Original Research Article

Effect of Environmental Factors on Bunker Temperature and Pressure; A Study from Region with Harsh Tropical Weather

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Abstract

Background: Stabilization of weather factors especially temperature, pressure and humidity in bunkers that housed the Linear accelerators is necessary for safety of equipment and their efficient function for our patients. Daily variation of such factors can lessen the performance of Linear accelerators resulting to an error in their output and wrong dosimetry. Sokoto centre being located in the North-Western region of Nigeria with three unique seasons (Dry hot, Harmattan winter and Wet raining seasons) require a study of this kind to ascertain the influence of those harsh environmental factors on bunker's internal air condition. *Methods:* Daily records of Linac bunker temperature and pressure were measured using Precision mercury-in-glass thermometer and Opus barometer (OPUS 10 THI) from January 2019 to December 2021. Similarly, the corresponding daily external environmental temperature and pressure for the study period were obtained from Nigerian Meteorological Agency. The values were grouped according to the months of year, mean values of temperature and pressure for each month of the year were generated and graphs and bar-charts were plotted for both bunker and external environment. Similarly, an overall mean score for both temperature and pressure of each month of the three years period were generated and graphs were plotted with those values for bunker and external environment. *Results:* The overall mean external temperature for the study period was 35.7°C, ± 3.82 as standard deviation (SD) and with a range of 26.0 – 43.6 °C, while for the overall mean bunker temperature it was 27.1°C ±1.7 SD and a range of 23.1 - 31°C. For the external environmental pressure, the overall mean value was 78.1hpa ± 1.5 as SD and a range of 68.1– 83.1hpa, while for the bunker it was 977.2 hpa ± 2.55 as SD and a range of 966.9 – 988.7 hpa. Using the pearsons correlation, it indicate that there is a significant association between environmental and bunker temperature (p-value=0.002). *Conclusion:* External environmental temperature showed a significant influence on bunker temperature despite the presence of chillers. But for environmental and bunker pressure, the relationship is complex and non-significant. Similarly, the seasons of the year also influenced bunker temperature.
Keywords: Stabilization of weather factors, Linear accelerators, environmental temperature, world climate.

INTRODUCTION

According to IPCC report on world climate condition, the climate will suffer a continuous change for several decades with tremendous consequences on both human health and natural resources [1]. Similarly, it was reported that the range and extremes of ambient temperature were expected to change with corresponding effects in both human and machineries that would be variable and more unstable on different regions of the world [2, 3]. In Nigeria, the climatic condition is tropical type with variable rainy and dry seasons and it varies from region to region of the country [4]. It is hot and wet most of the years in the south-eastern and south-west regions and farther inland [4]. In the south the rainy season lasts from March to November, whereas in the far north it is dry and lasts from mid-May to September [4]. Similarly, temperature and humidity remain relatively constant throughout the year in the southern part, but it varies considerably in the northern regions [4]. Sokoto State where this study was conducted is located in the extreme north-western region of Nigeria, it lies between Latitude 13°05' N and Longitude 05°15'E. Zamfara State form border in the eastern part of Sokoto, in the northern part, Sokoto

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shared border with Niger Republic, Kebbi State to the South-East and Benin Republic to the West [5]. The area is sandy savannah with hills that are sparsely distributed, it has an annual average temperature of 28.3°C (82.9°F), maximum daytime temperatures are generally under 40°C (104.0°F) but can exceed 45°C (113.0°F) during dry hot season [5]. The rainy season is short and begins from June to October, from late October to February the climate is dominated by the Harmattan, wind blowing Sahara dust over the land. Houses in the region were built with primary function of adapting to the prevailing climate and provide an internal and external environment that is comfortable and conducive to the occupants [6].

The build-up of greenhouse gases due to human activities imposed climate changes which becomes the greatest environmental challenge that affects every aspect of the buildings [7]. The Linac machine (Elekta precise) was housed in a bunker constructed with very thick concrete walls, reinforced by led materials to significantly minimize radiation leakage for safety to staffs and general public. However, the unique natures of Sokoto climate characterised by high temperature during the day make humidity low especially in the summer which causes rapid evaporation and low rainfall [8], this climate features had been reported to have impact on indoors operational machines [9]. This is what mandates us to conduct this study to ascertain the contribution of environmental weather factors, precisely the temperature and pressure on Linac bunker air condition.

