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Comparative Studies of the Effectiveness of Different Ultraviolet Radiation Protective Welding Google in Calabar, Nigeria

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ABSTRACT: Welding goggles provide a degree of eye protection while some forms of welding and cutting are being done. They are intended to protect the eyes not only from the heat and optical radiation produced by the welding, such as the intense ultraviolet light produced by an electric arc, but also from sparks or debris. This study therefore examined the effectiveness of different Ultraviolet radiation protective welding goggles in Calabar, using appropriate method at a distance of 20, 30, 40, 50 and 60 cm from the ultraviolet radiation source from welders and the incidence ultraviolet radiation measurements were obtained. This process was repeated by inserting each goggle 3 cm from the ultraviolet meter probe and ultraviolet radiation transmittance and energy measurements were taken. The results obtained show that at a range of current 200 – 215 Ampere, all the goggles A to E transmitted very low ultraviolet radiation between (0.00 – 0.303 mW/cm^2) for all the ultraviolet band. Hence, A, B, C, D and E had transmittances at the range of (0.000 - 0.303, 0.000 - 0.217, 0.00 – 0.024, 0.000 – 0.032, 0.000 – 0.039 (J/m2) respectively for all ultraviolet bands. This result is far below the recommended International Commission on Non - ionizing Radiation Protection Standard of 30 J/m^2. Therefore, all the goggles under investigation are found to be suitable for use during welding. It is recommended that arc welders in Calabar Metropolis should continue to wear protective goggles to prevent ultraviolet radiation from entering their eyes.

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Arc welding is a fundamental technology of the manufacturing and construction industries. It is mostly used in the production of various industrial products, such as vehicles, large metal structures, electrical products and household products. Thus, arc welding plays an extremely vital role in many industrial fields. However, many hazards such as fumes (powder dust), poisonous gases, spatter (sparks), electrical shocks and hazardous optical radiation are emitted during arc welding (Walsh, 2016). These hazardous emissions can affect the health of workers and cause disastrous occupational accidents. Arc welding has diverse effects on welders and those working around the welding site because of the hazardous emissions that come from it (Mercede et al., 2014). Iwan et al.(2017) observed that major hazards welders can encounter if overlooked can cause photophthalmia, keratoconjuntivitis, cataracts; other acute effects could be skin burn (erythema) due to thermal radiation energy exposure that involve intense concentration of ultra violet(UV), infrared and intense visible light. UV is the most important modifiable risk factor for skin cancer and sight damage. Humans are exposed to various intensity levels of light from different sources and the sun is the largest single source of light providing a solar irradiance of at least 120 Watts per square meter (World Meteorological Organization, 2013). Light is hazardous and directly affects the human body and our ecosystem. Light also plays a central role in the mechanism of the destruction of the ozone layer which has resulted to global warming. Studies have shown that non-ionizing radiation in form of ultraviolet light interact with living tissues to produce severe health effects. The effect of ultraviolet radiation (UVR) (295nm-400nm) on cells is well documented, especially in the UVB region (295-320 nm).

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The effect of very long-wave UVA (>380nm) and visible radiation. (>400nm) are much less known (Karl et al, 2018). This region of UVR is known for photodamage which leads to cells viability, DNA damage (delayed cyclobutane pyrimidine dimers), and differential gene expression for genes associated with inflammation, oxidative stress photoageing and induction of oxidizing species in HaCaT(Joseph et al, 2014). This has led to the classification of ultraviolet radiation (UV) as a carcinogen by the International Agency for Research on Cancer (IARC, 2019). UV (A, B and C) are associated with increased chance of cancer and eye defects this effects can be as a result of prolonged exposure of living tissue to UV. Energy from UV radiation is known to be too small to ionize matter, but components from the higher ranges can cause alterations in bonds and normal structure of living tissue which leads to abnormal function and development in these tissues (Maier et al, 2005). Ultraviolet radiation may have positive as well as negative effects on human health, depending on the conditions of exposure and wavelength of radiation. Ultraviolet radiation is produced by many sources, in the occupational environment. There are also many artificial sources, of which welding arc are the predominant and most intense source of ultraviolet radiation (Canadian Centre for Occupational Health and Safety, 2018). An electric arc gives off visible light (wavelength 0.4 to 0.75 nm) of high intensity with brilliance 10,000 times the safe glare level of the eye (Mgonja, 2017). Arc welding is well known as artificial light source that generates strong ultra violet radiation, infrared radiation and blue light at the same time (Walsh, 2016). Bright light from arc welding is known to cause sight defects and skin cancer (International Agency for Research on Cancer, 2019). To ensure workplace health and safety, both employees and employers need to recognize hazards and prevent accident. The protection of eye against UV radiation is necessary to avoid short term damage, as well as long-term ailments. Technology advancement and use of Personnel Protective Equipment (PPE) play a key role in reducing the hazard (e.g. electricity, heat, spark, smoke, noise, UV light, among others) associated with arc welding (Cary and Helzer, 2005). The eye protection rules require that eye protectors be appropriate to a specified welding process. It is important that welders be appropriately clothed and protected from the heat, UV light, noise and spark produced during welding. A welding helmet, hand held welding shield or goggle with filter plate and cover plate is mandatory for eye protection from harmful rays of arc. It is therefore imperative to evaluate the effectiveness of welding goggles used by welders as a protection against UV radiation exposure. However, due to high increase in arc welding shops in Calabar, the need therefore arises for the evaluation of the effectiveness of eye shield used by welders in Calabar for protection against intense UV light arising from welding. Therefore, the objective of this paper is to evaluate the effectiveness of different ultraviolet radiation protective welding goggle in Calabar, Nigeria.

