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RESEARCH ARTICLE

THE EFFECT OF SALT CONCENTRATION ON ABSORBANCE AND CONDUCTANCE OF FRICKE DOSIMETER

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ABSTRACT

An instrument used to detect, and measure radiation dose is called radiation dosimeter. However, it should be reasonably sensitive to irradiation exposure, chemical transformation yield (expressed as G-value) must be sufficiently high, adequate reproducibility, and having stability of chemical solution before and after irradiation is called ideal dosimeter. A dosimeter meeting all these basic requirements is referred as "Fricke dosimeter" proposed a chemical dosimeter based on oxidation of ferrous ions in acidic aerated medium. It had maximum stability and reproducibility and most widely accepted as a standard in measurement of radiation dose. The range of Fricke dosimeter at 304 nm is 4 to 40 K rad. In this research work, absorbance efficiency and change in conductance of Fricke dosimeter has been estimated when we change the concentration of salt. Cesium CS-137 source has been used as gamma radiation source. The change in absorbance and electrical Conductivity verses time was measured individually.

KEYWORDS

Gamma, Radiation; Dosimeter, Fricke

1. INTRODUCTION

Gamma radiations are short wavelength and extremely high energy electro-magnetic radiations that can cause ionization effects resulting physical and chemical changes in body. According to advanced physics concepts, the radiations are basically of two types 1) electromagnetic radiations and 2) corpuscular radiations [1]. Electromagnetic radiations are of different kinds and distinguished on the basis of the range of wave length (or frequency). These radiations are classified as atomic radiations (ultraviolet and X-ray), microwave (MW), infrared (IR), etc. It was observed that high energy particles including electrons, high energy photons, X-rays and Gamma rays could ionize target atoms or molecules by striking the most loosely bounded valence electrons from their outermost shells, hence, referred as ionizing radiations". These ionizing radiations are part of electromagnetic spectrum [2]. These radiations are identical in their physical properties and exposure effects but only differ in their origins. For example, X-rays produced by man-made machines whereas gamma rays are emitted from natural radio-isotopes.

Nowadays high energy radiations are used for different research, development and industrial purposes. The main primary objectives may include inducing physical, chemical and/or biological changes in the target material. For this purpose, it is very necessary to measure the dose of radiation stated as 'Radiation Dosimetry'. When the high energy ionizing radiations penetrate into the target medium, whole or a part of incident radiation energy is absorbed in the medium. The absorbed dose is conventionally measured in the unit of Gray (Gy) which is equivalent to one joule of energy absorbed per kilogram (J/kg). Its smaller unit is called rad such that one rad is equal to 100th part of Gy [3]. Whereas the energy absorbed per unit of time is called "Dose Rate". For research and industrial purposes, it is very essential to measure the actually absorbed dose by the medium under irradiation and hence lead to the development of Dosimeteric techniques [4]. Dosimetry has large number of of applications such as medical device sterilization, graft copolymerization of several chemical compounds, crosslinking of thermo-plastics, film badges, colour bleaching, livestock water purification and other high sensitive radiation dose measurement etc. [5-7]. The Dosimeters are of basically two types i.e., physical dosimeters and chemical dosimeters. Physical dosimeters include Geiger Muller Counters, Ionizing chambers, Scintillation detectors, Solid state detectors, Wilson cloud Chambers, Thermonuclear dosimeter and Film badge dosimeters, etc. [8-10]. All these dosimeters are very costly, fragile and difficult to handle. In addition, they can be used for measurement of low doses of radiations [11].

In the Fricke dosimeter, when Gamma radiations fall on Ferrous sulfate solution, the Ferrous (Fe^{++}) ions are firstly converted into ferric (Fe^{+++}) ions [12]. For Gamma source, yield of Fe+++ ions is usually 15.6 ions per 100ev. This is the chemical change is evaluated by measuring the absorbance of the solution at 304 nm wavelength by spectrophotometer which gives direct measure of the absorbed dose. The dose range of Fricke dosimeter is from 40 to 400 Gy for wavelength of 304 nm in the ultraviolet region [12]. Hence, the Fricke dosimeter is most widely accepted as the standard dosimeter other dosimeters calibration tool. The Fricke dosimeter has also some limitations. Ferrous sulfate solution remains stable for just a few days. This is due to spontaneous oxidation of the cations. It is, therefore, essential that at each time of data collection, fresh solution of Ferrous sulfate must be prepared. It is also not sufficiently sensitive to the gamma radiation in biological range of 0-1000 rad. Therefore, many efforts were made to improve the Fricke dosimeter [13]. It was suggested that in order to increase the upper dose range, the yield of Ferric ions in the solution may be reduced by adding the cupric sulfate in the solution. Such a system would be referred as 'Ferrous Cupric sulfate dosimeter'. Such arrangement would increase the upper range limit to few "M rads". When Cupric sulfate ions are added to the system, the formation of Ferric ions is reduced from 15.66 to 0.66 which is of biological importance region [14]. On the other end, the lower dose range of Fricke dosimetric system can be extended by increasing yield of Ferric ions.

2. MATERIALS AND METHOD

The typical Fricke dosimeters were prepared from analytic grade chemicals. First 0.28 gm $FeSO_4.7H_2O$ and 0.06 gm NaCl was dissolved in the triply distilled water already taken separately, and then mixed all chemicals together in a measuring flask [15]. One liter of final solution was made by adding 22 ml concentration (95-98%) H_2SO_4 and triply distilled water in the above solution. Divided this solution into 6 equal parts (150ml standard), then added 1g NaCl in three of solutions and 3g NaCl in remaining of solutions. Similar six solutions with same protocol were made from already irradiated water collected from Mark IV pool at Nuclear Institute of Agriculture and Biology Faisalabad, Pakistan and six solutions made from tap water of TDS 900ppm separately, as shown in table 1 [16]. These solutions were then irradiated at dose rate 100Gy, 200Gy and 300Gy in Gamma Radiation cell 1000 Elite/3000 Etan. The absorbance of these dosimeters was observed at 304 nm using Parkin Elmer Precisely Lambda 25 Spectrophotometer and electric conductivity was measured periodically [17]. The data was analyzed statistically by using regression analysis and graphs were drawn for estimated absorbance and estimated electric conductivity by taking time along x-axis.

