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RESEARCH ARTICLE

A STUDY ON GAMMA RADIATION RESPONSE OF CERIC SULFATE DOSIMETER

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ABSTRACT

Nuclear radiation is highly beneficial in controlled way. On the other hand, it has shown severe damaging effects on human health when our body is directly exposed to it. To prevent its exposure or overdose several dosimeters have been synthesized with different performances. In this research work, we prepared Ceric sulfate chemical dosimeter from three different water samples of TDS value 0.00ppm, 500pm and 900ppm. These dosimeter samples were then irradiated by Cs-137 gamma radiation source at different dose rates 100Gy, 200Gy and 300Gy. Gamma radiation effect in these samples was studied for different concentrations of salt. Variations in the absorbance of dose rate verses time was plotted and measured spectrophotometricaly at 320nm after the interval of 24 hours respectively.

KEYWORDS

Gamma, Radiation, Dosimeter, Ceric Sulfate

1. INTRODUCTION

Gamma rays being shortest wavelength and very high energy electro-magnetic radiations have very high ionization effects causing many chemical and physical changes like change in oxidation states, pH, electrical conductivity and redox potential changes. These radiations are the result of an excited nucleus when it is transitioned to relatively lower nuclear level. In physics laboratory, this excited state of nucleus is created by decay of parent radionuclides. The most commonly used sources of gamma radiations are Cs^{137} and Co^{60}. The Cs^{137} radioactive source is used in high energy gamma irradiator [1]. Physical and chemical dosimeters are used to measure the effect of ionization radiations. Chemical dosimetery has wide ranges of applications and reproducibility and is based on the measurement of radiation of high dose from chemical changes that are produced in the irradiated medium. Chemical dosimeters are relatively cheaper, easy to produce and yield reproducible results. They can be handled easily and have high dose ranges. It is effective as the chemical changes induced is related to the energy absorbed in the medium exposed to ionizing radiation. Practically only those changes can be measured which remain stable for a reasonable long period [2]. Furthermore, only the induced changes should be measureable by standard procedures such as analytical titration or spectrometericaly. The characteristics of a standard dosimetric system include: -

- The chemical transformation yield (expressed as G-value) must be sufficiently high.
- The system should be reasonably sensitive to irradiation exposure.
- Adequate reproducibility (a precision of b/w + 1% and + 5% is acceptable).
- Stability of chemical solution before and after irradiation is required.
- The transition of post-irradiation changes should be of short duration.
- The product yield should be independent of dose rate, quality of radiation, linear energy transfer (LET) and temperature.
- The product yield should be independent of pH of the aqueous system.
- It should be insensitive to small amounts of impurities in the aqueous solution.
- There should be linear relationship between amount of radiation products and radiation exposure dose over a wide range (approximately 1 x 10^{18} rad).
- The procedure should be easy and simple in preparations, operation and analysis of the dosimetric system.
- The system should not involve extensive purification of chemical reagents.

A dosimeter system meeting with these requirements is considered as ideal one. A dosimeter meeting all these basic requirements for ideal dosimeter is referred as “Ferous sulfate dosimeter” proposed a chemical dosimeter based on oxidation of ceric sulfate ions in acidic aerated medium. It had more stability and reproducibility and accepted most extensively as a standard of measurement for radiation dose [3]. The range of these dosimeters are from 4 to 40 K rad at wavelength of 320 nm [4]. Currently, there are several other kinds of dosimeters depending on the kind of use. Ferrous ammonium sulphate is a dosimeter for measuring very high radiation dose. The chemical response of iron salt in above dosimeter has shown very low influence of irradiation temperature. Dosimetry has a verity of applications such as crosslinking of thermo-plastics, medical devices sterilization, graft copolymerization of numerious chemical compounds, livestock water Purification, film badges, colour bleaching and all other highly sensitive radiation-dose measurements etc. [5-9].