MATERIALS AND METHODS

Study area: The research area of this study is Cross River State, Nigeria. It is located in the south south geopolitical zone. There are diverse cultures festivals of the people as symbolised in traditional/ new yam festival, skills in carving pottery, skills in cloth/ basket weaving, farm practices.The people of Calabar are predominantly traders, fishermen, carvers, weavers and some are engage in civil service which serves as a source of income to them. Crops like maize, yam, cocoyam, vegetables, maize etc. The study area has a lot of tourists' attractions which include the Mary Slessor Tomb, Calabar Drill Ranch, Cross River National Park, Kwa falls, Tinapa Business Resort, Marina Resort, the Botanical Garden, the Old Residence Museum, the Millennium Par.

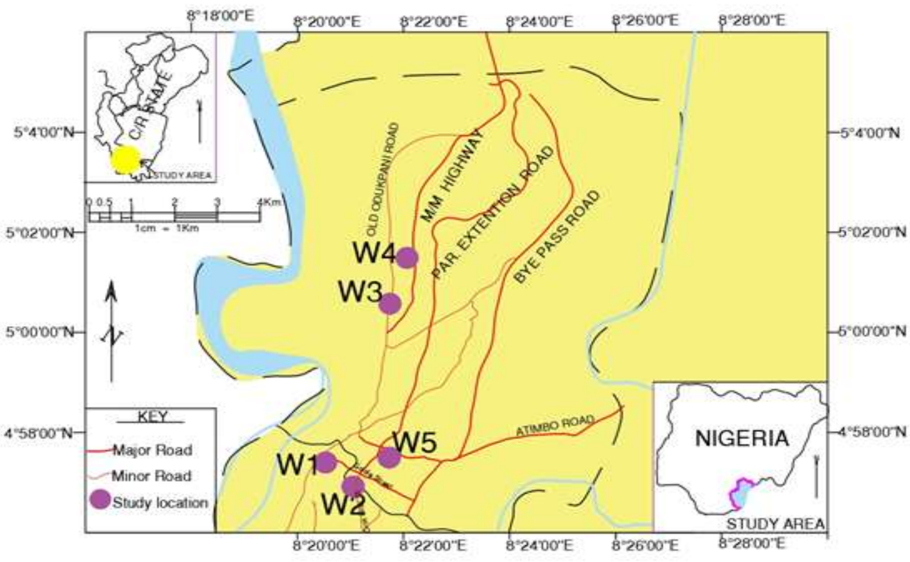

Fig.1. Location map of the study area

Data collection: In taking measurements, the UVA probe was attached to the hand-held UV meter and the probe sensor was placed in the direction of UV at a distance of 20 cm from the UV source. The radiation meter was turned on and the maximum, minimum, and average energy readings taken in every 10 seconds for 60 seconds. This process was repeated for all the probes and at 30, 40, 50 and 60 cm to obtain the amount of UV that the eye was exposed to without goggles at the respective distances.

