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Modelling risks using Quantum physics principles for health projects: Mangaung Metropolitan Municipality, South Africa

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ABSTRACT

Skin cancer and cataracts are the most important public health concerns. The social cost of these diseases, such as death, disfigurement and blindness, can be overwhelming both in terms of human suffering and the financial burdens. Much of this could be avoided by reducing exposure to solar radiation. The sun is the principal source of Electromagnetic radiation exposure for most individuals. Exposure to the sun is known to be associated with various skin cancers, accelerated skin aging, cataract (opacity in the lens of the eye) and other eye diseases, and possibly has an adverse effect on a person's ability to resist infectious diseases. Thus the current study sought to characterise long term solar radiation effects with specific reference to human health from the ground reflection (grass and dry soils) in order to alert both the public and government authorities to take measures against these catastrophic biological and anatomical effects which are likely to translate to health risk disasters including cancer. The study revealed non-significant Mann Kendall trends in both annual and seasonal (summer) temperature time series. All wavelengths computed by Wiens' Law fell within only one EM spectral band (infrared) giving a 100% probability of infrared radiation in the Mangaung Metropolitan Municipality over decades. The situation therefore needs government through health and disaster management departments to put proactive measures in place given the current rapidly changing climatic conditions in the world including but not limited to Mangaung Metropolitan Municipality.

Key words : *Stefan Boltzmann's law, Wien's law, Disaster, Health risk, Stationarity, Health project.*

Introduction

Infrared radiation is increasingly used for cosmetic and wellness purposes ranging from infrared imaging, heating, lamps, thermography, Photobiomodulation, Spectroscopy, Climatology and Astronomy, these radiation also causes numerous health risks to humans (Hubpages, 2013). Infrared is therefore defined as a thermal radiation within an electromagnetic spectrum with a wavelength ranging from 750 nm^{-1} mm (International Commission on Non-Ionisation Radiation Protection, 2016). This author further assests that despite the uses of infrared as indicated above, prolonged intensity and duration of infrared (IR) exposure damages cornea, iris, lens and retina of the human eye. Lee *et al.* (2006) emphasises that human skin is in direct contact with numerous environmental factors including solar radiation, which is one cause of photo-aging. Characterised clinically by wrinkles, mottled pigmentation, rough skin, and loss of skin tone, the major histologic alterations associated with

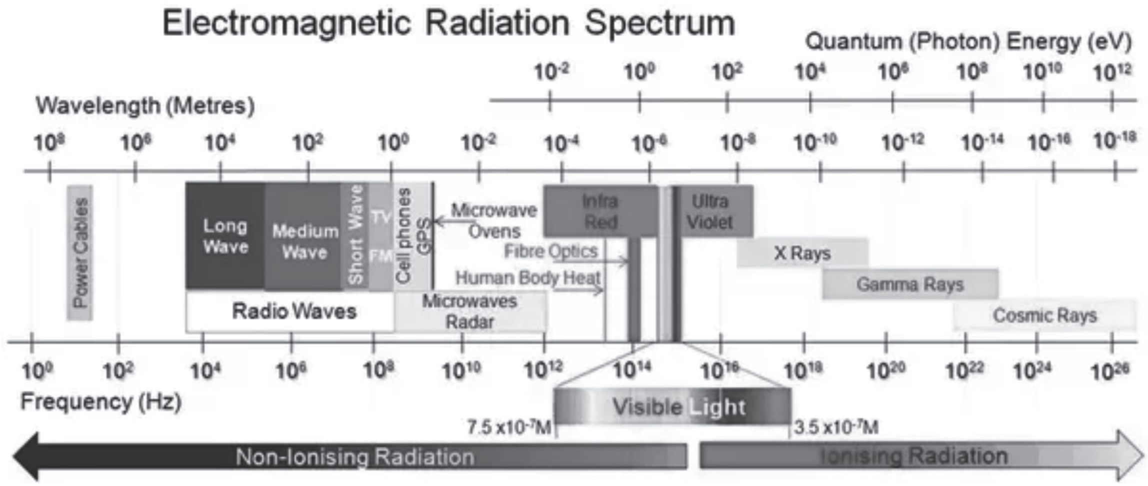

Fig. 1. Electromagnetic radiation spectrum

Source: NASA, 2016.

photo-aging lie in dermal connective tissue.