MATERIALS AND METHODS
This is a three years (2019 to 2021) retrospective study conducted in the Radiotherapy Department of Usman Danfodiyo University Teaching Hospital Sokoto, Nigeria. Data were extracted from previous records of daily bunker temperature and pressure obtained during the quality audit. Opus barometer (OPUS 10 THI) fixed on the wall inside the radiotherapy bunker was used to measure the bunker's pressure and relative humidity, similarly the bunker temperature was measured using a Precision mercury-in-glass thermometer placed inside the slabs cavity before inserting ionization chamber. The corresponding external environmental temperature and pressure of Sokoto city were obtained from the daily records of Nigerian Metrological Agency.

The data obtained were analyzed using the Statistical Package for Social Sciences version 20.0 (Chicago L). The daily records of temperature and pressure for both bunker and external environment were monthly averaged for each year and the overall study period. The range, mean and standard deviation of temperature and pressure for both bunker and external environment were calculated for the overall years of study. Similarly, graphs and bar charts were plotted according to each year of study and the overall study

period. The mean monthly records of temperature and pressure for both external and bunker were grouped according to three distinct seasons of the year (hot, wet and harmattan) and graphs were plotted each year and overall study period.

RESULTS
The extracted data records of temperature and pressure from daily quality audit and that of external environment from 2011 to 2013 were analysed. The overall mean daily external environmental temperature was 35.7°C with standard deviation of ±3.8 and range of 26-43.6 °C, while the overall mean bunker temperature was 27.1°C with standard deviation of ±1.7 and range of 23.1-31°C (table 1). Similarly, the overall environmental pressure was 780.5 hpa with standard deviation of ±15.2 and range of 681-831hpa, while the bunker overall mean daily pressure was 977.2 hpa with standard deviation of ±2.6 and range of 966.9-988.7 hpa (Table 2). Figure 1-3 shows that the highest temperature for external environment and bunker exhibit a bimodal peak, first is seen between March to May with temperature range of 40-43°C and 28-29°C respectively, the second peak is between October to December (31-40°C and 26-27°C). Similarly, the lowest also has bimodal peak, first in January and February (30-37°C and 25-26°C) and the second is between July to September (30-35°C and 25-27°C). Figure 4 shows an overall temperature pattern for the study period, it rises from late February to early June (34-43°C and 25-30°C) and from September to November (32-40°C and 26-27°C). It also showed a temperature fall from December to late February (35-31°C and 26-24°C).

Figure 5-7 shows a pressure changes for external environment and bunker. In 2011, the environmental and bunker pressure rises from June to January (790-800 hpa for environmental and 990-1000 hpa for the bunker) and fall around February to May (790-770 hpa for environmental and 990 hpa for bunker). Same pattern were noted for the year 2012 and 2013.

Figure 8 shows an overall mean pressure for the study period, the external environmental temperature fall from January to April (800hpa to 760hpa) and 975hpa for bunker. Between April to December, the environmental pressure rises from 760 hpa to 800 hpa, while the bunker pressure maintained a steady record of 990 hpa.

In Figure 9, the mean monthly temperature was graphically plotted according to the seasons of the year. From November to late February (harmattan season) the environmental temperature dropped between 38-31°C and that for bunker falls between 27-24°C. Similarly, from end of February to May (hot season), the environmental temperature rises from 31-43°C with corresponding rise of bunker temperature from 24-30°C. During wet season (late May to early

October), the environmental temperature dropped from 43-32°C and that of bunker dropped from 30-26°C. In figure 10, the external environmental pressure follows temperature behaviour, from November to early February (harmattan) the environmental pressure shows a gradual rise from 790 pha to 810 pha and then return to 780 pha at the end of February. The corresponding bunker pressure within the stated months looks relatively steady, from 975-980 pha. During hot season (late February to May) the environmental pressure dropped from 780 to 755 hpa in April and return to 760 hpa in May, the corresponding bunker pressure change was minimal, it fluctuate from 975 to 970 pha. Between May to October (wet season) the environmental pressure rises from 760 hpa to 815 hpa and then returned to 780 hpa in October. The corresponding bunker pressure during wet season maintained a relatively steady pressure of 970 to 975 pha.

