EXPOSURE RATE ASSESSMENT FROM SELECTED CATHODE RAY TUBE DEVICES

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Abstract. Cathode Ray Tube (CRT) Television (TV) receivers and Personal Computer (PC) monitors have become major elements in the modern work environment and everyday life as TV receivers serve a good number of useful applications in information dissemination while PC monitors serve as interface between users and computers. The concerns as to whether the use of these devices can affect human health have been due to observed effects such as eye changes or discomfort, adverse reproductive outcomes, skin disorders etc. This study is an assessment of the exposure rate in air due to radiation from these devices with sample measurements taken using a Geiger- Muller counter (Kindenoo blueGeiger PG-15). All the CRT devices show relatively high values of ambient dose rates in the range of 0.28±0.01 – 0.32±0.01 μSv/h for TV receivers and 0.25±0.01 – 0.31±0.02 μSv/h for PC monitors above their respective background measurement of 0.24±0.01 μSv/h average. The study also revealed that all the CRT units showed a decreasing trend of exposure rates with distance with correlation coefficient as high as -0.97. The exposure rates are well below the Food and Drug Administration regulations in 21 C.F.R of 0.5 mR/h. The Annual Effective Dose (AED) results (i.e. 0.17 – 0.91) mSv/y are well below the limits of the *International Commission on Radiological Protection (*ICRP) 60 recommendations for detrimental effects and those to prevent non-stochastic effects in the ICRP 26 recommendation for the lens of the eye, foetus/embryo, skin and hands.

KEYWORDS: Cathode Ray Tube, Television, Dose Rate, Annual Effective Dose.

1 INTRODUCTION

All matter is made up of atoms. Some atoms are naturally stable while others are unstable. Radioactivity is a natural phenomenon that occurs when an atom with an unstable nucleus spontaneously transforms, releasing energy in the form of ionizing radiation. The released radiation may take the form of particles (including electrons, neutrons, and alpha particles) or of electromagnetic gamma radiation or X-rays, all with different amounts of energy. Radiation can also be generated artificially by machines [1]. Ionizing radiation refers to radiation that has enough energy to remove an electron from a neutral atom or molecule, creating a free radical. Ionizing radiations are known for the DNA damage and cancer causing capabilities. Radiation from sources such as power lines, cell phones, and traffic radars are all classified as non-ionizing radiation because they are not capable of removing an electron from an atom [2]. Radiation may be emitted when charged particles deposit energy to a medium through direct coulomb interactions with orbital interactions with orbital electrons of the atoms in the medium [3] Different types of radiation have distinct damage potential described by their Linear Energy Transfer (LET). Alpha radiation has high- LET because it deposits a relatively large amount of energy in a small area before it stops. Beta, gamma and x-radiation are low-LET because they deposit energy in a more diffuse pattern [4]

Naturally occurring radioactive materials are common in the environment and in the human body. Ionizing radiation from outer space (cosmic radiation) bombards the earth constantly. The ionizing radiation from these and similar natural sources is called background radiation [5]. Average natural radiation background in the United States (U.S.) ranges between 0.526 mSv/y and 1.31 mS/y [6]. Man-made sources of radiation (from commercial and industrial activities) account for approximately 0.2 μSv of the annual radiation exposure. X-rays and other diagnostic and therapeutic medical procedures account for approximately 1.2 mSv a

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year. Consumer products like tobacco and smoke detectors account for another 0.1 mSv of the exposure to radiation each year [7]. The Health Physics Society recommends that exposures below 0.1 Sv only be evaluated qualitatively as the risks are too small to be observed. Doses below 0.1 Sv are considered to be low [2].

Medical exposure remains by far the largest artificial source of exposure to ionizing radiation and continues to grow at a remarkable rate as it accounts for 98% of the contribution from all artificial sources and are now the second largest contributor to the population dose worldwide representing approximately 20% of the total [1]. In non-medical X-rays shielding, a protective tube housing is one that surrounds the X-ray tube itself, or the tube and other parts of the X-ray apparatus (for example, the transformer), and is so constructed that the leakage radiation at a distance of 1 m from the target cannot exceed 10 mSv in 1 hour when the tube is operated at any of its specified ratings [8]. However, there is no difference between the effects caused by natural or man-made radiation [9]. We live in a world where technology is rapidly evolving especially those related with the design of electronic equipment and gadgets. Since the last three decades, electromagnetic radiation (EMR) from power lines, home wiring, airport and military radar, substations, transformers, computers, cell phones and domestic appliances have been of great concern and the phenomena underlying this have been thoroughly studied over the past few decades. This is because they are suspected to be largely part of the cause of brain tumors, leukemia, miscarriages, chronic fatigue, headaches, cataracts, heart problems, stress, nausea, chest pain, forgetfulness, depression, aggressive behavior, sleep disturbance and other health and dermatological problems [10].