Ionisation radiation is defined as energy released by atoms which travel in Electromagnetic wave form (WHO, 2018). The spontaneous disintegration of atoms is called radioactivity, and the excess energy emitted is a form of ionizing radiation. Unstable elements which disintegrate and emit ionizing radiation are called radionuclides (WHO, 2018). All radionuclides are uniquely identified by the type of radiation they emit, the energy of the radiation, and their half-life. Furthermore people are exposed to natural sources of radiation on everyday basis from cosmic rays especially in high altitudes. Over 80% of the radiation received by man is due to naturally occurring both cosmic and terrestrial radiation sources. The emitted radiation is dependent on both geographical and geological features of the environment. Human exposure to radiation also comes from human-made sources ranging from nuclear power generation to medical uses of radiation for diagnosis or treatment (Villasenor-Mora, 2009). Today, the most common human-made sources of ionizing radiation are medical devices, including X-ray machines.

Radiation exposure may be internal or external, and can be acquired through various exposure pathways. Internal exposure to ionizing radiation occurs when a radionuclide is inhaled, ingested or otherwise enters into the bloodstream for instance, by injection or through wounds (Bosset *et al*, 2003). Internal exposure stops when the radionuclide is eliminated from the body, either spontaneously (such as through excreta) or as a result of a treatment. Moreover,External exposure may occur when airborne radioactive material such as dust, liquid, or aerosols is deposited on skin or clothes. This type of radioactive material can often be removed from the body by simply washing. Exposure to ionizing radiation can also result from irradiation from an external source, such as medical radiation exposure from X-rays. External irradiation stops when the radiation source is shielded or when the person moves outside the radiation field. People can be exposed to ionizing radiation under different circumstances, at home or in public places at their workplaces or in a medical setting (as are patients, caregivers, and volunteers). Exposure to ionizing radiation can be classified into 3 exposure situations. The first, planned exposure situations, result from the deliberate introduction and operation of radiation sources with specific purposes, as is the case with the medical use of radiation for diagnosis or treatment of patients, or the use of radiation in industry or research. The second type of situation, existing exposures, is where exposure to radiation already exists, and a decision on control must be taken for example, exposure to radon in homes or workplaces or exposure to natural background radiation from the environment. The last type, emergency exposure situations, result from unexpected events requiring prompt response such as nuclear accidents or malicious acts (Bandeen *et al.* 1961). Radiation damage to tissue and organs depends on the dose of radiation received. However, the potential damage from an absorbed dose depends on the type of radiation and the sensitivity of different tissues and organs. Given that over half of the solar energy that reaches the earth surface ins in the IR range. There is clinical evidence indicating that chronic heat exposure of human skin may cause alterations. The skin disease called erythema ab igne is known to be caused by chronic heat exposure. It is characterized clinically by reticular pigmentation of the skin and histologically by the presence of solar elastosis in the dermis similar to what is seen in photoaged skin. The reflective properties of the ground have an influence on UV exposure. Most natural surfaces such as grass, soil and water reflect less than 10% of incident UV. However, fresh snow strongly reflects (80%) UV (Bucklingham, n.d). During spring in higher altitudes, under clear skies, reflection from snow could increase UV exposure levels to those encountered during summer. Sand also reflects (10-25%) and can significantly increase UV exposure at the beach. Long term intense exposure to IR could lead to cancer. Skin cancer is the most common human cancer. About 95% of these are basal and squamous cell carcinomas commonly referred to as non-melanoma skin cancers, the remaining 5% are malignant melanoma. The scientific evidence that sunlight is an important factor in the cause of skin cancers is convincing. While it is not unusual to have some moles or freckles, it is important to watch for any moles that change colour, become bigger, itchy or inflamed, or that weep or bleed. These may be symptoms of melanoma or other skin cancers (Bandeen *et al.* 1961). Thus the current study characterises long term solar radiation effects with specific reference to human health from the ground reflection (grass and dry soil) in order to alert both the public and government authorities to take measures against these catastrophic biological and anatomical effects which are likely to translate to health risk disasters.

