EPR studies performed in TAEA- SANAEM and two more approaches on nail dosimetry: An EPR study

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The missions of Turkish Atomic Enery Authority and its center called Sarayköy Nuclear Research and Training center (SANAEM) and the accreditation scope of SANAEM (Table 1) will be presented. Electron Paramagnetic Resonance (EPR) studies of Dosimetry laboratory in Technology Department cover Retrospective Dosimetry, Detection of Irradiated Foods, Biodosimetry and Dating. To fulfill the accreditation requirements of TS EN ISO/IEC 17025 standard, this laboratory have performed intercomparion studies on dosimetry and detection of irradiated foodstuffs. In this presentation, EPR studies on fingernail dosimetry as biodosimetry for emergency will also be discussed in detail. These studies have been performed for a long time in means of rapid and accurate retrospective dosimetry. The most important outcome of these studies is the identification of a stable radiation induced signal (RIS5) component in nails by IRSN, France. Here, we present the result of two approaches on nail dosimetry; one based on the described protocol by Trompier et al. 2014 and the other used classical added dose method.

The nail samples were collected from same donor cutting after 3 weeks, divided into two groups; one was for non-exposed and the other was exposed to an accident dose as 15 Gy checked by alanin dosimeter, cut into small parts, humidified in distilled water about 10 min. and dried on the towel in air about 1 day (in the dark). To control humidity, the samples were weighted (~ 24 mg) before and after each measurement. In the first protocol; when adding new dose, the process of humidification and drying were repeated before each set of measurements. In the second one; these process were performed only before the first measurement to avoid mechanical induced signals (MIS). The samples were irradiated with ^{137}Cs gamma rays (0.5 kGy/h). EPR measurements were carried out using a Bruker e-scan X-band EPR spectrometer. A microwave power of 1 mW was adjusted during the experiment according to MW studies of background, MIS and RIS signals (not presented). The samples irradiated up to dose of 30 Gy and 168 Gy was used to construct the added dose-response curves in steps of 5 and 10 Gy. The reported intensities of RIS5 and center field signal (near g=2.004) were derived from peak-to-peak distance of the ESR signal. In the first protocol, the dose saturation for the non-exposed sample was reached after having added dose 15 Gy, whereas for exposed, the signal intensity decreased already for the first post-irradiation (Figure 1). It seems that the nails have used have a dose saturation point about 15 Gy. That's why the signal of sample given accident dose was decreased when adding dose, because of the initial dose of 15 Gy, after it reaches a level for which even with added new dose, the intensity did not change any more. On the other hand, in the second protocol, the ESR signal intensity increases with increasing added dose. The experimentally measured ESR signal intensity values (y) were fitted well by polynomial function ($y=aD^2+bD+c$; -0.003±0.0004, 1.15± 0.07 and 29.29±2.54 ,r^2=0.9922). The extrapolated dose was calculated to be 15.84 Gy (Figure 2).

Consequently, a new approach in nail dosimetry using the RIS5 component and classical approach using center field RIS signal have been found to be successful methods for the evaluation of dose to fingernails exposed high-

doses . Further studies should be planned to test them for lower accident dose on more samples from different individual.

Keywords: TAEA SANAEM , EPR , nails, biodosimetry, added dose response.