The UVA probe was again attached on a cotton arrangement where UV goggle was inserted at a distance of 3 cm away the UV sensor. The cotton arrangement was placed in the direction of the UV source such that the probe was 20 cm from the UV source, the meter was switched on and the maximum, minimum, average energy and power readings were taken in every 10 seconds for 60 seconds. This process was repeated at a distance of 30, 40, 50 and 60 cm to mimic the different welding positions of the welders and readings were obtained at each interval. This process was repeated for all the probes. The ambient radiation was also measured in each of the selected location.

Table 1 Midpoint coordinates of the study area

Location	Label	Latitude	longitude
Chinanso Welding Workshop 139 Goldie Street - Calabar	W1	N4°56'57"	E8°20'18.618"
Iyene Welding Fabrication shop24 Orok Orok Street - Calabar	W2	N4°56'44.85"	E8°20'18.972"
Usoro Welding Workshop 39 Old Odukpani Road - Calabar	W3	N5°4'24.204"	E8°20'56.82"
Myam Welding Workshop 265 Murtala Mohammed Highway- Calabar	W4	N5°3'37.308"	E8°21'12.918"
Scarcity Welding and fabrication Workshop 97 Atimbo Road- Calabar	W5	N4°58'7.818"	E8°21'32.49"

Data analysis: The data were analyzed using Microsoft Excel and the results are presented in Fig.2 to Fig.16.

RESULTS AND DISCUSSION

The transmitted UV-A, UV-B and UV-C measured from five brands of goggles are presented in Fig. 2 - Fig.16. From Fig.2 (where the current used was 200 A, with a voltage of 180V) indicates that goggles A and B transmitted a little fraction of UV-A light (0.0001 mW/cm^2) at a distance 50 cm from UVR source, goggles C and D do not allow UV-A to pass through even at a shorter distance of 20 cm from the UVR source while the transmittance of UV-A by goggle E was observed to be 0.0001 mW/cm^2 at a distance 30 cm from UVR source. This result depicts that goggles C and D are good for the protection of UV-A compared to the other goggles used in this study.

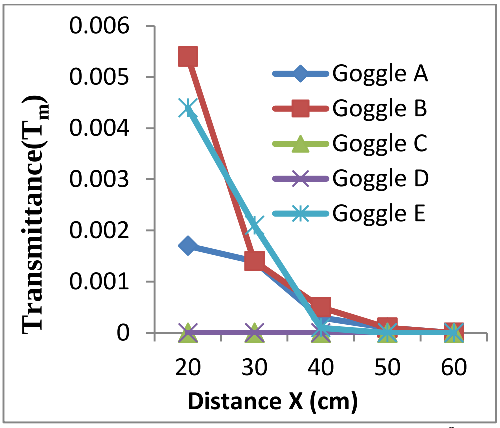

Fig.2. Incidence and transmittance of UV-A (mW/cm^2) from different Goggles
Current (I) = 200 A, Voltage (V) = 180V

Fig. 3 where the current used was 200A, and a Voltage of 180V shows that goggle A transmitted UV-B of 0.0001 mW/cm^2 only at 20 cm from UVR source and no transmission is observed at further distance. While goggles B, C, and D attenuate all UV-B ray that falls on them at 20 cm distance, a transmittance of 0.0023 mW/cm^2 was observed for goggle E at 20 cm distance and total attenuation occurred at 30 cm distance. This result shows that goggles A, B, C, D are better for the protection of UV-B compared to goggle E.

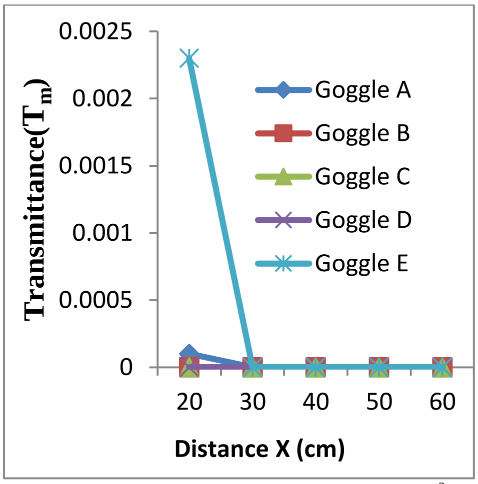

Fig.3. Incidence and transmittance of UV-B (mW/cm^2) from different Goggles
Current (I) = 200 A, Voltage (V) = 180V