Table 1: Overall mean daily environmental and bunker temperature

Location	Overall mean daily temp (°C)	Range	Standard deviation
External environment	35.7	26-43.6	±3.8
LINAC bunker	27.1	23.1-31	±1.7

Table 2: Overall mean daily environmental and bunker temperature

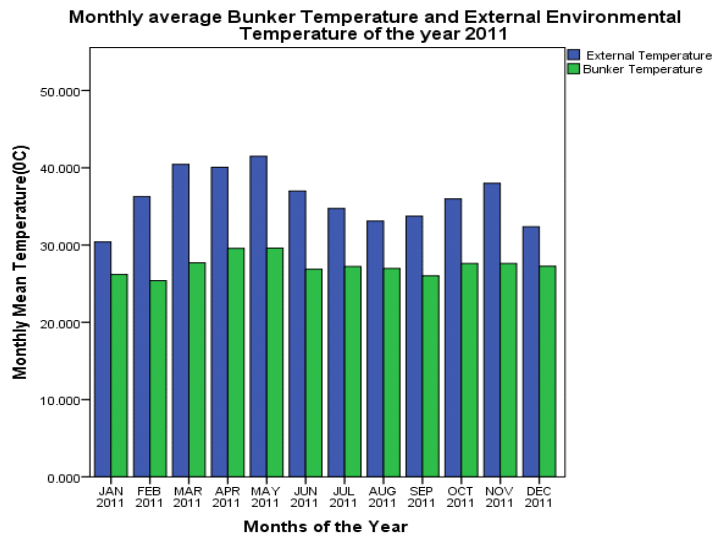| Location	Overall mean daily temp (°C)	Range	Standard deviation
External environment	780.5	681.0-831.0	±15.2
LINAC bunker	977.2	966.9-988.7	±2.6

Figure 1: Bunker and environment mean monthly temperature for the year 2011
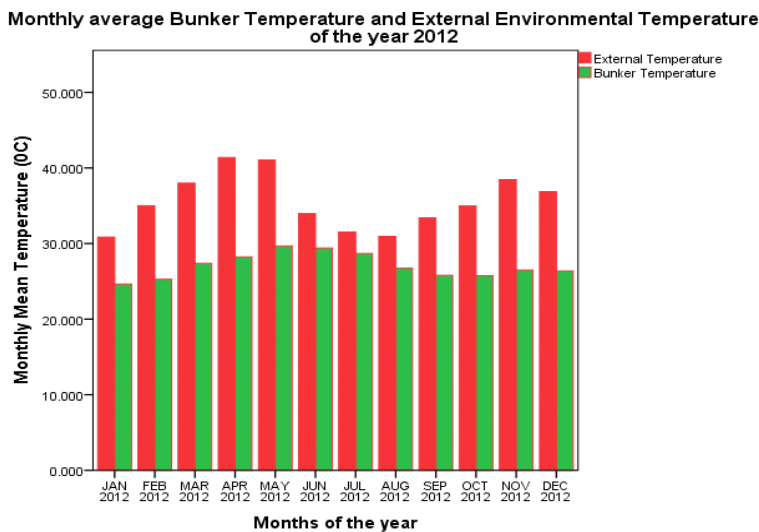