Introduction

The missions of Turkish Atomic Energy Authority (TAEA) are to determine the basis of the national policy and the related plans and programmes in connection with the peaceful utilization of atomic energy for the benefit of the State and to submit them to the Prime Minister for approval; to do all kinds of research, development, studies and activities and have them done for the use of atomic energy is the State's scientific, technical and economic development and to coordinate and support such activities in this field. Sarayköy Nuclear Research and Training Center (SANAEM) was founded in 2005 by reconstitution of the Ankara Nuclear Research & Training Center and the Ankara Nuclear Agriculture & Animal Health Research Center. SANAEM was assigned as a Designated Institute for the field of ionizing radiation in 2007. The missions of SANAEM are to carry out Research&Development and implementation by using nuclear techniques and to perform radiologic and non-radiologic measurements of all kinds of samples and to contribute to the routine services provided by TAEA for radiation safety of public and environment and to carry out training programs needed on nuclear techniques and technology in Turkey. The objectives of SANAEM are to improve the infrastructure for SANAEM to become and internationally recognized research center in measurement and analysis and to be a reference laboratory in radioactivity measurements and to prepare and supply standard reference material to other laboratories in Turkey.There are 14 different tests in acrreditation scope of SANAEM (Table 1). One of them is "The Detection of Irradiated Foods Containing Cellulose By ESR Spectroscopy" as TS EN 1787:2005 standard carrying in Dosimetry laboratory of Technology Department. Electron Paramagnetic Resonance (EPR) studies of this laboratory cover Retrospective Dosimetry, Detection of Irradiated Foods, Biodosimetry and Dating. To fulfill the accreditation requirements of TS EN ISO/IEC 17025 standard, this laboratory have performed intercomparion studies on dosimetry and detection of irradiated foodstuffs. As an accident dosimetry, sea sands, window glasses, watch glasses, eggs, egg shells, hair, shrimp shells, sugars..etc have been analyzed in this laboratory so far.

Biodosimetry has the potential to provide the information needed from individuals to respond to unplanned exposures to ionizing radiation in a way that enables the medical response system to function effectively. There are two different but potentially complementary types of biodosimetry: those based on an individual's biological responses or on physical phenomena. Because of the different nature of these types of biodosimetry, they have different strengths and limitations that, if considered carefully, lead to their appropriate use in specified circumstances. While the biologically based parameters have limitations because of inherent differences in the response to damage in individuals; prior or concurrent pathophysiologically-based processes; and changes over time in an individual's response to radiation after the exposure, The physically-based parameters have strenght due to be perturbed less likely by these factors that they measure only the dose at the body location measured. As physical based biodosimetry in ESR technique, the signal intensity is directly proportional to the amount of free radical generated by ionizing radiation. The dose absorbed by biologic tissue used as for dosimetry is determined with the help of ESR spectra recorded before and after irradiation. In case of radiation accident, the ESR signal intensity is a measure of the amount of dose absorbed by sample. The tissue as a biologic dosimeter can be get

easily, painless and without transaction from individuals, the damage which is proportional to dose should be spesific of radiation, the dose measurement should be easy, fast and the results should be possible in a short time.

Within the scope of this study, the nail samples were analyzed ex vivo by ESR technique and they have been tested as a biodosimetric system for emergency. To achieve this goal the defined steps; the ESR signal characterization, the sample treatment, sample deconvolution, the factors affecting RIS signal, provide this method to be used easily by also non-expert person. Therefore in the name of our country, the biodosimetry using nail samples has been discussed to resort it in the case of unplanned radiation exposure. The nail dosimetry studies have been performed for a long time in means of rapid and accurate retrospective dosimetry. The most important outcome of these studies is the identification of a stable radiation induced signal (RIS5) component in nails by IRSN, France. Here, we present the result of two approaches on nail dosimetry; one based on the described protocol by Trompier et al. 2014 and the other used classical added dose method.

Material and method

The nail samples were collected from same donor cutting after 3 weeks, divided into two groups; one was for non-exposed and the other was exposed to an accident dose as 15 Gy checked by alanin dosimeter, cut into small parts, humidified in distilled water about 10 min. and dried on the towel in air about 1 day (in the dark). To control humidity, the samples were weighted (~ 24 mg) before and after each measurement. In the first protocol; when adding new dose, the process of humidification and drying were repeated before each set of measurements. In the second one; these process were performed only before the first measurement to avoid mechanical induced signals (MIS). The samples were irradiated with ^{137}Cs gamma rays (0.5 kGy/h). EPR measurements were carried out using a Bruker e-scan X-band EPR spectrometer. A microwave power of 1 mW was adjusted during the experiment according to MW studies of background, MIS and RIS signals (not presented). The samples irradiated up to dose of 30 Gy and 168 Gy was used to construct the added dose-response curves in steps of 5 and 10 Gy. The reported intensities of RIS5 and center field signal (near g=2.004) were derived from peak-to-peak distance of the ESR signal.