Methods and Materials

Data control

Temperature data was obtained from an online source (Tutiempo) from the Bloemfontein Airport station in Mangaung Metropolitan Municipality in the Free State of South Africa. A few gaps existed in the collected monthly maximum temperature data set. However, these gaps were filled with Expectation Maximum algorithm (EM). EM algorithm has always been applied in signal processing as well as in the missing data (Guerreiro and Aguiar, 2002). This procedure uses Maximum Likelihood Estimates to produce estimates of the missing data sets (Baker *et al*., 1988).

After filling the gaps in the data with the aid of SPSS software program, the data set was tested for stationarity. The stationary means that statistical structure of the series is independent of time. It allows preserving model stability that is the model which parameters and structure are stable in time. Stationarity matters because it provides a framework in which averaging can be properly used to describe the time series behaviour. The results indicated the data set stationary implying no spurious final results in the study.

Calculations

Stefan Boltzmann law states that that the power radiated from a black body is proportional to its temperature, raised to the fourth power (Bonin *et al.* 2009).

$F = \varepsilon\, \sigma\, T^4$ … Eqn 1]

Where

F =thermal radiation

ε =emissivity of the body of interest

σ = Stefan Boltzmann's constant = 5.670367×10^3

Wien's displacement law states that the black body radiation curve for different temperatures peaks at a wavelength inversely proportional to the temperature. The shift of that peak is a direct consequence of the Planck radiation law which describes the spectral brightness of black body radiation as a function of wavelength at any given temperature (Weisstein, 2017).

$\lambda_{max} = \frac{0.0029mK}{T\ (K)}$ .. [Eqn 2]

where

λ_{max} = wavelength in metres

T = temperature in Kelvins

The above two equations were used to compute both the radiant exitance and the corresponding wavelengths on annual and seasonal time steps. In order to compute the thermal radiation/radiant exitance the study the average value of the emissivities of grass and dry soil which is 0.92. This decision was based on the premise that the entire Free State province within which the study area is found, is fully covered with grassland biome. Moreover this province was been undergoing drought disaster regime from 2015 till to date. Emissivity is defined as a measure of the efficiency in which a surface emits thermal energy. It is defined as the fraction of energy being emitted relative to that emitted by a thermally black surface (a black body). A black body is a material that is a perfect emitter of heat energy and has an emissivity value of 1.

Both these time series were tested for trends using a Mann Kendall's trend test. The purpose of the Mann-Kendall test (MK) is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time. A monotonic upward trend means that the variable consistently increases through time, but the trend may or may not be linear. The MK test can be used in place of a parametric linear regression analysis, which can be used to test if the slope of the estimated linear regression line is different from zero. The regression analysis requires that the residuals from the fitted regression line be normally distributed; an assumption that is not required by the MK test, this means that the MK test is a non-parametric/distribution-free test. Finally the seasonal wavelength time series was fitted to weibull probability distribution using Kolmogorov Simonov test criterion aided by Easyfit software for modelling purposes.

Results and Discussion

This section presents the study results. Table 1 shows the statistical summary of the temperature data used in the study in Kelvins, with both minimum and maximum values were 273.85 and 299.35 kelvins respectively.

Figure 2 below also shows the graphical plot of the temperature data used in study plotted against time in years. From this graph, it can be deduced that there is change in the series across all years in the study area.

The observed lack of change was tested by a non-parametric Mann Kendall's trend test as depicted in Table 2. A two-tailed was used deployed and the null hypothesis that a trend existed was rejected with a p-value of 0.734 at 5% significance level.

Prior to any further analysis in the time series, it is important for that data sets to be examined for stationarity in order to avoid spurious end results.

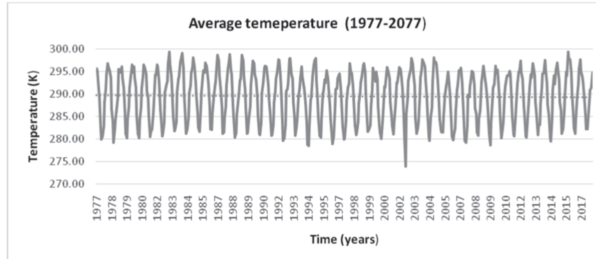

Fig. 2. Average maximum temperature plot (1977-2017)

Table 2. Mann Kendall's trend tests

Kendall's tau	-0.010
S	-1236.000
Var(S)	13191165.333
p-value (Two-tailed)	0.734
alpha	0.05
Sen's slope	$-5.196\text{x}10^{-4}$

For this reason, a Dickey-Fuller stationarity test was conducted and results showed that the series was indeed stationary and was ready for further analysis. Table 3 shows the stationarity test results with one tailed probability value of less than 0.0001 indicating that data was stationary.