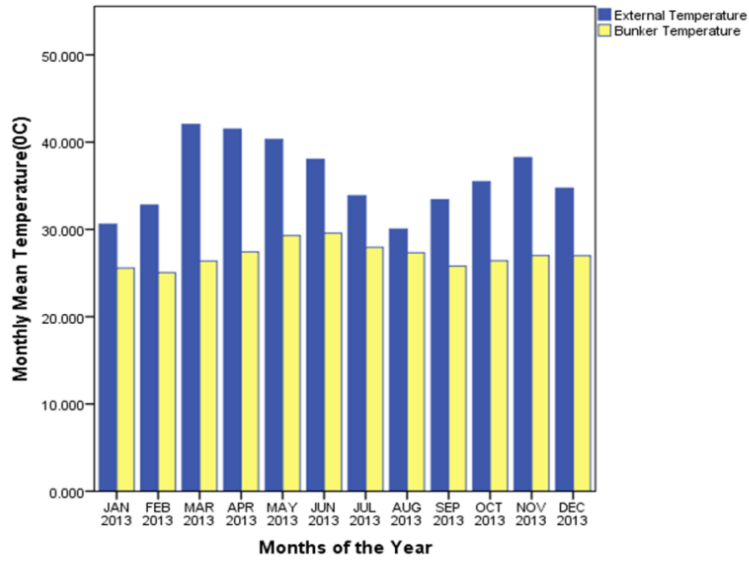**Figure 2: Bunker and environment mean monthly temperature for the year 2012**

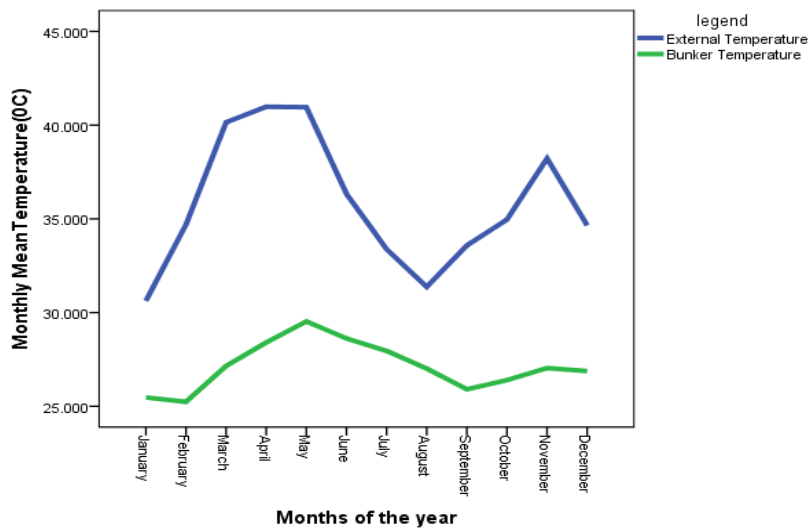**Figure 3: Bunker and environment mean monthly temperature for the year 2013**

Figure 4: Overall bunker and environment mean monthly temperature for the study period
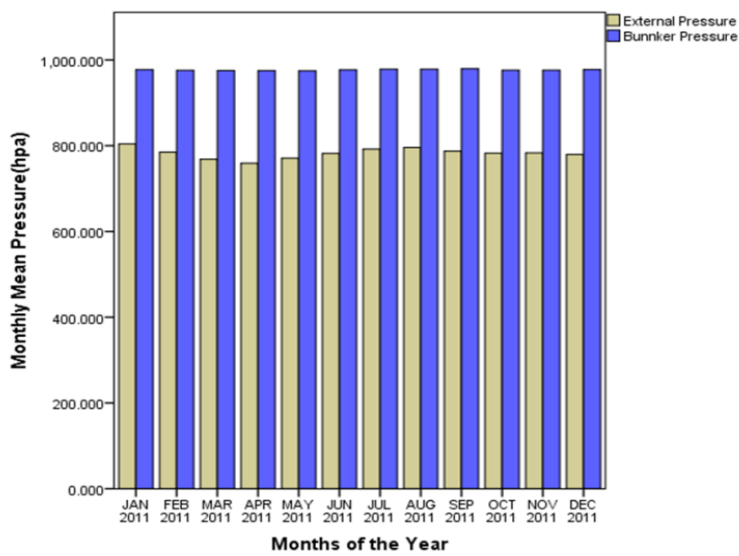