Results

Evolution of the RIS5 intensity regarding multiple irradiation doses for two samples: the first sample was not irradiated (simulation of a non-exposed sample; ■), while the second sample was irradiated at 15 Gy before the cycle of post-irradiation started (simulation of an accidental exposure of 15 Gy; ●) was given in Figure 1. It seems that the nails have used have a dose saturation point about 15 Gy. Unirradiated (■) and irradiated (●) samples of added dose response curves were seen in Figure 2. The experimentally measured ESR signal intensity values (y) were fitted well by polynomial function ($y=aD^2+bD+c$; -0.003±0.0004, 1.15± 0.07 and 29.29±2.54, $r^2=0.9922$). The extrapolated dose was calculated to be 15.84 Gy.

Discussion

Electron paramagnetic resonance (EPR) spectroscopy is a versatile and key tool for dose assessment after a severe radiological accident using biological materials collected from victims (bones and tooth enamel) or other materials

irradiated during the accident (sugars, glass from personal items, etc.). Human nails were already considered several decades ago for radiation accident dosimetry (Dalgarno and McClymont 1989; Symons et al. 1995) and for triage in case of large scale events (2007). Nails are easy to collect and can possibly give an estimation of the dose distribution when nails from each finger or toe can be analyzed separately. More recently, large efforts have been made to understand the free radicals mechanism in nails and establish EPR nail dosimetry with different approaches (Romanyukha et al. 2007, 2010; Reyes et al. 2008, 2009, 2012; Trompier et al. 2007, 2009; Black and Swarts 2010; Wilcox et al. 2010; He et al. 2011). Different EPR signals (RIS, MIS and intrinsic) identified in nails are reported in the paper of Trompier et al. 2014. The major finding was the identification of a stable RIS, labeled RIS5. A more detailed investigation of this EPR signal is presented in that study. This new finding has made possible to foresee a practical application of human nail dosimetry. Based on the that work, a new protocol of EPR nail dosimetry is proposed. This protocol is designed to identify and estimate a high dose of ionizing radiation to fingers, which is currently the common case of localized irradiation to hands. The protocol has been applied by IRSN for the analysis of nail samples collected from different victims of four radiological accidents that occurred between 2008 and 2012 (Trompier et al. 2013; Romanyukha et al. 2013). In the latest case (Chilca accident), nail dosimetry could be performed in the early management phase which allowed identification of those fingers with the highest dose before the appearance of any clinical signs (IAEA 2012). The data have been decisive in the management of the victims and open the possibility to use human nail EPR dosimetry in radiological accidents, to assist casualties before they become symptomatic. Recent comparison with doses estimated by means of EPR bone dosimetry has also shown the reliability of this newly developed approach (Trompier et al. 2013).

All the components of the MIS and RIS, except one (the RIS5), can be eliminated by humidification of the nails. Due to its stability, the only component that can be used for dosimetric application is the RIS5. Due to its weak intensity and its similarity to the BKG, a dedicated protocol remains to be established. For high-dose application, which is of major interest regarding the number of accident cases with localized severe irradiations to the hands, a new approach in dosimetry using the RIS5 component has been developed and applied. This approach is based on the saturation behavior of the RIS5.

In the present study, in the first protocol, the dose saturation for the non-exposed sample was reached after having added dose 15 Gy, whereas for exposed, the signal intensity decreased already for the first post-irradiation (Figure 1). It seems that the nails have used have a dose saturation point about 15 Gy. That's why the signal of sample given accident dose was decreased when adding dose, because of the initial dose of 15 Gy, after it reaches a level for which even with added new dose, the intensity did not change any more. On the other hand, in the second protocol, the ESR signal intensity increases with increasing added dose. The experimentally measured ESR signal intensity values (y) were fitted well by polynomial function ($y=aD^2+bD+c$; -0.003±0.0004, 1.15± 0.07 and 29.29±2.54 ,r^2=0.9922). The extrapolated dose was calculated to be 15.84 Gy (Figure 2).