CRTs are the video display components of televisions and computer monitors [11]. A CRT consists of three basic parts: the electron gun (neck) assembly, the viewing surface (panel), and the glass envelope (funnel). The basic raw material in the CRT glass is silica (~50-60 wt. %) but other different metallic oxides such as barium oxide and lead oxide are required to be incorporated in CRT glass as shielding agents for harmful radiation [12]. The electron beam in the CRT is swept horizontally and vertically across the viewing face – the whole face normally being covered in about 1/70th of a second [13]. CRTs are usually housed in a plastic casing [14]. CRTs emit X-rays as a result of electron braking (bremsstrahlung) by the screen and walls of the tube and the amount of radiation increases proportionally to the accelerating voltage [15]. The bremsstrahlung energy spectrum is a continuum with photon energies that extend as high as the electron energy itself [4]. The box-shaped CRT computer monitors generally have quite high levels of radiation even at 30 cm compared to the modern low-radiation flat screens. Another item most likely to cause a health hazard in many offices is the computer monitor, or screen. For computer users, radiation from computers may be a substantial component of the total electromagnetic radiation which the body is exposed to; the magnetic portion of this electromagnetic radiation (which is probably more dangerous than the electric portion) can penetrate just about anything. The use of screen shields especially for computer monitors wills not totally reduce the effect of the radiations from the screen because of the magnetic portion of the electromagnetic radiation [16]. EMFs from TVs may be one of the biggest hazards in our home because children often love to sit very close to the TV, exposing themselves to a steady flow of harmful EMFs for hours. TV sets with larger screens tend to emit stronger fields because they contain larger cathode-ray tubes with the components that produce EMFs. In general, the larger the TV screen, the stronger the EMFs that are produced and the further away you need to be, to get out of the range of the electromagnetic fields [17].

In one survey, the Bureau of Radiological Health (1981) of the United States Department for Health and Human Services, Food and Drug Administration, made measurements under controlled laboratory conditions of X-ray emissions from 125 Visual Display Units (VDUs). Out of the VDUs tested no detectable level of X-rays was found for 117 units, while eight units emitted levels around or above 0.5 mR/h at 5 cm from the screen surface [18]. Vijay (2012) also opined that the radiations of EMFs from CRT TV/PC set are harmful for the life of blood tissue; it was concluded in the study that CRT TV/PC screens are harmful for the blood tissue of human beings at some distances and heights of the CRT TV/PC screen from ground level [17]. Kokalari (2011) compared the exposure according to the type of the monitor (i.e. CRT versus LCD), for the same way of placement in the classroom (around the walls). In all the working places where measurements were taken, the values of the electric field (of low frequency) and the values of the power density (high frequency) for the classroom equipped with LCD type monitors, were smaller than those for the classroom equipped with CRT type monitors [19]. In this research, the ionizing radiation emission from different TVs and PCs of CRT was measured at different positions and distances. This study further probes into the behavior of these devices with respect to the emission of ionizing radiation from them as well as monitor the exposure of users and individuals to these radiations.

2 METHODOLOGY

A total of 450 sample measurements were made from CRT computers and television receivers of different manufacturers, models and sizes. The product types were selected randomly based on their availability and popularity. Background measurements were also recorded when the devices were not switched on. Measurements were taken at different distances from screen front and lateral sides in time blocks of 30minutes for a total of about 2 hours for each device. At each point, four to six measurements were taken to cater for the statistical fluctuations in radiation measurements. While taking the measurements, the devices were isolated from other devices with possible EMR emission. A Geiger-Muller counter (blueGeiger PG-15) from Kindenoo France was used for all measurements [20]. This device is capable of detecting Beta, Gamma and X- radiations with a dose rate measurement range of 0.05µSv/h to 300µSv/h and a maximum radiation dose measurement of 250 mSv in a maximum time of ten (10) years. This blue-tooth enabled, 1- 2AA battery powered device displays the results on a monochrome Liquid Crystal Display on the device. It can also be connected to an Android (TM) cell phone or interfaced with a computer for easy data logging. The sensor location for this device is well noted for proper exposure to the radiation to be measured.