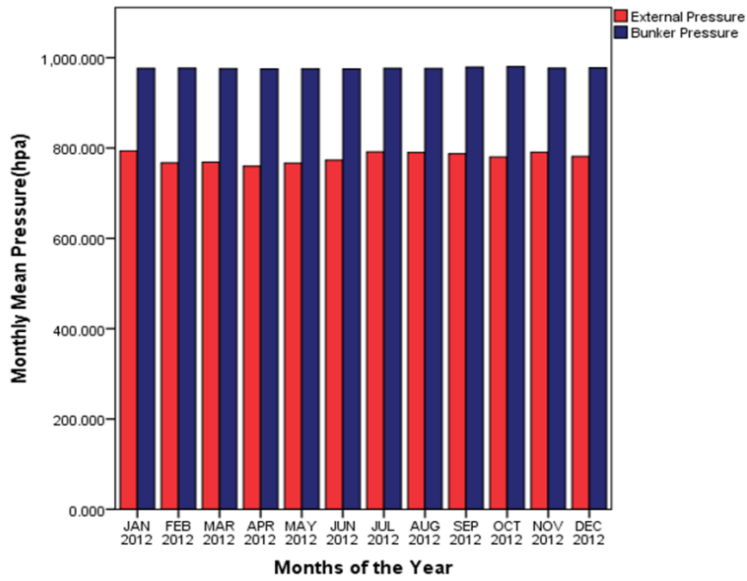**Figure 5: Bunker and environment mean monthly pressure for the year 2011**

Figure 6: Bunker and environment mean monthly pressure for the year 2012
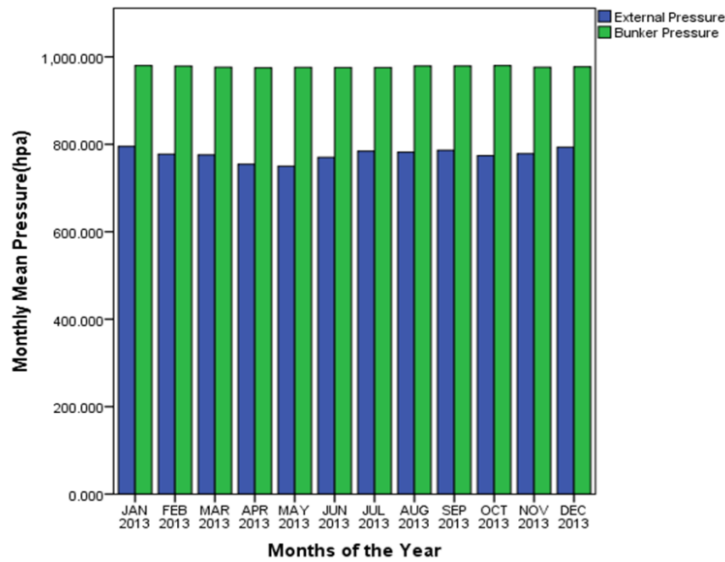

Figure 7: Bunker and environment mean monthly pressure for the year 2012
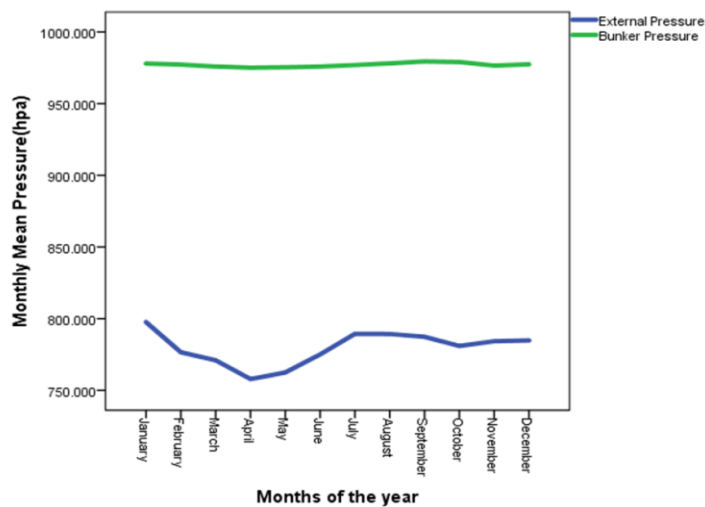