Table 1: Preparation scheme of Fricke Dosimeter

Fricke Dosimeter	Radiation Dose 100Gy		Radiation Dose 200Gy		Radiation Dose 300Gy	
Triply distilled water	S1 (1gm NaCl)	S4 (3gm NaCl)	S2 (1gm NaCl)	S5 (3gm NaCl)	S3 (1gm NaCl)	S6 (3gm NaCl)
Irradiated water	S13 (1gm NaCl)	S16 (3gm NaCl)	S14 (1gm NaCl)	S17 (3gm NaCl)	S15 (1gm NaCl)	S18 (3gm NaCl)
Tap water	S25 (1gm NaCl)	S28 (3gm NaCl)	S26 (1gm NaCl)	S29 (3gm NaCl)	S27 (1gm NaCl)	S30 (3gm NaCl)

3. RESULTS & DISCUSSIONS

3.1 Absorbed dose and fading time

The fading time of absorbance of dosimeter prepared with triply distilled water containing 1 gm of NaCl was measured periodically at 304 nm wavelength. Due to Irradiation oxidation of ferrous ion created. The absorbance decreased with the passage of time. The linear curve was fitted. The absorbed dose was calculated with equation Y= a+bx and was plotted graphically. The average value of regression coefficient 0.0003. The results are shown in the Figure 1. The average estimated value at X = 24 is 0.2452 and the average estimated value at X=360 is 0.144. The estimated regression line is Y = 0.2724-0.0003x. As the value of x does not cover X=0 therefore 'a' does not have any particular meaning while of b indicates that for a unit change in the value of X the value of absorbed dose decreases by an amount 0.0003.

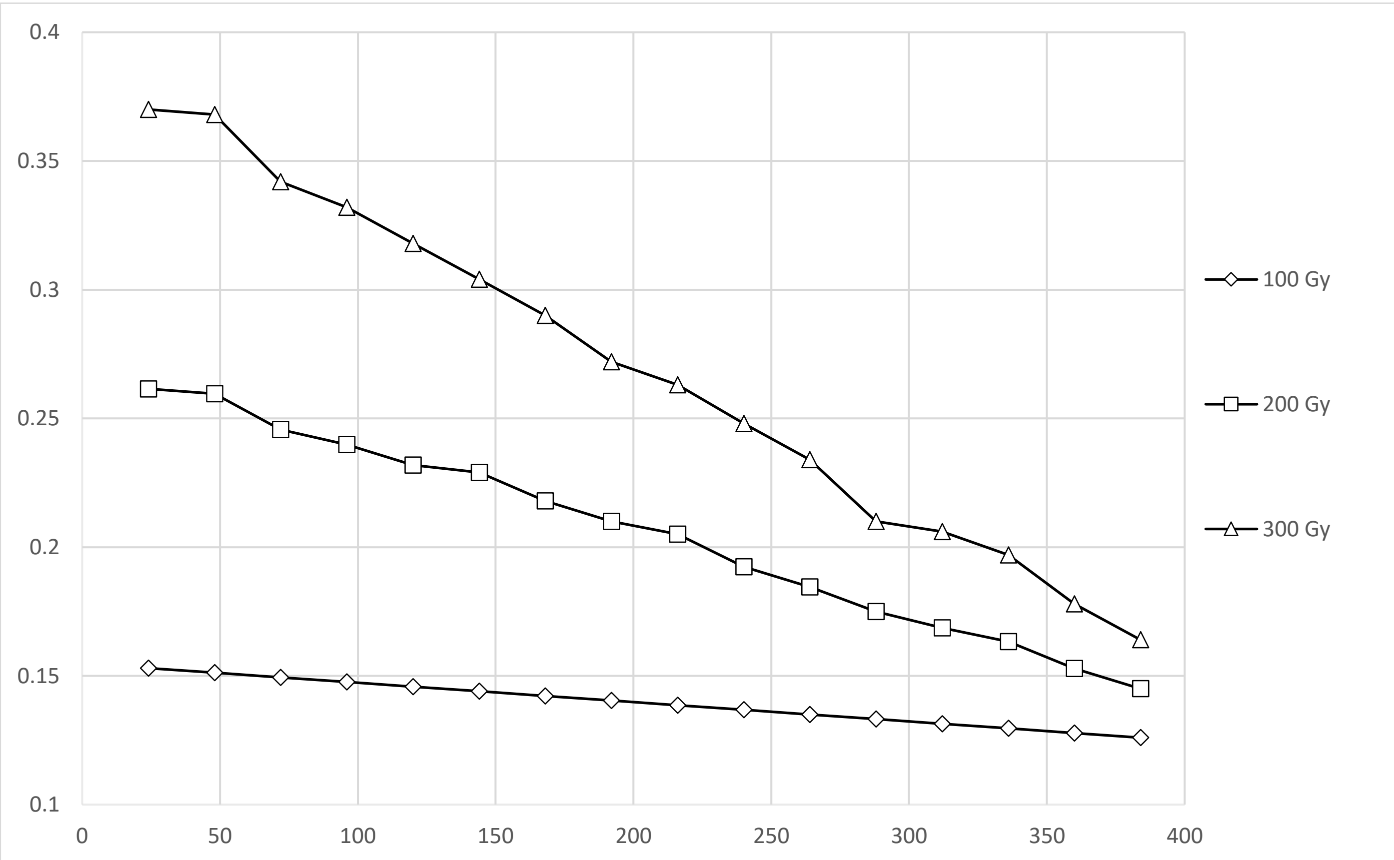

Figure 1: Fricke dosimeter with 1gm NaCl (Triply distilled water)

Figure 2 shows the fading time of absorbance of dosimeter prepared with triply distilled water containing 3 gm of NaCl was measured periodically at 304 nm wavelength. The absorbed dose was calculated with equation Y= a+bx, and was plotted graphically. The average value of regression coefficient 0.0004. The average estimated value at X = 24 is 0.41121 and the average estimated value at x=360 is 0.19385. The estimated regression line is Y = 0.482-0.0004x. As the value of x does not cover x=0 therefore 'a' does not have any particular meaning while of b indicates that for a unit change in the value of x the value of absorbed dose decreases by an amount 0.0004.