Table 3. Stationarity tests (Dickey-Fuller test)

Dickey-Fuller test	(ADF (stationary)
Tau (Observed value)	-12.826
Tau (Critical value)	-0.889
p-value (one-tailed)	< 0.0001
alpha	0.05

The aim of this study was to assess long term patterns of health risks imposed by high temperature values in Mangaung Metropolitan Municipality. Using both Stefan Boltzmann and Wien laws, the energy flux and the corresponding wavelengths were computed and plotted as shown in Figure 3 and Table 4 respectively.

Table 4 shows Electromagnetic (EM) spectrum wavelengths and relative frequency per band. All the wavelengths calculated by Wiens's law formula fell within the infrared EM band. This analysis was based on annual time step from 1977 to 2017. How-

Table 1. Summary statistics of temperature in kelvins

Variable	Observations	Min	Max	Mean	Std. dev
22.5	491	273.85	299.35	289.43	278.78

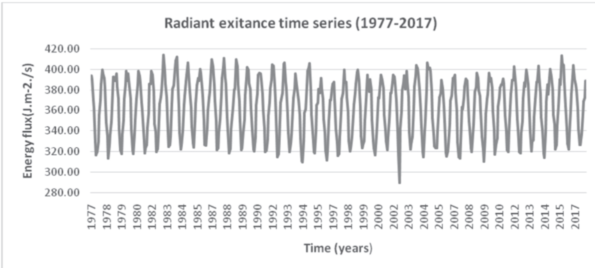

Fig. 3. Radiant exitance (Energy flux) time series (1977-2017)

Table 4. Electromagnetic spectrum wavelengths

Name	Wavelength in nm	Frequency
Gamma ray	<0.01	0
X-ray	0.01-10	0
Ultraviolet	10-400	0
Visible light	390-750	0
Infrared	750-10^6	492
Microwave	10^6-10^9	0
Radiowaves	10^6-10^12	0

ever, given no significant trends and a single EM wavelength band (infrared), it was imperative that a further temporal analysis be conducted. Most extreme temperatures are observed in summer seasons in South Africa (Bucklingham, n.d), therefore a summer season (November to January) was appropriate for this second analysis

The wavelength computed from Wien's law equation in nanometres was plotted against time in years. Figure 4 shows this plot over 41 years. Although this series was for summer season, the behaviour was the same compared to annual time step. The graph showed an increasing non-significant Mann Kendall's trend. An increase in wavelength implies a decrease in frequency thereby shifting from more dangerous EM spectral bands such as X-rays and gamma rays.

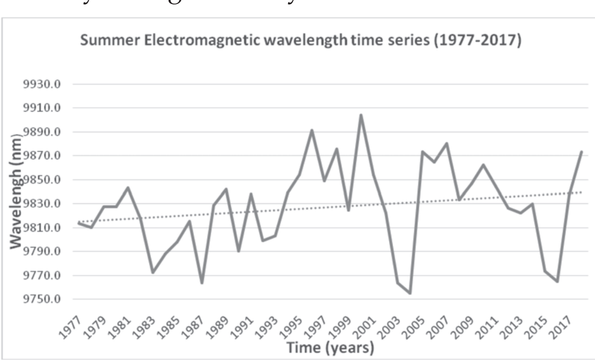

Fig. 4. Summer Electromagnetic wavelength

A corresponding summer Energy flux was plotted as shown in Figure 5 below. However there seemed to be a non-significant decreasing trend in the series with a p-value =0.18124 and a Sen' slope of -120. This finding and the previous ones indicate that whatever the conditions are, they are there to stay for next many years to come. All the wavelength values fell with the infrared EM band. From these temporal findings, the author fitted a suitable probability distribution in pursuit to model the EM radiation in the study area for the benefit and protection of lives against damaging effects of EM radiation in Mangaung Metropolitan Municipality.