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Ceric sulfate dosimeter is found an efficient in measuring doses usually in the range 0.1M to 100M-rad. It the dosimeter that can only be considered as standard for radiation dose rates higher than $5x10^4$ rad, that is upper limit for the aerated ferrous sulfate solution. The big advantage of this dosimeter is that the yield is independent of the oxygen present in it [10]. The range of this dosimeter is 10^3 rad to 10^8 rad at fixed wavelength of 320 nm. Moreover, the fading time rate of absorbed dose and the electrical conductivity are considerably affected by changing concentration of inorganic salts like NaCl. Dosimeters with dissimilar salt concentrations have shown effects on the stability and sensitivity are generally studied as solid state, polymer gel dosimeter, poly vinyl alcohol films and frozen acid solutions [11-12]. Ferrous ammonium sulphate dosimeter is considered as the dosimeter that can measure high radiation dose. The chemical response of iron salt in Ferrous ammonium sulphate dosimeter has very less influence of ir-radiation temperature [13].

2. MATERIALS AND METHOD

Ceric dosimeter was prepared from three different water samples; triple distilled water (TDW) of TDS value 0.00ppm, irradiated water (IRW) of TDS value 500pm collected from Mark-IV pool, Nuclear Institute of Agriculture and Biology Faisalabad, Pakistan, and Brackish water (BKW) of TDS value 900ppm from Rakh branch canal, Faisalabad, Pakistan. First, one litter 0.8 N H_2SO_4 solution was prepared in each water. For 250 ml of 100 mM ceric sulfate stock solution 10.1gm Ce $(SO_4)_2.4H_2O$ was dissolved in 0.8 N H_2SO_4 [14]. Then 15 ml of stock solution was dissolved in 0.8N H_2SO_4 to make one liter of diametric solution [15]. These three different water samples dosimeters were then halved and mixed separately with 1gm and 3gm of NaCl. Then each of 6 samples were then further subdivided into 3, and each part was irradiated for 1 hour for different intensities of gamma radiations including 100 Gy, 200 Gy and 300 Gy separately using Gamma Radiation cell 1000 Elite/3000 Etan having radiation source Cs-137, as shown in Figure 1 [16]. After irradiation these samples were kept at 25°C temperature during entire period. Variation in absorbance of doses verses time were measured by Parkin Elmer Precisely Lambda 25 Spectrophotometer at 320 nm for (Ceric sulphate dosimeters) after every 24 hours interval for 16 days.

2.1 Reaction Mechanism

The primary products formed in the water radiolysis are

$$H_2O \rightarrow H, e^-_{aq}, OH, H_2O_2, HO_2,$$

In the presence of oxygen, H is converted to HO_2 then reduces ceric ions (Ce^{+4})

$$H + O_2 \rightarrow HO_2$$
$$HO_2 + Ce^{+4} \rightarrow Ce^{+3} + H^+ + O_2$$

The ceric ions (Ce^{+4}) directly attacked by hydrogen atoms,

$$Ce^{+4} + H \rightarrow Ce^{+3} + H^+$$

Whether the hydrogen atoms usually react with ceric ions or oxygen, making no change to the final product.

The primary H_2O_2 also reduces ceric ions.

$$H_2O_2 + Ce^{+4} \rightarrow Ce^{+3} + HO_2 + H^+$$

Where HO_2 also reduced Ce^{+4} further. The contribution of primary HO_2 will be neglected. The primary OH radicals appear to be consumed in oxidizing the cerous ions.

$$OH + Ce^{+3} \rightarrow Ce^{+4} + OH^-$$

In the absence of oxygen the reaction scheme is

$$e^-_{aq} + H_3O^+ \rightarrow H + H_2O$$
$$H + Ce^{+4} \rightarrow Ce^{+4} + H^+$$
$$H_2O_2 + Ce^{+4} \rightarrow C^{+3} + H^+ + HO_2$$
$$HO_2 + Ce^{+4} \rightarrow Ce^{+3} + H^+ + O_2$$
$$OH + Ce^{+3} \rightarrow Ce^{+4} + OH^-$$

Here each molecule of H_2O_2 gives rise to one molecule of Oxygen.