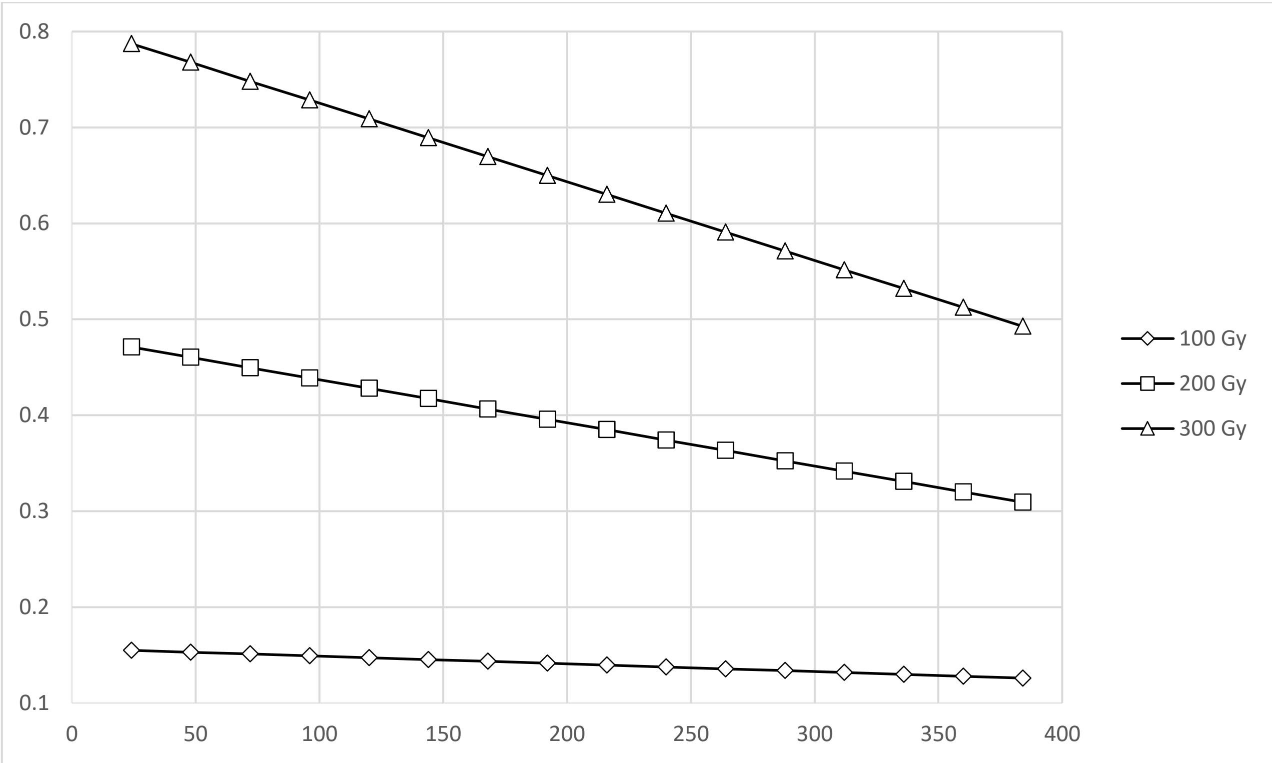

Figure 2: Fricke dosimeter with 3gm NaCl (Triply distilled water)

Figure 3 shows the fading time of absorbance of dosimeter prepared with Irradiator containing 1 gm of NaCl was measured periodically at 304 nm wavelength. The average value of regression coefficient 0.0001. The average estimated value at X = 24 is 0.901 and the average estimated value at x=360 is 0.6733. The estimated regression line is Y = 0.7873-0.0001x. As the value of x does not cover x=0 therefore 'a' does not have any particular meaning while of b indicates that for a unit change in the value of x the value of absorbed dose decreases by an amount 0.0001.

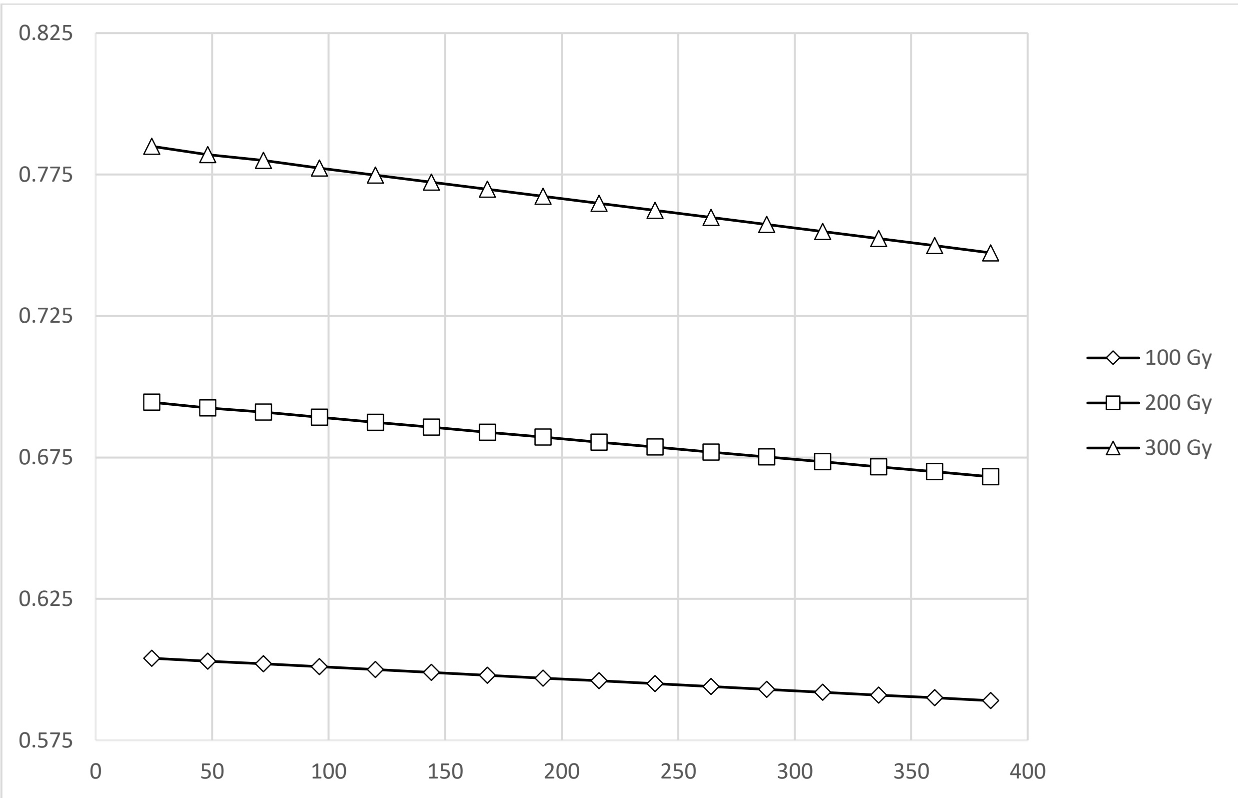

Figure 3: Fricke dosimeter with 1gm NaCl (Irradiator water)

Figure 4 shows the fading time of absorbance of dosimeter prepared with irradiator water containing 3 gm of NaCl was measured periodically at 304 nm wavelength. The value of regression coefficient 0.0001. The average estimated value at X = 24 is 0.6310 and the average estimated value at x=360 is 0.41112. The estimated regression line is Y = 0.7873-0.0001x. As the value of x does not cover x=0 therefore 'a' does not have any particular meaning while of b indicates that for a unit change in the value of x the value of absorbed dose decreases by an amount 0.0001x.