Fig.4 indicates that all the goggles under study except goggle A attenuate all the incidence UV-C from a current of 200 A, and voltage of 180V that falls on then, while goggle A allowed a transmittance of 0.0001 mW/cm^2 at 30 cm and total attenuation occurs at 40 cm. this result shows that goggles B, C, D and E are good for the protection of UV-C. Fig. 5 indicates that current of 210A and voltage of 200V were used indicates that goggles A, B and E transmitted UV-A in a greater amount compared to when a current 200 A was used. The observation also shows that goggle B transmitted high amount of UV-A (0.0008 mW/cm^2) at 50cm compared to goggle A (0.0008 mW/cm^2) and goggle E(0.0008 mW/cm^2), while goggles C and D attenuate the entire incidence UV-A. This result implies that goggle C and D were best suited from the studied goggles for the protection of UV-A.

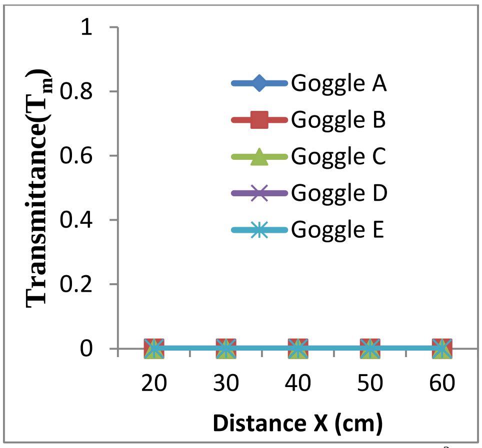

Fig.4. Incidence and transmittance of UV- C (mW/cm^2) from different Goggles
Current (I) = 200 A, Voltage (V) = 180V

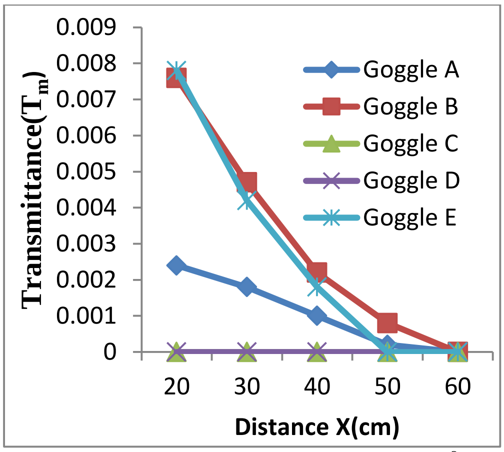

Fig.5. Incidence and transmittance of UV-A (mW/cm^2) from different Goggles
Current (I) = 210 A, Voltage (V) = 200V

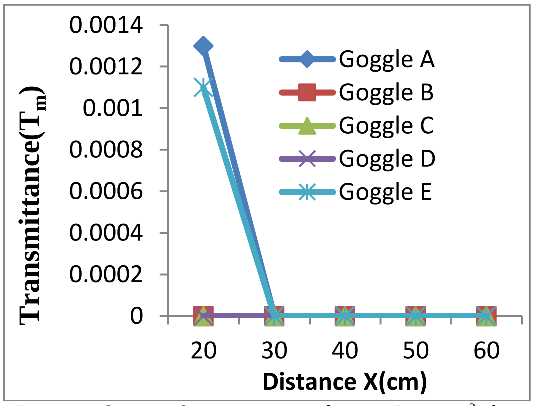

Fig. 6. Incidence and transmittance of UV-B (mW/cm^2) from different Goggles
Current (I) = 210 A, Voltage (V) = 200V

Fig. 6 where the current and voltage used were 210 A, 200V respectively, the results indicate that goggles A and E allowed the passage of UV-B (0.0013 mW/cm^2) and (0.0011 mW/cm^2) respectively through it at 20 cm from the UVR source, and the total attenuation of UV-B occurs at 30 cm for both goggles. The result further shows that goggles B, C, and D do not allow transmittance of UV-B to occur on them. This result indicates that goggles B, C and D are best among the studied goggles for UV-B protection at a current and voltage of 210A, 200 V respectively. Fig. 7 gives the incidence and transmittance of UV-C at a current and voltage of 210 A and 200V respectively for the selected goggles. The result indicates that only goggle A that allow the transmittance of UV-C (0.0003 mW/cm^2) at 30 cm to occur on it, while goggles B, C, D and E attenuate all incidence UV-C. This result depicts that goggles B, C, D and E are good for the protection of UV-C at a current and voltage of 210 A and 200V respectively.