The mean and standard error for repeated measurements was determined and recorded for each measurement position. Analysis of variance (ANOVA) with MINITAB 16.0 statistical software was also used to test the significance of difference between the sampling means of the measurements at various distances from emission screen. The null hypothesis was:

$$H_0^{(1)} - \text{All treatment (distance)means are equal}$$

A test of significant difference between means was also carried out within a 95% confidence level to determine if there was a statistically significant difference between the emissions at the screen front and lateral sides or if the difference could have arisen due to chance. The Linear correlation coefficient (r) was used to evaluate the degree of relationship between the dose rates and both the distances from emission screen and the corresponding area of emission The Annual Effective Dose (AED) for the mean values of background only and for background plus contribution to radiation from measured

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equipment, for the most relevant sets of measurements were obtained under the conditions shown in table 1 for **continuous** exposure, **occupational** exposure and exposure for the **general public.**

Table 1: Duration of exposure for occupational and general public exposures

S/N	CODITIONS	OCCUPATIONAL	GENERAL PUABLIC
1	Continuous exposure to background radiation	24 h/d, 365d/y	24 h/d, 365d/y
2	Exposure to background + PC monitor	24 h/d, 365.25 d/y for background radiation;8 h/d, 300 d/y for PC monitors	24 h/d, 365 d/y for background radiation; 2 h/d, 300 d/y for PC monitors
3	Exposure to background + PC monitors + TV receivers	24 h/d, 365.25 d/y for background radiation, 8 h/d, 300 d/y for PC monitors ; 2 h/d, 365 d/y for TV receivers	24 h/d, 365.25 d/y for background radiation, 2 h/d, 300 d/y for PC monitors ; 4 h/d during a 365 d/y for TV receivers

3.0 RESULTS AND DISCUSSION

Mean values and Standard errors of Dose Rates (DRs) in (µSv/h) at different distances (d) and Time Blocks (TB) were recorded and used for further analysis.

3.1 Distribution of Measurements

All the CRT devices show relatively high values of DR (0.2848±0.0134 – 0.3232±0.0093) µSv/h average for TV receivers and (0.2484±0.0105 – 0.3112±0.0195) µSv/h average for PC monitors above their respective BG measurements 0.2426±0.0077 µSv/h average. The distribution of these measurements and the percentage of maximum DR above BG measurements are shown in figure 1 and 2 respectively. CRTs emit X-rays as a result of electron braking (bremsstrahlung) by the screen and walls of the tube and the amount of radiation increasing proportionally to the accelerating voltage [15]. This result is in contrast with the survey of the Bureau of Radiological Health (1981) of the United States Department with no detectable X-ray found for 117 units out of 125 [13].