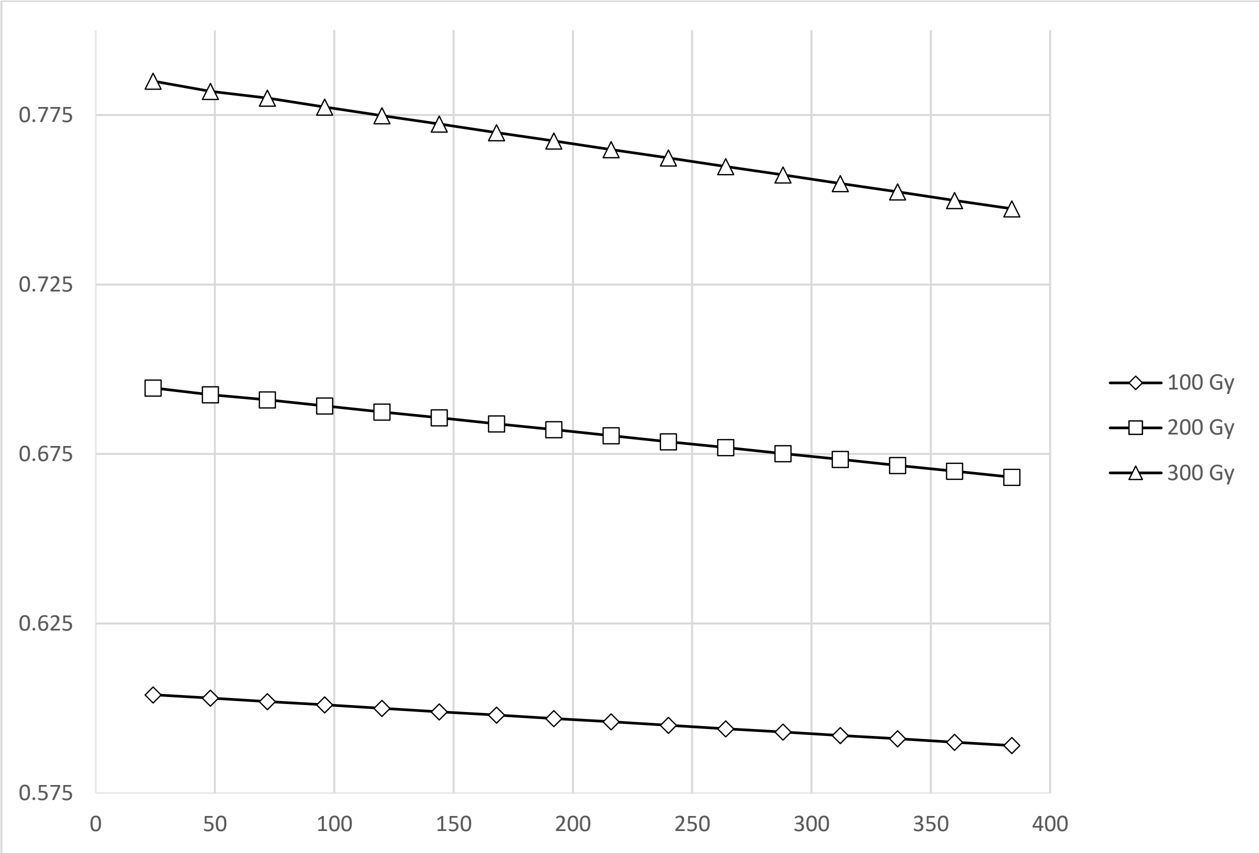

Figure 4: Fricke dosimeter with 3gm NaCl (Irradiator water)

Figure 5 shows the fading time of absorbance of dosimeter prepared with tap water containing 1 gm of NaCl was measured periodically at 304 nm wavelength. The average estimated value at X = 24 is 0.51001 and the average estimated value at x=360 is 0.1318. The estimated regression line is Y = 0.5298-0.001x. As the value of x does not cover x=0 therefore 'a' does not have any particular meaning while of b indicates that for a unit change in the value of x the value of absorbed dose decreases by an amount 0.001.

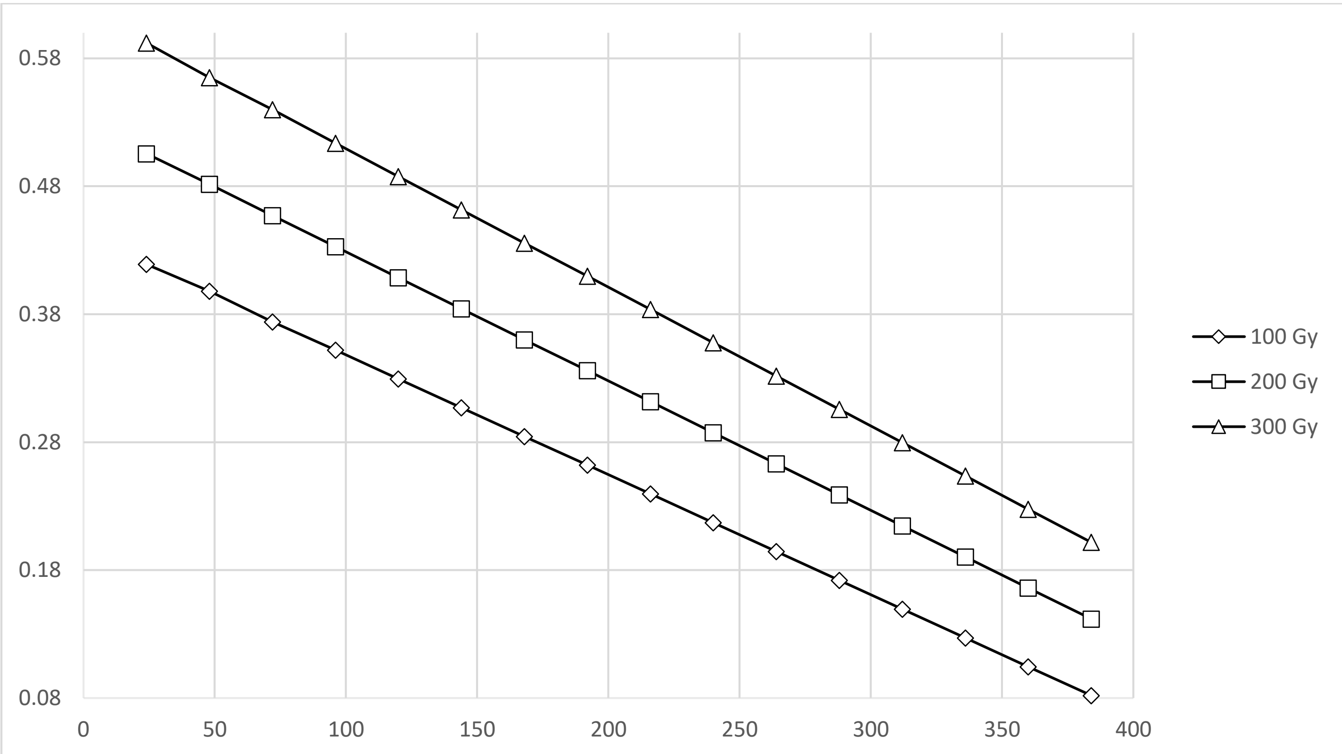

Figure 5: Fricke dosimeter with 1gm NaCl (Tap water)

Figure 6 shows the fading time of absorbance of dosimeter prepared with tap water containing 3 gm of NaCl was measured periodically at 304 nm wavelength. The value of regression coefficient 0.0015. The average estimated value at X = 24 is 0.5901 and the average estimated value at x=360 is 0.0811. The estimated regression line is Y = 0.6452-0.0015x. As the value of x does not cover x=0 therefore 'a' does not have any particular meaning while of b indicates that for a unit change in the value of x the value of absorbed dose decreases by an amount 0.001.