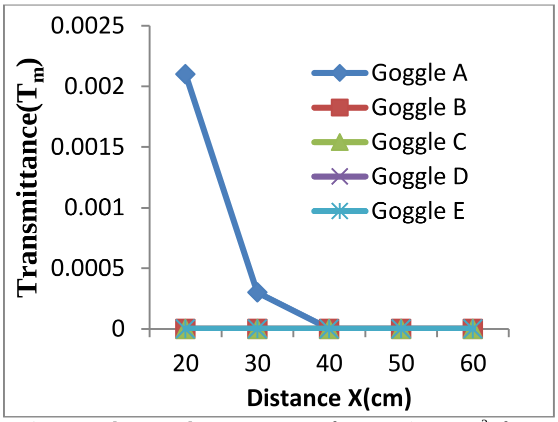

Fig.7. Incidence and transmittance of UV- C (mW/cm^2) from different Goggles
Current (I) = 210 A, Voltage (V) = 200V

Fig.8 shows the transmittance of UV-A at a current and voltage of 215 A and 250V respectively, for the selected goggles, the result indicates that goggle A has the highest transmittance (0.0016 mW/cm^2) followed by goggle B at 50 cm from the UV source. The result further indicates that transmittance of 0.0022 mW/cm^2 for goggle E at 40 cm with total attenuation occurring at 50 cm away from the UV source. Furthermore, transmittance of 0.0011 mW/cm^2 and 0.0013 for goggles C and D at 20 cm was observed with a total attenuation occurring at 30 cm away from the UV source. These results suggest that goggles C and D are better at a current and voltage of 215 A and 250 V respectively. Fig. 9 gives the transmittance of UV-B from the selected goggles, this result shows the transmittance of UV-B at 20 cm to be 0.0018, 0.0012, 0.0003, 0.0005 and 0.0014 mW/cm^2 for goggles A, B, C, D and E respectively, and the total attenuation for all the selected goggles occurred at 30 cm from the UV source. This result indicates the effectiveness of the selected goggles in the order, goggle C, D, B E and A respectively at a current of 215 A with a voltage of 250 V.

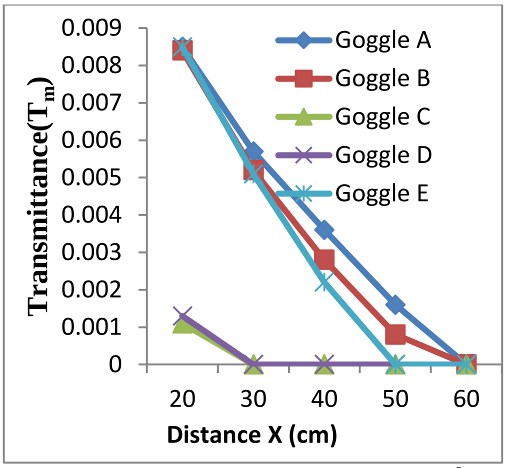

Fig.8. Incidence and transmittance of UV-A (mW/cm^2) from different Goggles
Current (I) = 215 A, Voltage (V) = 25 V

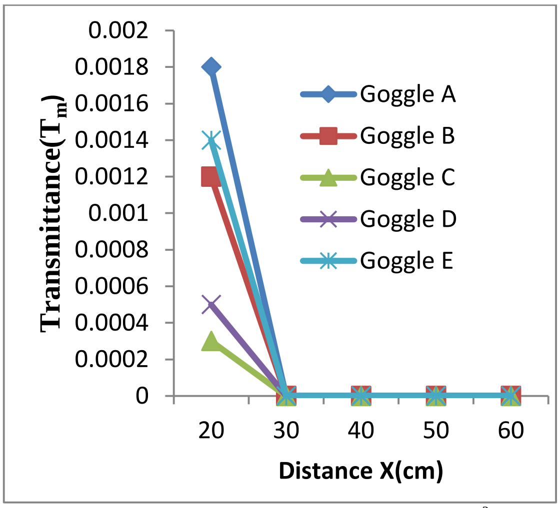

Fig. 9: Incidence and transmittance of UV-B (mW/cm^2) from different Goggles
Current (I) = 215 A, Voltage (V) = 250V