Consequently, in this study, a new approach in nail dosimetry using the RIS5 component and classical approach using center field RIS signal have been found to be successful methods for the evaluation of dose to fingernails exposed high-doses . Further studies should be planned to test them for lower accident dose on more samples from different individual.

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Table 1. Accreditation scope of SANAEM

	Tested Materials / Products	**Name of Test**	**Testing Method (National, International standards, in house methods**
1	Drinking Water	Tritium Analysis	ASTM D 4107-2008
2	Drinking Water	Gross Alpha/Beta Radioactivity	EPA 900.0:1980
3	Food	Radioactivity Analysis of Cs-137 and Cs-134 In Foodstuff with Gamma Spectrometric Method	ASTM E-181:2003
4	Soil and Construction Materials	Radioactivity Analysis of Ra-226, Th-232, K-40 and Cs-137 in Soil And Construction Materials with Gamma Spectrometric Method	ASTM E-181:2003
5	TL Dosimeter	Hp10 and Hp0.07 with Thermo Luminescence Dosimeter (TLD)	In House Method
6	Film Dosimeter	Determination of Hp(10) and Hp (0.07) with film dosimeter	In House Method
7	Geological Samples Such as Soil, Sediments, Rock and Clay Samples	Element (Na, Mg, Al, Si, K, Ca, Ti, Mn, Fe, P, Sc, V, Cr, Co, Ni, Cu, Zn, As, Rb, Sr, Y, Zr, Nb, Pb, La, Th and U) Analysis by WDXRF Spectrometry	In House Method
8	Medical Product	Establishing the Radiation Sterilization Dose	ANSI/AAMI/ISO 11137-2:2006; TS EN ISO 11137-2:2008)
9	Medical Product	Determination of the Population of Microorganisms on Medical Product	ANSI/AAMI/ISO 11737-1:2006; TS EN ISO 11737-1:2006
10	Medical Product	Sterility Control (for medical purposes)	TS 8232: 1990 EP 5.7 (01/2005:20601): 2007
11	Foodstuffs (Animal and plant origin)	DNA Comet Assay for the Detection Foodstuffs- Screening Method	TS EN 13784 : 2004
12	Foods Containg Cellulose	The Detection of Irradiated Foods Containing Cellulose By ESR Spectroscopy	TS 1787:2005
13	Drinking Water	Alpha Spectrometric Analysis of ^{226}Ra Radioisotope in Water	In House Method
14	Drinking Water	Alpha Spectrometric Analysis of ^{234}U,^{238}U Radioisotopes in Water	In House Method