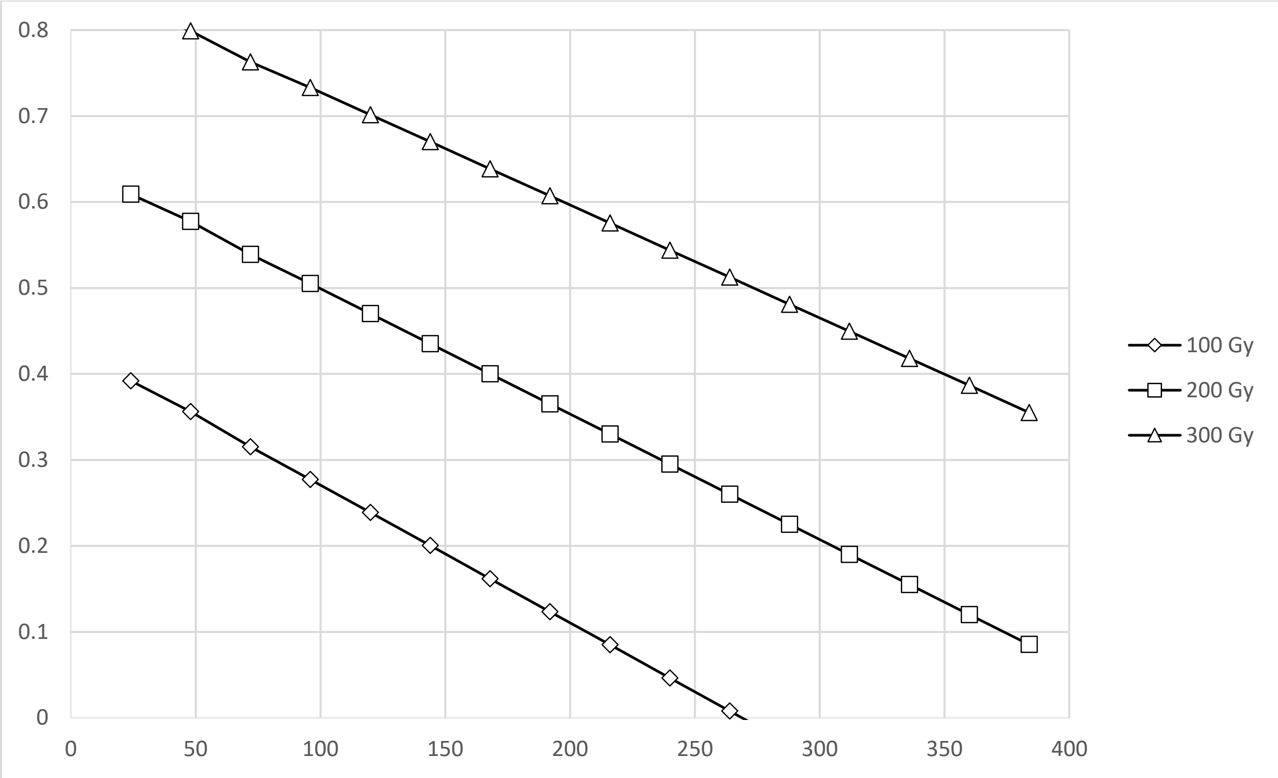

Figure 6: Fricke dosimeter with 3gm NaCl (Tap water)

3.2 Electric conductivity and time

This dosimeters samples S1, S2, and S3 was observed in Figure 7. the effect of electrical conductivity attains it maximum value, then decreases gradually. But here as 1 gm of NaCl was used so the decrease in electrical conductivity with the passage of time is not abrupt. The linear curve was fitted. The data showed that electrical conductivity decreased slowly with the passage of time. The estimated electrical conductivity was calculated with equation Y= a+bx, and was plotted graphically. The value of regression coefficient was 0.390. The average estimated value at X = 24 is 182 and the average estimated value at x=260 is 138.75. The estimated regression line is Y = 185.38- 0.1198X. As X cannot be equal to zero therefore a does not have any particular meaning. But the value of b indicates that for a unit change in the value of X 0.1198. The value of electrical conductivity decreases by an amount 0.1198.

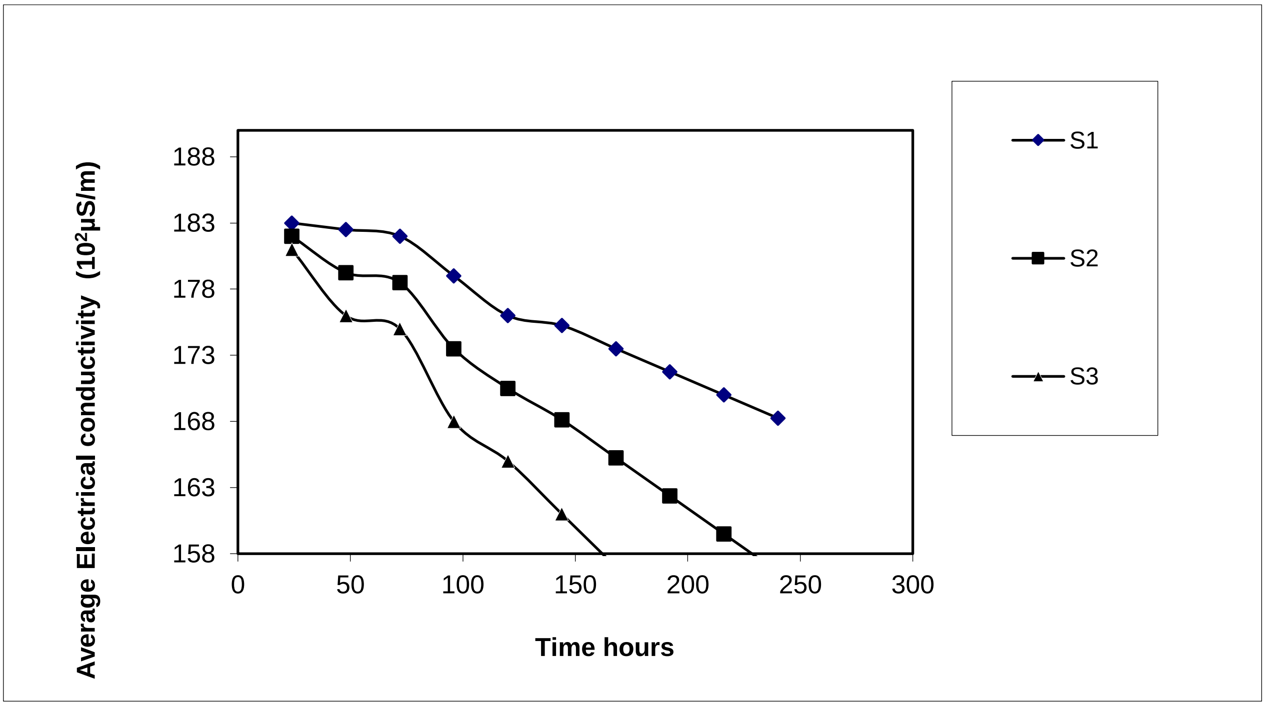

Figure 7: Fricke dosimeter with 1gm NaCl (Triply distilled water)