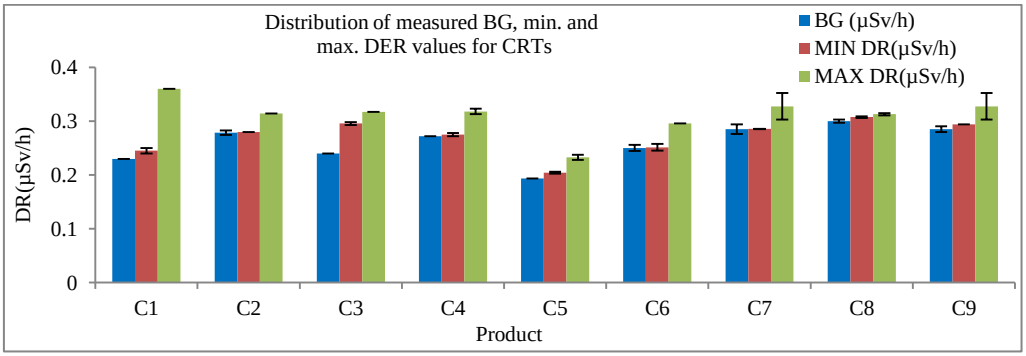


Figure 1.0: The distribution of DR measurements for CRT units

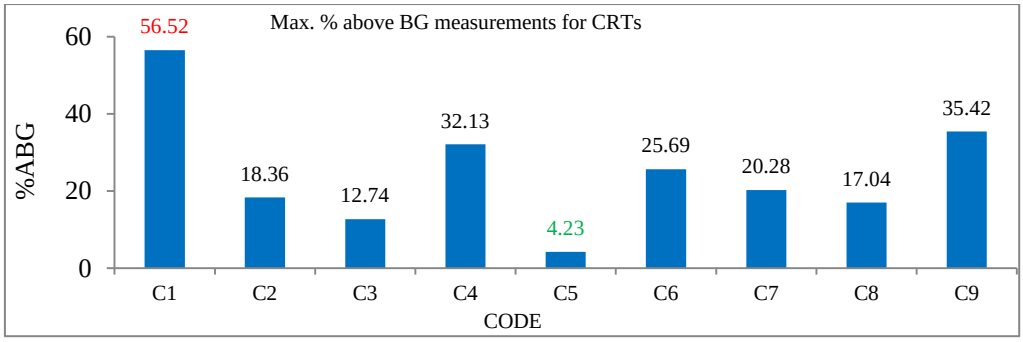
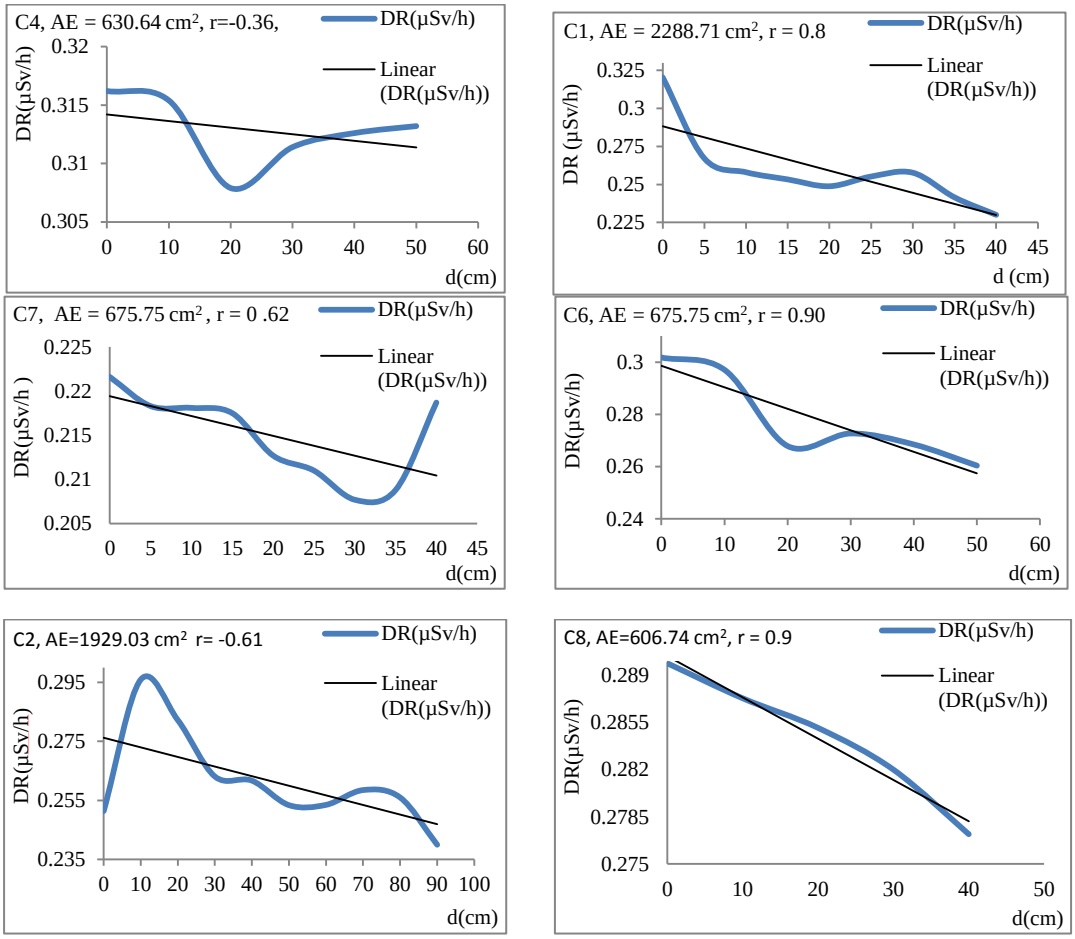


Figure 2.0: Percentage of maximum DR above Background measurements for CRTs

On the average, the exposure rate from the CRTs was 0.3091±0.0113 µSv/h i.e. 24.85% above BG. This value is well below the Food and Drug Administrations 21 C.F.R. 1020.10 of 0.5 mR/h equivalent to 4.67 µSv/h at a distance of 5cm from any external surface [18].