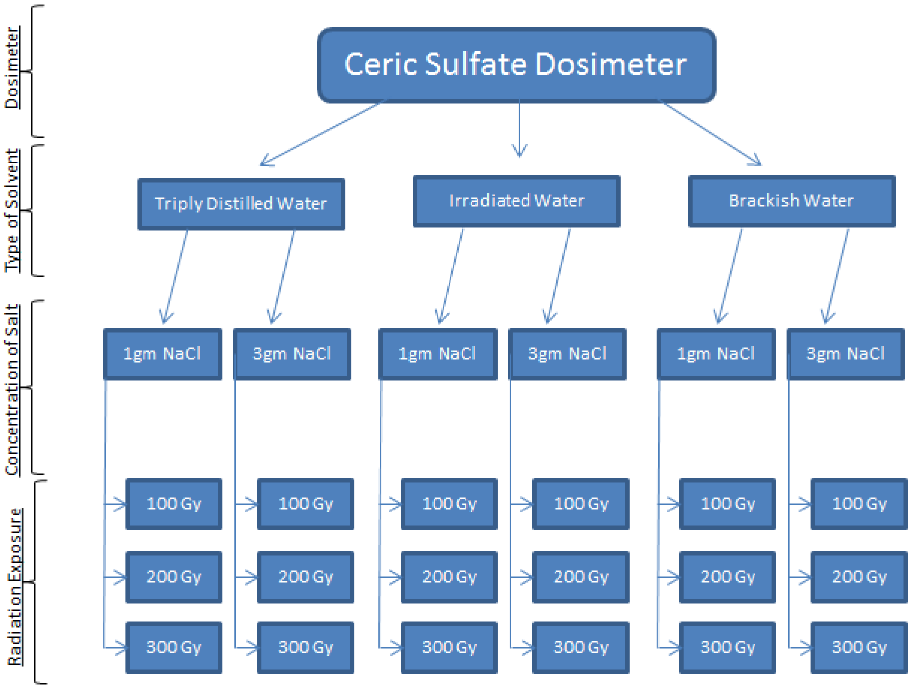

Figure 1: Preparation scheme of Ceric Sulfate Dosimeter

3. RESULTS

The main objective was to study the potential of Ceric Sulphate dosimeter for different gamma radiation doses and salt concentrations. Fading time of absorbed dose and electrical conductivity were measured. Figure 2 showed that dosimeter IRW with both 1gm and 3gm NaCl showed greater absorbance for longer time at radiation dose 100Gy. But dosimeter BKW (3gm NaCl) showed highest stability. Figure 3 showed that dosimeter made from IRW water with 1gm NaCl showed less absorbance change for longer time. Figure 4 showed that dosimeter IRW (1gm NaCl) also stayed for longer time, but dosimeter BKW 1g NaCl again showed highest stability.