This dosimeters samples S4, S5, and S6 was observed in Figure 8. The value of regression coefficient was observed to be 0.125. The average estimated value at X = 24 is 183.5 and the average estimated value at X=360 is 138.3586. The estimated regression line is Y = 186.75-0.125X. As X cannot be equal to zero therefore a does not have any particular meaning. But the value of b indicates that for a unit change in the value of X=0.125. The value of electrical conductivity decreased by 0.125.

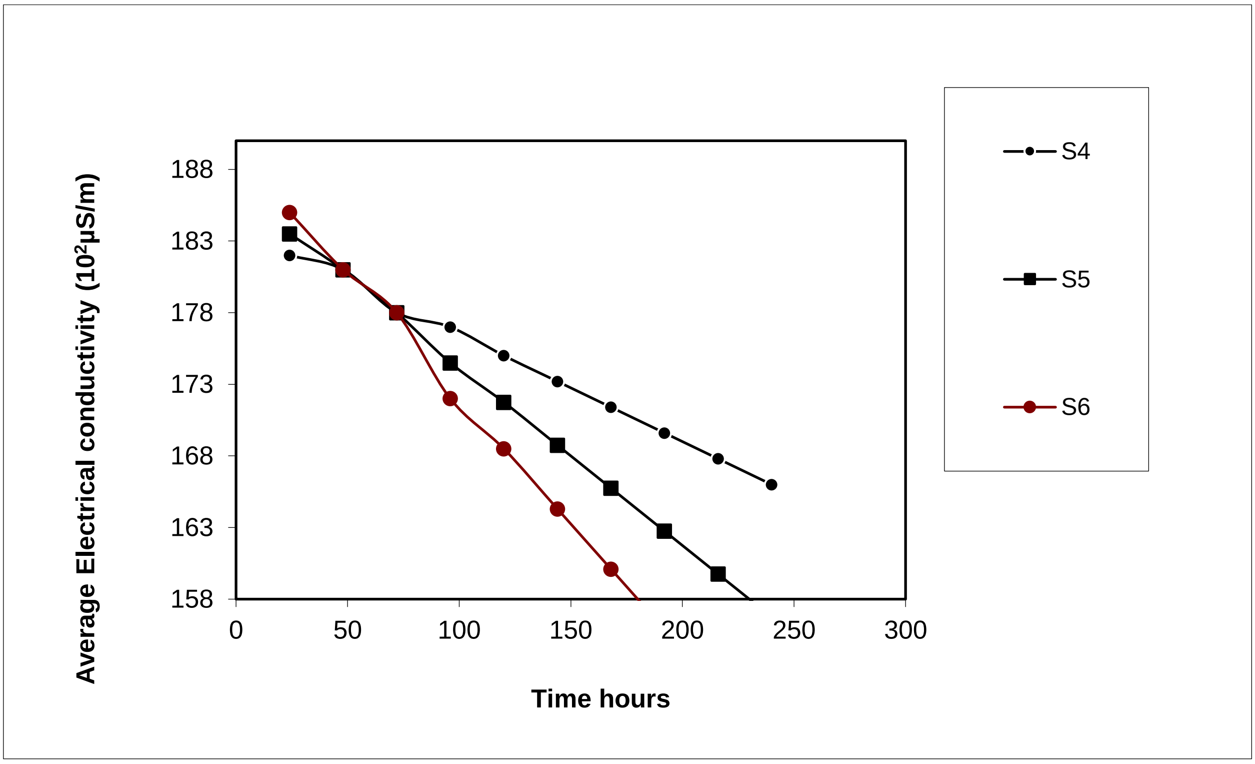

Figure 8: Fricke dosimeter with 3gm NaCl (Triply distilled water)

This dosimeters samples S13, S14, and S15 was observed in Figure 9. The value of regression coefficient was 0.1292. The average estimated value at X = 24 is 176.5 and the average estimated value at X=360 is 130.9. The estimated regression line is Y = 180.5 – 0.1292X. As X cannot be equal to zero therefore a does not have any particular meaning. But the value of b indicates that for a unit change in the value of X the value of electrical conductivity decreases by 0.1292.