3.2 Variation of Dose Rate with distance

All the CRT units showed a decreasing trend of exposure rates with distance as shown in figure 3 (a-i) with correlation coefficient as high as -0.97. The shapes of the curves also show that the X-rays produced are continuous (which is characteristic of bremsstrahlung) rather than having sharp spikes that denote characteristic discrete X-rays. This confirms that the X-rays produced are of low energy as discrete characteristic X-rays are expected be produced in tubes with high voltages.



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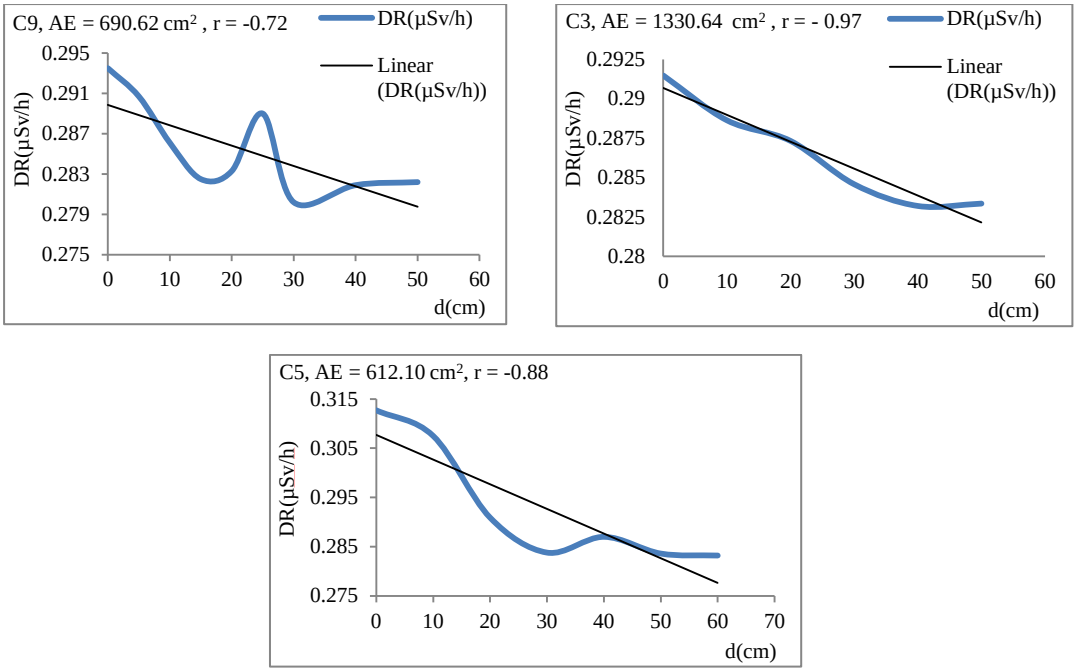

Figure 3 (a-i): DR against distance for CRT products

The cyclic (sinusoidal) variations observed reveal that the emissions do not travel in straight lines. This is likely to be as a result of the manner the electron beam is swept horizontally and vertically across the viewing face – the whole face normally being covered in about 1/70th of a second [13].

A further investigation of the results of Constantino *et. al.* (2000) that not only the screen, but also the lateral surfaces of CRTs emit low-level radiation, show that the lateral surfaces for CRTs have a generally lower exposure rate (0.2661±0.0083) µSv/h than the screen surface (0.2898±0.0050) µSv/h. The statistical test for difference between means of DRs for screen front and lateral sides at the 95% confidence level showed that five (5) out of the six (6) CRTs (i.e. 83%) as shown in table 2 had statistically significant differences that are not due to chance. It can be said that the lateral surfaces for CRTs have generally lower exposure rate compared to the emission screens as shown in figure 4.