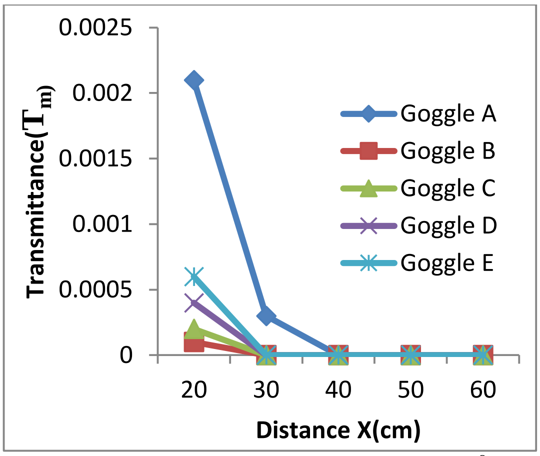

Fig. 10: Incidence and transmittance of UV- C (mW/cm^2) from different Goggles
Current (I) = 215 A, Voltage (V) = 250 v

Fig. 10 shows the transmittance of UV-C at a current of 215 A, with voltage of 250 V for the selected goggles. This result shows that goggles B, C, D and E has transmittances of 0.0001, 0.0002, 0.0004 and 0.0006 mW/cm^2 respectively at 20 cm from UV source. This result shows that goggles B, C, D and E are good for protection from the effects of UV-C compared to goggle A with 0.0021 mW/cm^2 at same distance from the UV-C source. Fig.11 where a current of 222 A and voltage of 300V was used shows transmittance of 0.0011 mW/cm^2 at 60 cm for goggle A, 0.0012 and 0.0002 at 50 cm for goggles B and E, while total attenuation of UV-A occurs at 30 cm for goggles C and D. This results depict that goggles C and D are better for the protection of UV-A.

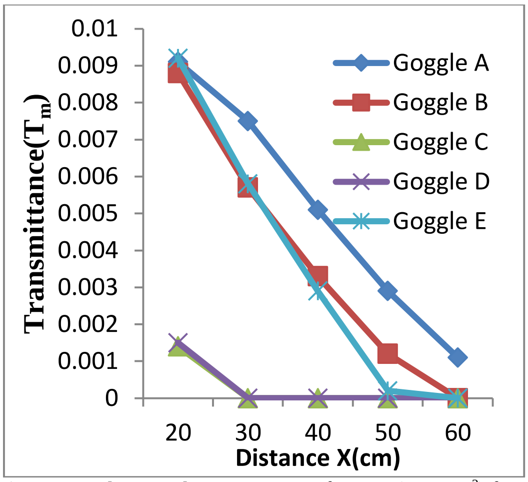

Fig. 11: Incidence and transmittance of UV-A (mW/cm^2) from different Goggles
Current (I) = 222 A, Voltage (V) = 300V

Fig.12 shows that transmittance of UV-B occurs only at 20 cm for all the observed goggles at a current of 222A and a voltage of 300V with transmittance of 0.0018, 0.0009, 0.0006, 0.0007 and 0.0016 mW/cm^2 for goggles A, B, C, D and E respectively.

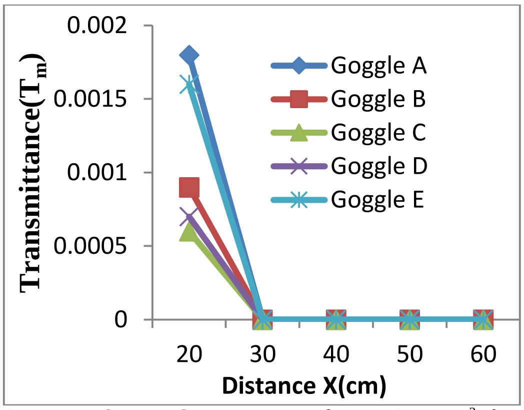

Fig. 12: Incidence and transmittance of UV-B (mW/cm^2) from different Goggles
Current (I) = 222 A, Voltage (V) = 300V

Fig. 13 shows transmittance of UV-C (mW/cm^2) from different goggles at a current of 222 A and a voltage of 300 V. This result shows that transmittance of UV-C occurs for all the study goggles at 20 cm with limited amount with highest transmittance occurring on goggle A which extends at 30 cm. this result indicates that goggles B, C, D and E are good for the protection of UV-C.