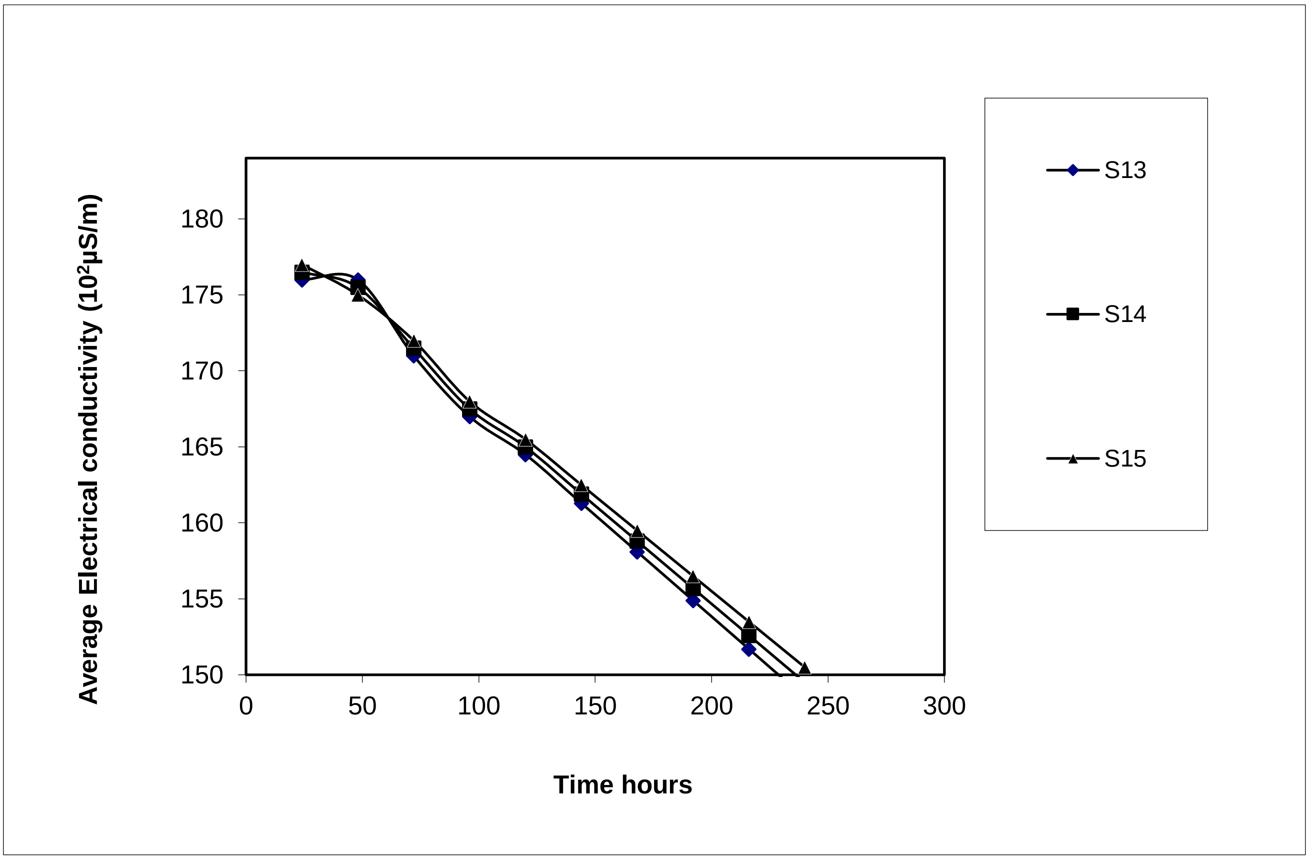

Figure 9: Fricke dosimeter with 1gm NaCl (Irradiator water)

This dosimeters samples S16, S17, and S18 was observed in Figure 10. The value of regression coefficient was 0.0729. The average estimated value at X = 24 is 181 and the average estimated value at X=360 is 154.75. The estimated regression line is Y = 182.75-0.0729X. As X cannot be equal to zero therefore a does not have any particular meaning. But the value of b indicates that for a unit change in the value of X the value of electrical conductivity decreases by an amount 0.0729.

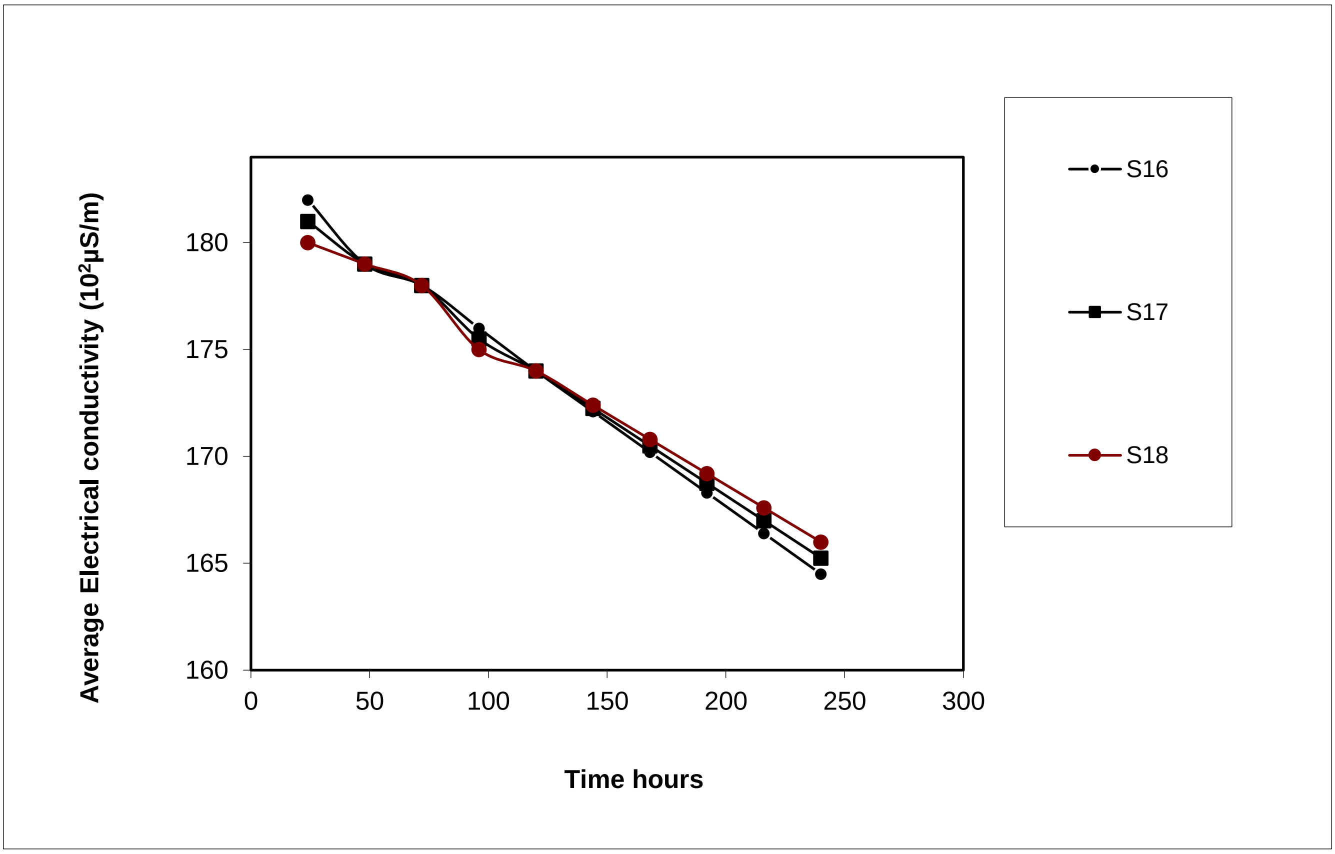

Figure 10: Fricke dosimeter with 3gm NaCl (Irradiator water)

This dosimeters samples S25, S26, and S27 was observed in Figure 11. The value of regression coefficient was 0.0292. The average estimated value at X = 24 was 176 and the average estimated value at x=360 was 165.8. The estimated regression line was Y = 176.75 – 0.0292x. As X cannot be equal to zero therefore a does not have any particular meaning. But the value of b indicates that for a unit change in the value of X the value of electrical conductivity decreased by 0.0292.