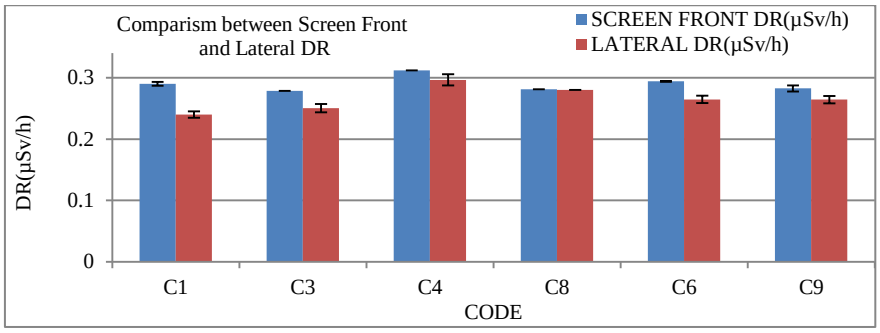

Figure 4: Comparison between screen front and lateral DR

The (0.2661±0.0083) µSv/h than the screen surface (0.2898±0.0050) µSv/h. For the CRT devices, there is no strong correlation between the DRs and AEs within and between different products.

Table 2: DRs (screen and Lateral measurements) for CRTs and LCDs

CODE	SCREEN FRONT DR(µSv/h)	LATERAL DR(µSv/h)	TEST RESULT FOR DIFFERENCE IN MEAN
C1	0.2900±0.0032	0.2400±0.0050	not due to chance
C3	0.2788±0.0000	0.2506±0.0067	not due to chance
C4	0.3121±0.0000	0.3200±0.0100	due to chance
C8	0.2811±0.0000	0.2802±0.0000	not due to chance
C6	0.2942±0.0003	0.2646±0.0006	not due to chance
C9	0.2827±0.0049	0.2645±0.0006	not due to chance

As can be seen from the figure 5.0 the excess effective dose from PC monitors amount to (0.05-0.60) mSv/y; i.e. (2.3 - 28.17) % above BG. Continuous exposure to both PC monitors and TV receivers results in an annual effective dose (17.37 – 32.86) % higher than that of BG alone. These results are comparable with that of Constantino *et. al.* (2000) with an excess annual absorbed dose from PC monitors only of 0.104 mSv/y; i.e. 11% above BG radiation and 28.8% for both PC monitors and TV receivers [15]. The AED results (2.13 – 2.83 mSv/y) obtained under various conditions due to exposure to these devices are well below the limits of ICRP 60 recommendations shown in table 4.8 for detrimental effects and those to prevent non-stochastic effects in the ICRP 26 recommendation for the lens of the eye, skin and hands; the AED values however exceed the ICRP 60 recommendation for Foetus/embryo.

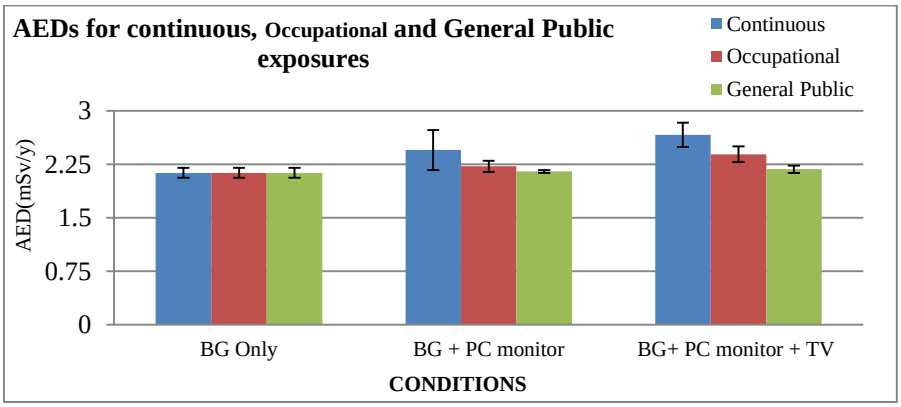

Fig. 5: AEDs for continuous, occupational and general public exposures

5.0 CONCLUSION

CRT PC monitors and TV receivers of were found to have ionizing radiation emissions higher than the Background levels. Maximizing distance from the emission source is a control measure for the amount of ionizing radiation from PC monitors and TV receivers as the dose rates generally decreased with distance from emission screen. Larger Screen sizes do not necessarily result in increased ionizing radiation emission. They however result in more tissues/organs susceptible to biological effects of ionizing radiation. Since emission takes place through all the screen and lateral surfaces (Constantino *et. al.*, 2000). This study reveals that TV receivers and PC monitors constitute a part of artificial sources of ionizing radiation.

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