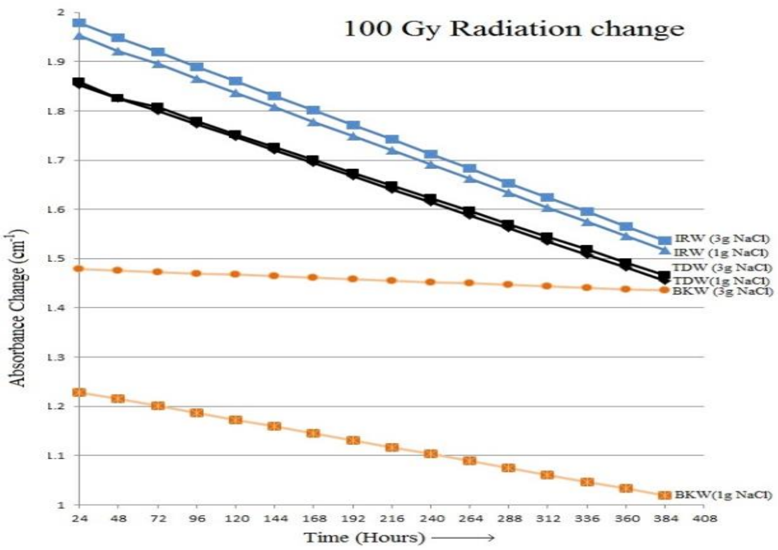

Figure 2: Exposure of dosimeter samples at 100 Gy radiation

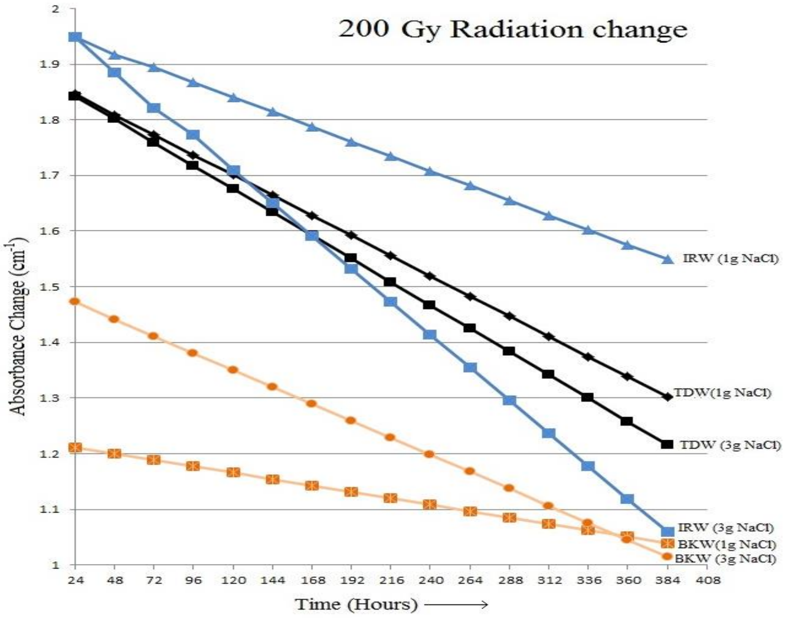

Figure 3: Exposure of dosimeter samples at 100 Gy radiation

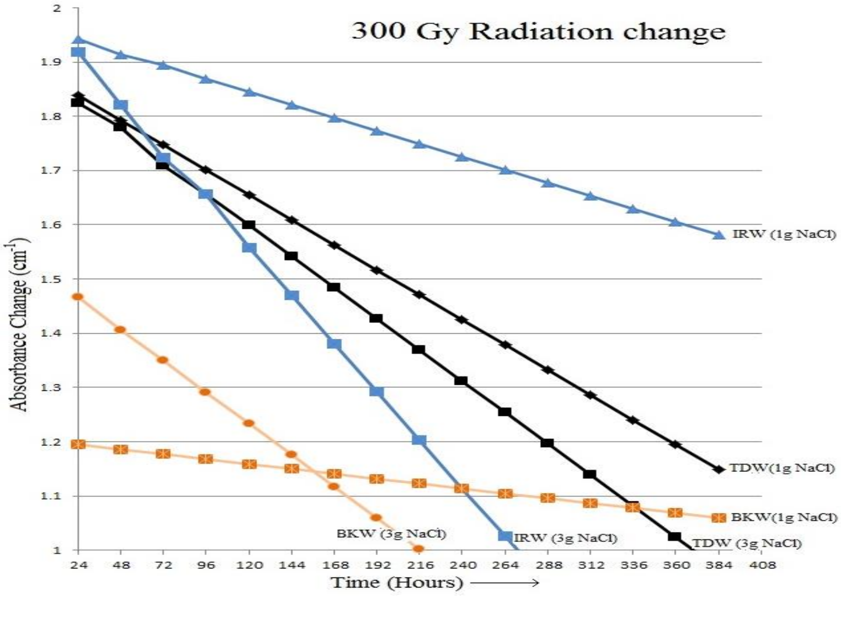

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Figure 4: Exposure of dosimeter samples at 300 Gy radiation

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