Figure 8: Overall bunker and environment mean monthly pressure for the study period
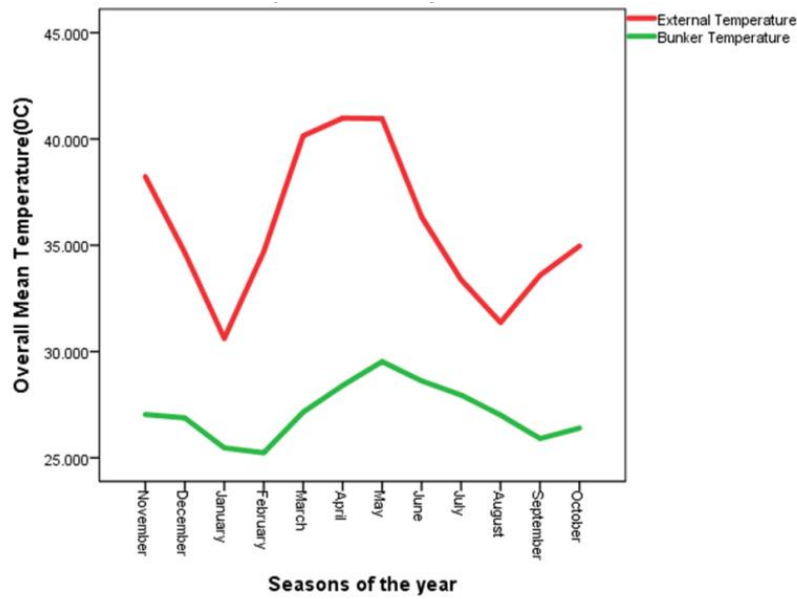
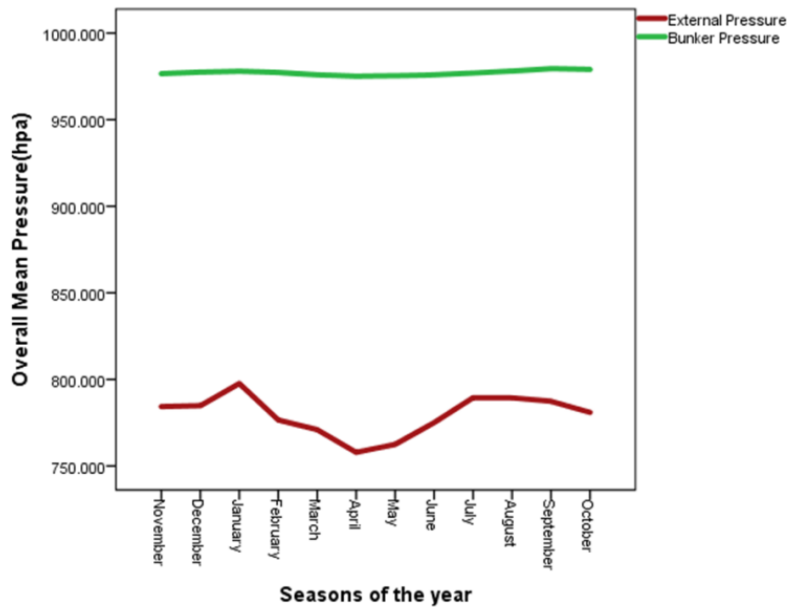**Figure 9: Seasonal behaviour of environmental and bunker mean monthly temperature for the study period**

Figure 10: Seasonal behaviour of environmental and bunker mean monthly pressure for the study period

DISCUSSIONS

The susceptibility of machines to fail increases exponentially with temperature especially in those with electronic devices [10]. In addition, there is a relationship between the performance, including the lifespan or lifecycle of an electronic component and its particular range of operating temperature [11]. This study confirmed that the daily variation of environmental temperature and pressure has a corresponding effect on bunker internal air condition where Linac is kept. Sokoto state is associated with higher temperature during hot season, with an overall environmental mean temperature recorded in this study as 35.7°C but it can go as higher as 46°C during April and May. Isezua reported similar findings, with minimum daytime temperatures to be under 40°C

