of regulatory systems being in place. Medical physicists who are also radiation safety officers (RSO) of their institutions in several countries, like India, have the responsibility of radiation protection of the staff, carers and comforters of the patients, visitors and public at large, apart from ensuring patient-specific treatment planning for accurate dose delivery, adoption of optimized practices, and minimization of chances of radiation accidents in radiation therapy, radio-diagnostic, and nuclear medicine practices. Theft and mishandling of ^{137}Cs teletherapy source in 1987 in Goiania (Brazil) in which 28 people suffered radiation burns and five people (three men, one woman, and one child) died[1,2] and several other incidents demonstrated that mishandling of a source from a place like hospital cannot be ruled out. In the recent times, especially after terrorist attack on World Trade Center, New York, USA (on September 11, 2001), apprehensions of radiation terrorism and other malevolent uses (Dirty Bomb) of radioactive materials[1] have considerably increased all over the world. To meet the situation of any radiation accident (due to external sources or the hospital-based sources), preparedness for dosimetry of the exposed persons in the quickest possible way becomes important for the implementation of the necessary follow-up procedures.

Experiences gained from the overexposures of radiation workers covered by personnel monitoring services have made it clear that in the cases of suspected excessive exposures, the first doubt always arises whether the personal dosimeter indicating the actual exposure incurred by the person or the badge alone got exposed due to any oversight or some other intentional or unintentional reasons. It is, therefore, well recognized that in the cases of overexposures, the need of corroborative measurement by using human body-based dosimeter always exists for arriving at the decisions necessary for the follow-up procedures. This need becomes much more acute in radiation accidents where no official dosimeter (personal dosimeter) is available with the exposed persons.

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Biological dosimetry (mostly cytogenetic techniques) of scoring dicenteric of chromosome aberrations (dicentrics and rings) in metaphases prepared from human lymphocytes from blood samples has been the most preferred technique because the presence of no other dosimeter can be as reliable as the human body itself. Unfortunately, the cytogenetic dosimetric techniques have been found to be impracticable as they exhibit high uncertainty in the estimation of doses below 0.1 Gy (the lower detectable limits), need specialized laboratories and time consuming processing and evaluation procedures, and hence unsuitable for large number of measurements.[3] In the earlier days (about two decade ago in India), when the film badge personnel monitoring service (using film as dosimeter) used to be in vogue, some information on the type of the exposure was possible in a few cases from the density pattern under different filters of the badge constituents (metal filter edges) which was helpful to some extent in deciding the genuineness of the exposure. But this merit of the film badge could not help its survival and replacement in personnel monitoring services by thermoluminescence dosimeter (TLD) personnel monitoring badge service and more recently by optically stimulated luminescence (OSL) dosimeters became inevitable the world over. The superiorities of TLD and OSL, namely capability of measurements lower doses, accuracy and precision, coverage of wide dose range, and the reliability of the dose information in adverse climatic conditions, have far outweighed the availability of film as a record for reverification of dose measurement and the image pattern of the film badge.

Electron spin resonance/electron paramagnetic resonance spectroscopy (ESR/EPR) signals from biological objects (especially tooth enamel) of the exposed persons have been widely explored for the corroborative measurement of doses and for situations in which no official dosimeter is available on the person. The physical dosimetry using ESR of ubiquitous materials had a limited success because it suffered from the limitations of poor sensitivity and the need of very costly and sophisticated equipment with highly trained and expert operators. In addition, ESR is an invasive technique and needs corrections for previous exposures (dental and medical exposures), especially for the use of tooth enamels which exhibited reasonable ESR signals.[3] Efforts have been constantly on for exploring possibilities of measuring accident doses by using ubiquitous materials as dosimeters and a noticeable progress has been made in the use of thermoluminescence (TL) and optically stimulated luminescence (OSL) in the commonly available materials. TL and OSL processes are fairly simpler and the reader systems (which are very easy to operate and provide straight forward linear relationship of the signal with the dose due to exposure to ionizing radiation) are generally available in most dosimetry laboratories and cancer hospitals due to their wider use in dosimetry. Household and environmental materials, such as bricks, tiles, pottery, salt, sugar, etc.,[4-6] have been tested and used to a significant extent. Recently, OSL of electronic components of personal gadgets and devices (as personal objects) have been found to have high potential in accident dosimetry.[7-14] The superiority of OSL over TL is not limited to the generic properties of OSL (namely optical stimulation requiring no heating to higher temperature to alter properties, possibility of use of low melting point materials in view of all optical nature of readout, enabling repeated readout, etc.) but the OSL in several materials has also been found to exhibit much lower nonradiation-induced signal than TL[9] in addition to much higher sensitivity.[10]

For accident dosimetry, much attention is being paid to the personal electronic equipment such as mobile phones, i-pods, mp3 players, USB drives, and chip cards (ID cards, SIM cards, credit/ATM cards, etc.).[9-14] Such devices are usually worn or carried by individuals close to their body and can be regarded as good as a set of personal dosimeters and the presence of these on the body of person could be taken for granted for all including the members of the general public. It is noted that the material responsible for OSL and TL signals are the ceramic materials (namely Al_2O_3, BeO, SiO_2, etc.) which are used as substrates in the electronic components. In chip cards, it is SiO_2 powder grains which are added for controlling thixotropic properties of the epoxy which is needed for holding the memory chip modules in the cards. These ceramic-based components are usually resistors, capacitors, resonators, antenna switches, and transistors in electronic gadgets/devices. Although, the ceramic materials had been known to exhibit thermoluminesce (TL) since a long time, the applicability has been enhanced by the exciting developments of OSL, in which the information on the amount of energy deposited by ionizing radiation (directly related to absorbed dose) could be obtained by just shining (stimulating) with light from an appropriate laser beam or LEDs and holding them under an appropriate light detector such that the stimulation light does not reach the detector and only the light emitted due to the stimulation of the exposed material is recorded. Successful experiments of accident dosimetry have been performed[7,10,11] by simulating the exposures of appropriate phantoms with attached devices/dosimeters and by using appropriate single aliquot regenerative-dose protocol (accuracy within 10 %) for the evaluation of doses. In these experiments, one of the major factors to limit the accuracy has been attributed to anomalous fading of OSL and TL signals often exhibited by these materials (much lower for TL than OSL). However, one of the attractive features of the OSL dosimetry using electronic components is that the dose information is not affected by the normal use requiring flow of current during the irradiation and prior or after the irradiation.[15,16] It may be noted that there has been great success in online dosimetry measurements by using the optical-fiber OSL system for real-time measurements, as the readout process is completely optical for transporting both the stimulating light and the emitted OSL signal by means of a long optical fiber. If such a system becomes sensitive enough, one could expect many more useful applications. For the immediate future, it is evident that a single electronic device (e.g., mobile phone) could provide several dosimeters within it (resistors, capacitors, resonators, etc.) and this could be used in getting detailed dose information of the accident. Doses could also be measured using chip cards used in health insurance, ID, cash cards, credit cards, etc.[12,13] by taking read out on commercial reader systems if the system is pre-calibrated with established protocols.

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