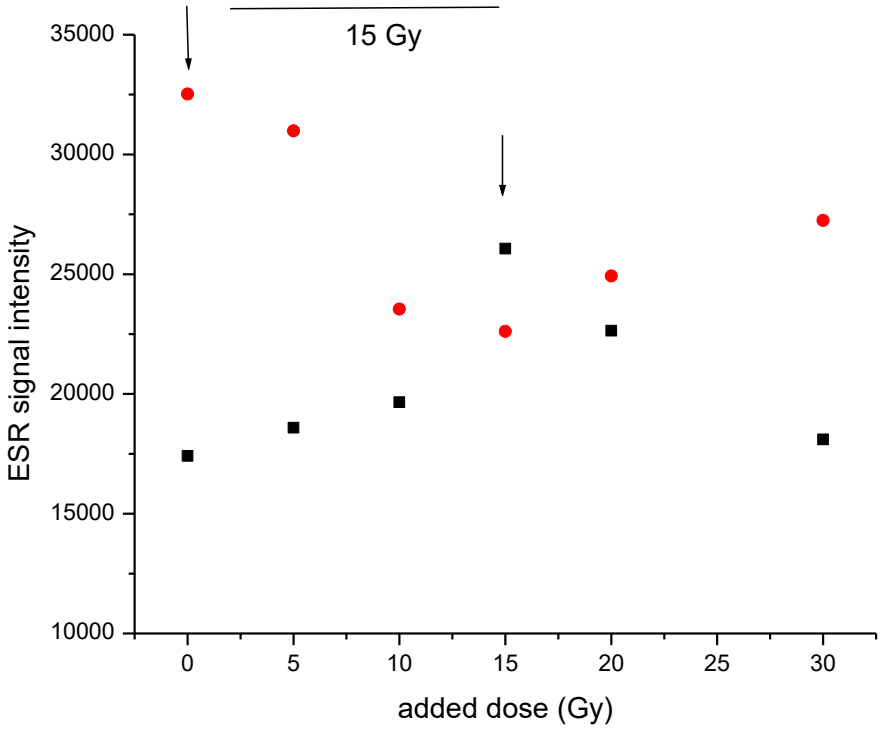


Figure 1. Evolution of the RIS5 intensity regarding multiple irradiation doses for two samples: the first sample was not irradiated (simulation of a non-exposed sample; ■), while the second sample was irradiated at 15 Gy before the cycle of post-irradiation started (simulation of an accidental exposure of 15 Gy; ●). EPR Measurements were performed at X-band

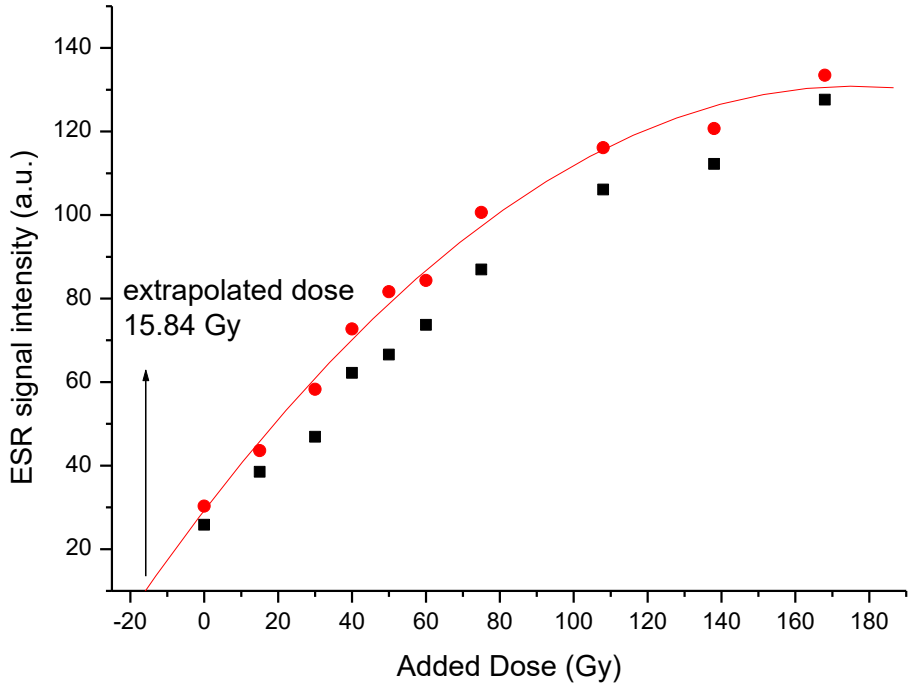


Figure 2. Unirradiated (■) and irradiated (●) samples of Added dose response curves. The experimentally measured ESR signal intensity values (y) were fitted well by polynomial function ($y=aD^2+bD+c$; -0.003±0.0004, 1.15± 0.07 and 29.29±2.54 ,r^2=0.9922). The extrapolated dose was calculated to be 15.84 Gy.