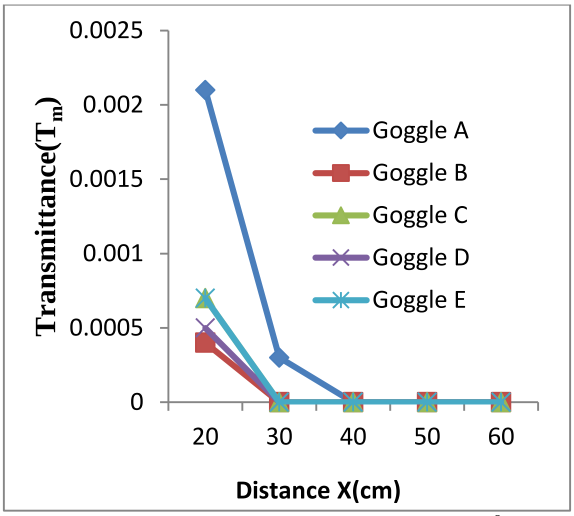

Fig. 13: Incidence and transmittance of UV-C (mW/cm²) from different Goggles
Current (I) = 222 A, Voltage (V) = 300V

Fig. 14 shows the transmittance of UV-A (mW/cm²) across different goggles at a current of 230A and a voltage of 350V. This result shows that goggles C and D are better for the protection of UV-A, since transmittance of UV-A (0.0001 mW/cm²) occurs at 30 cm for both goggles. Transmittance of 0.0034 mW/cm² was observed for goggle A at 60 cm while that for goggle B and E were observed to be 0.0012 and 0.0005 mW/cm² respectively at 50 cm.

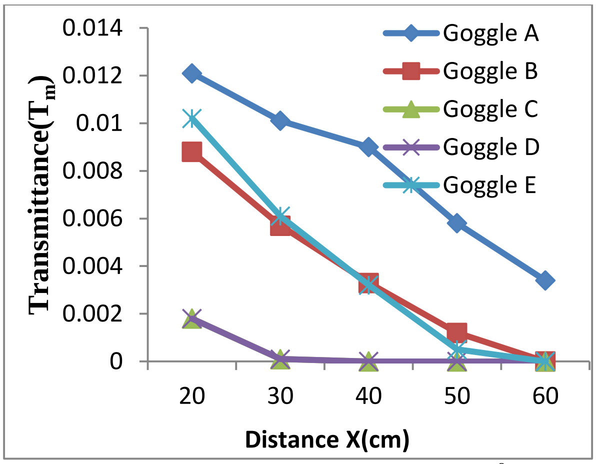

Fig. 14: Incidence and transmittance of UV-A (mW/cm²) using different Goggles
Current (I) = 230 A, Voltage (V) = 350V

Fig.15 shows the transmittance of UV-B (mW/cm²) from different Goggles at a current of 230A and a voltage of 350V. This result shows that goggles B, C, and D are good for UV-B protection they allow a little of its ray to transmit through only at a short distance of 20 cm.

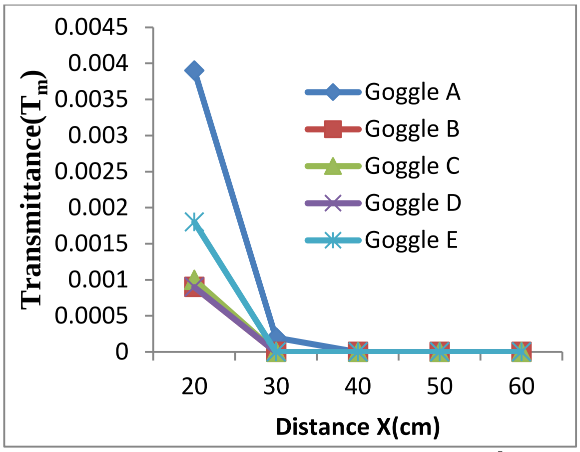

Fig. 15: Incidence and transmittance of UV-B (mW/cm²) from different Goggles
Current (I) = 230 A, Voltage (V) = 350V

Fig. 16 shows the transmittance of UV-C from different Goggles at a current of 230 A and a voltage of 350V. This result also shows that goggles B, C, and D are good for UV-B protection since a very little of UV-C rays were transmitted through only at a short distance of 20 cm and attenuates completely at a further distance (30 cm).