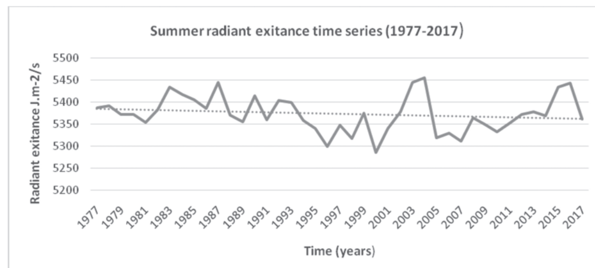

Fig. 5. Summer radiant exitance time series (1977-2017)

The summer EM wavelength time series was fitted to a Weibull probability distribution with the following determined location and shape parameters; 321.54 and 9841.9 respectively using Kolmogorov-Simonov test criterion from Easyfit computer software. Figures 6 and 7 show both Q-Q and P-P plots of the Weibull probability distribution summer EM wavelength time series.

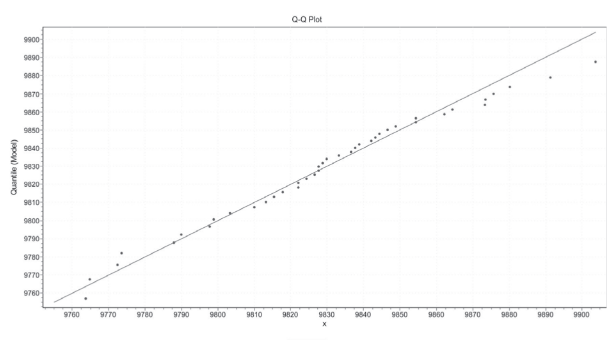

Fig. 6. Weibull probability distribution summer EM wavelength Q-Q plot

Conclusion

In conclusion, the study revealed non-significant Mann Kendall trends in both annual and seasonal

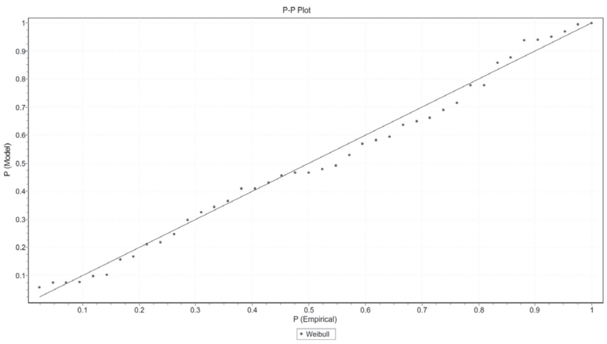

Fig. 7. Weibull probability distribution summer EM wavelength P-P plot

(summer) time series. All wavelengths computed by Wiens' Law fell with only one EM spectral band (infrared) giving a 100% probability of infrared radiation in the study area over decades. The situation therefore needs government through health and disaster departments to put measures in place given the current vast changing climatic conditions in the world. In some countries concern about high incidences of skin cancer and eye damage have led to national educational campaigns to encourage people to protect themselves against excessive IR exposure from the sun and in the workplace. Educational programmes directed at both the workforce and the public are intended to create an awareness of the adverse health effects that can result from exposure to IR and to encourage changes in behaviour to reduce this exposure. Currently, in several different countries around the world, daily environmental IR levels are supplied to the general public in the form of IR indices. Their provision is intended to educate the public on changes in IR levels, to increase awareness of the hazards of IR and to provide information necessary to plan protection. The IR index used in some countries describes the likely IR level at noon on the following day. This index may be widely publicized by radio and television stations. Therefore everyone should enjoy outdoor activities in the early morning and late afternoon on summer days, but there is good reason to adopt protective measures if a person is exposed to the sun within the 4-hour period around the middle of the day. Shade is a useful method of protection for the skin, but protects the eye only when a person faces the shaded areas. Protection is always necessary for both the skin and eyes when there is sun over snow such as hat wearing and use of sunscreens for skin protection against radiation. Parents are therefore particularly encouraged to keep IR exposure of their children to minimum levels in order to reduce the risk of IR-induced problems in later life. If the child has freckles, then sun exposure should be kept to the minimum.

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