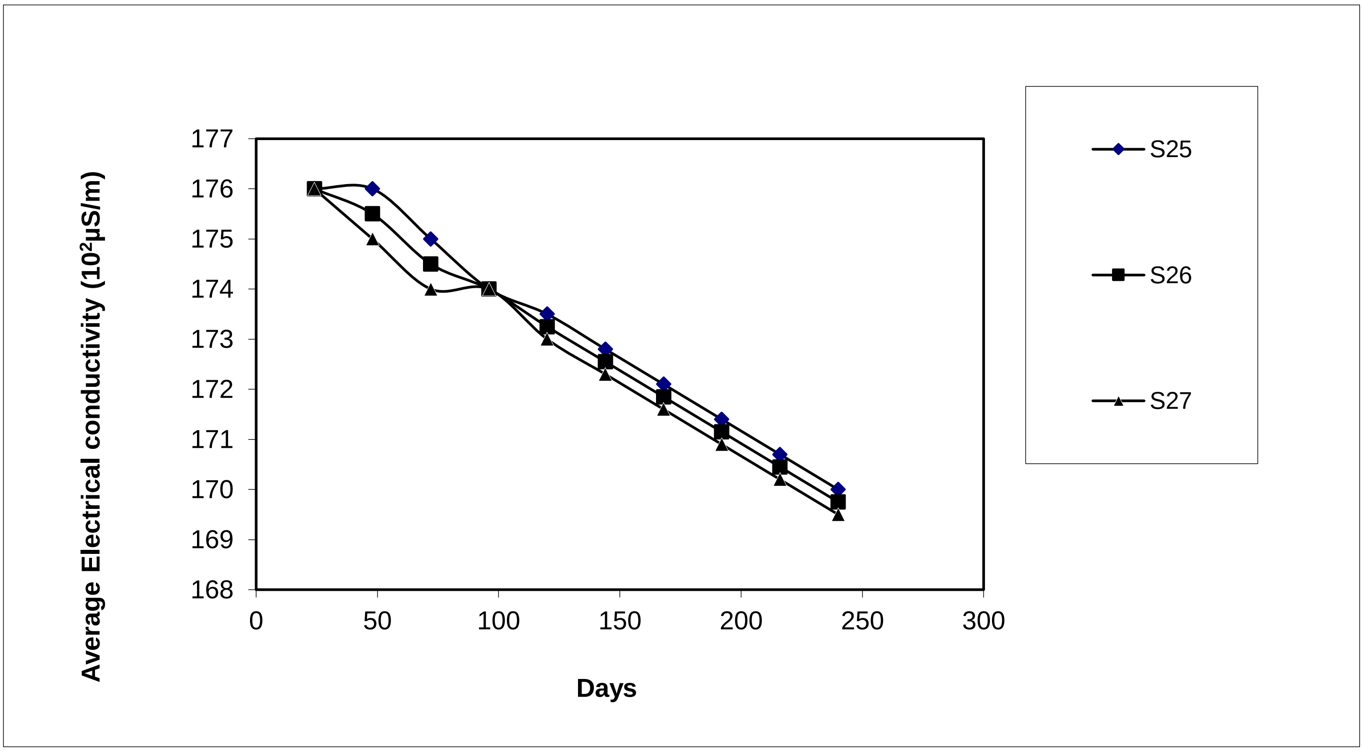

Figure 11: Fricke dosimeter with 1gm NaCl (Tap water)

This dosimeters samples S28, S29, and S30 was observed in Figure 12. The value of regression coefficient was 0.075. The average estimated value at X = 24 was 180 and the average estimated value at x=360 was 152.45. The estimated regression line is Y = 181.25 - 0.075X. As X cannot be equal to zero therefore a does not have any particular meaning. But the value of b indicates that for a unit change in the value of X the value of electrical conductivity decreases by an amount 0.075.

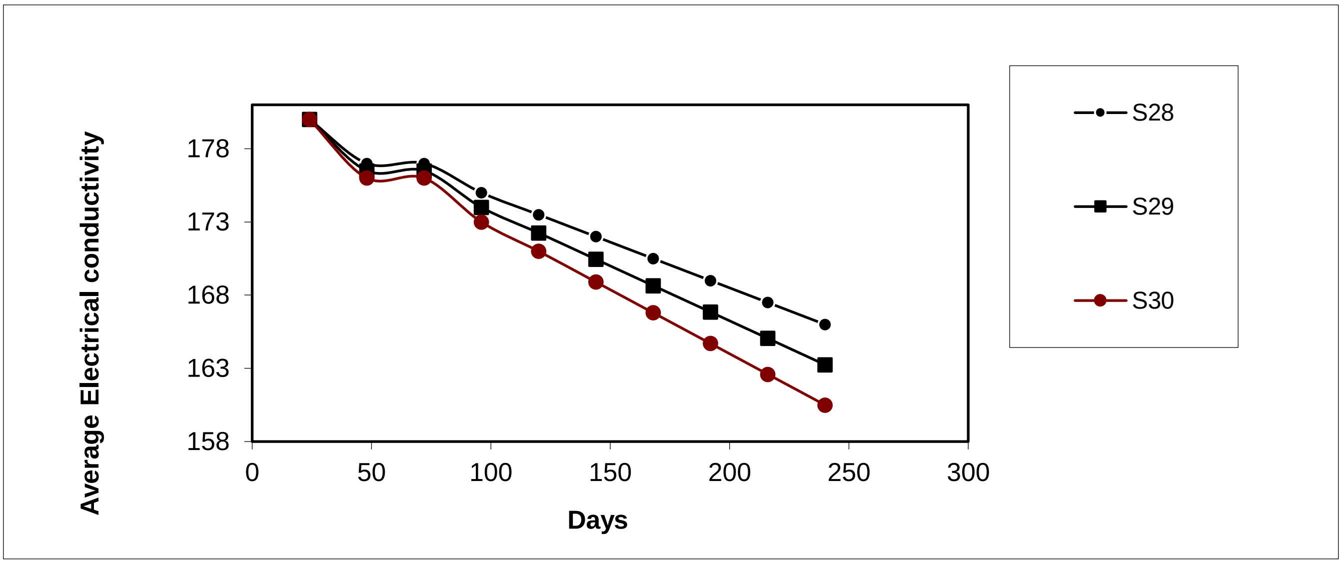

Figure 12: Fricke dosimeter with 3gm NaCl (Tap water)

4. CONCLUSIONS

4.1 Stability of electrical conductivity

(1) The regression coefficient of triply distilled water, irradiator water and tap water with 1g NaCl were 0.1198, 0.1292 and 0.0292, respectively. The electrical conductivity showed that tap water was more stable than other two waters which was an exception. (2) The regression coefficient of triply distilled water, irradiator water and tap water with 3g NaCl were 0.125, 0.0729 and 0.0750, respectively. The electrical conductivity of irradiator water was most stable here.

4.2 Stability of absorbance at 304nm

(1) The regression coefficient of triply distilled water, irradiator water and tap water with 1g NaCl were 0.0003, 0.0001 and 0.001, respectively. Here Fricke dosimeter of irradiator water was most stable one and that of tap water was the most unstable one. (2) The regression coefficient of triply distilled water, irradiator water and tap water with 3g NaCl were 0.0004, 0.0001 and 0.0015, respectively. Here Fricke dosimeter of irradiator water was more stable ones. Here tap water was more unstable one.

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