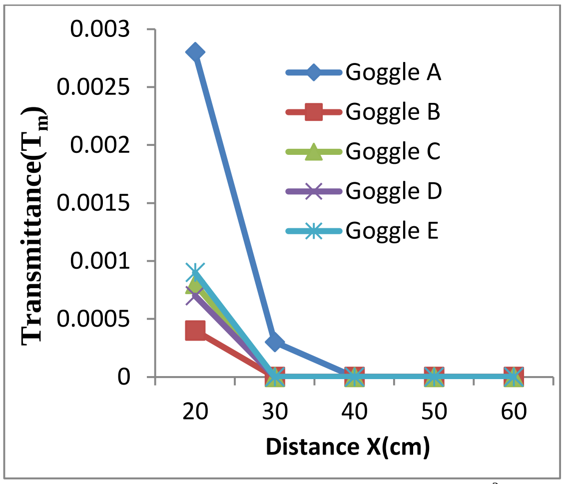

Fig. 16: Incidence and transmittance of UV- C (mW/cm²) from different Goggles
Current (I) = 230 A, Voltage (V) = 350V.

Average ultraviolet radiation (UVR) energy of goggles at selected distances (X) with varying current (I): UVR energy of goggles at selected distances (X) with varying Current (I) were measured and the average energy was computed and the result is presented on Table 2 – Table 4 for UV-A, UV-B and UV-C respectively.

Table 2: Average Energy (J/m²) of UV-A from Different Goggles at Selected Distances and current

X(cm)	I(A)	Goggle A	Goggle B	Goggle C	Goggle D	Goggle E
20	180	0.303	0.217	0.022	0.032	0.193
30	210	0.199	0.205	0.015	0.001	0.117
40	215	0.111	0.076	0.000	0.000	0.059
50	222	0.039	0.037	0.000	0.000	0.021
60	230	0.025	0.000	0.000	0.000	0.000

Table 3: Average Energy (J/m^2) of UV-B from Different Goggles at Selected Distances and Current

X(cm)	I(A)	Goggle A	Goggle B	Goggle C	Goggle D	Goggle E
20	180	0.014	0.01	0.008	0.017	0.039
30	210	0.004	0.000	0.000	0.000	0.000
40	215	0.000	0.000	0.000	0.000	0.000
50	222	0.000	0.000	0.000	0.000	0.000
60	230	0.000	0.000	0.000	0.000	0.000

Table 4: Average Energy (J/m^2) of UV-C from Different Goggles at Selected Distances and Current

X(cm)	I(A)	Goggle A	Goggle B	Goggle C	Goggle D	Goggle E
20	180	0.097	0.007	0.024	0.01	0.022
30	210	0.03	0.000	0.000	0.000	0.000
40	215	0.000	0.000	0.000	0.000	0.000
50	222	0.000	0.000	0.000	0.000	0.000
60	230	0.000	0.000	0.000	0.000	0.000

Table 2 indicates that the highest amount of UV-A energy (0.303 J/m^2) at 20 cm at a current of 180 Ampere was observed in goggle A followed by goggle B (0.217 J/m^2). Table 3 indicates that the highest amount of UV-B energy (0.017 J/m^2) was observed in goggle D at 20 cm followed by goggle A. Table 4 indicates that the highest amount of UV-C energy (0.017J/m^2) was observed in goggle A (0.097 J/m^2) at 20 cm followed by goggle C. The results in Table 2-Table 4 show that all the goggles are good for the protection of UV-A, UV-B and UV-C. This is based on the fact that their ultra violet energy is far below the International Commission on Non-ionizing Radiation Protection (ICNIRP) standard of 30 J/m^2 for eyes and skin. This finding is in line with Bah et al (2021) who revealed that the use of protective equipment during welding operations will reduce the cause of great ocular morbidity among welders. Also Sawyerr *et al* (2020) observed that when irradiance level is below the recommended standard, it indicates that UV radiation from arc welding may not be harmful to the eyes and vice versa. The finding is also in consonance with Saeed *et al.* (2016) who revealed that the values of transmittance of the investigated goggles varied from each UV brand and showed an overall reduction in transmittance in all wave bands in addition, Majolagbe *et al* (2015) observed that eyesight defects (watery eyes and aches in the eyes after continuous operation with no eye goggle.

Conclusion: The energy transmitted through all the goggles studied shows that the energy transmitted were far below the 30 J/m^2 recommended standard indicating that all the goggles under investigation are good to be used during welding. Based on the findings of this study, it was recommended that arc welders should be encouraged to use protective goggles at all times during welding operations to protect their eyes from ultra violet radiation. Also arc welders should be educated on the dangers and risks associated with their operations without using suitable protective goggles.

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