(104.0°F) and the maximum exceeding 45°C.[12] This environmental temperature changes was observed to have a linear correlation with bunker temperature, the overall mean bunker temperature was found to be 27.1°C for the study period and the highest was 32°C despite the cooling effect of chillers inside bunker. The temperature behaviour for both environmental and bunker for each of the study years shows similarity and ranged between 37.5 and 46°C for environmental and 27.1 and 32°C for bunker, with little disparities between the years. From seasonal perspectives of our environment, during harmattan period (late November to early February), the environmental temperature dropped between 38 and 37°C, correspondingly the bunker temperature also dropped between 27 and 24°C. Even though, Jannifer L. Nguyen reported a weak

correlation between indoor and outdoor temperature during winter season in the western world [13], but fall in environmental temperature and its corresponding effect on bunker temperature should not be ignored, because it had been reported to affect the electronic component of machines [14]. Similarly, it can also affect the collection efficiency of gantry ionization chamber and other dose measuring devices leading to error in output measurement [15]. Hossain M. reported on effect of season on Linac output, he recorded positive output variation in summer and negative in winter [15]. Although many factors like temperature, pressure and humidity might have an inter play, but seasonal changes and it's corresponding impact on bunker had been reported to affect the performance of machines [14]. Harmattan season in our environment is synonymous with winter in western world and generally characterised by fall in both environmental and bunker temperature with similar consequences to output variation from Linac. During hot season in our environment (late February to May) the environmental and bunker temperature rises from 31 to 43°C and from 24 to 32°C respectively, this season of the year is referred to as summer in western world. Jennifer L. Nguyen reported their finding that is consistent with our result, they showed a strong correlation between indoor and outdoor temperature especially during summer period [13], this rise in temperature is also associated with Linac output changes as previously reported by Hossain M [15]. Between late May to early October marked the wet season (rainy season) and the environmental temperature dropped from 43 to 32°C and the bunker temperature also falls between 30 to 26°C. Apart from negative temperature changes which had been reported to have an influence on Linac output, wet season is also associated with higher atmospheric moisture (humidity). Although the impact of humidity changes in the bunker was reported to have minimal effect on ionization chamber [16, 17], but humidity can have adverse impacts on the other electrical components of dose measuring devices resulting to serious error in dosimetry.

The environmental pressure shows an inverse relation to temperature, it falls when temperature rises. This observation is contrary to gas law which stated that for a fixed mass of gas, at a constant volume, the pressure (p) is directly proportional to the absolute temperature (T). The reason for this contradicting behaviour of environmental temperature and pressure might be attributed to the issue of fixed volume, the environmental air is open and volume is not fixed. The air can expand in a limitless area as temperature increases, hence the relative fall in pressure as temperature rises. Despite the controversial behaviour of rising and falling of environmental pressure, it shows no corresponding effect to bunker pressure. The bunker pressure was observed to maintain a relatively constant reading; reason for this consistency might be due to the fact that the air in the bunker is denser than that of

environmental due cooling effect of chillers. These differences in density between indoor and outdoor air allow a one way flow of denser air from bunker to environmental air, since no mixture between the two, the bunker maintained a relatively constant pressure. Batolac *et al.*, reported that air pressure readings in treatment rooms did not exhibit periodic variation on a seasonal timescale [18]. This confusing phenomenon of pressure need further investigation especially in relation to atmospheric air humidity. Humidity has been observed to change over the time, with the lowest humidity recorded during dry period and the highest humidity occurring in late August during wet season. Therefore, we recommend a multi-centre study on effect of humidity on Linac output, since the country has different climatic zones.

CONCLUSION

Daily variation of external environmental temperature showed a corresponding influence on bunker temperature despite the presence of bunker chillers. However, the correlation of bunker and external environmental pressure is a complex type and non-significant, with bunker pressure being relatively constant and higher than the fluctuating external environmental pressure. Seasons of the year also affects bunker temperature, and similar complex pressure behaviours were observed between external pressure during Wet and Harmattan with slight rise in bunker pressure.

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