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Skin Cancer: The Ozone Layer and UV Radiation

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ABSTRACT

The ozone layer is a thin, invisible layer that protects life on earth. It is made up of several ozone molecules that are recreated and destroyed by ultraviolet radiation from the sun. Ultraviolet radiation, commonly known as UV radiation, is not visible to the human eye and exhibits wavelengths from 10 to 400 nm. UV radiation has three types: UVA, UVB, and UVC. The ozone layer completely absorbs UVC, mostly absorbs UVB, and slightly absorbs UVA. UVB and UVA radiation are the primary non-genetic factors for skin cancer and disease. UV radiation causes DNA damage, resulting in uncontrolled cellular growth of cancerous cells and mutations. Types of skin cancer are divided into melanoma and nonmelanoma. Both are commonly marked by abnormal formations on the skin. This research paper uses statistics and data on the ozone layer, UVR, and skin cancer to highlight the correlation between these three factors. The ozone layer directly affects the penetration of UVR into the atmosphere; UVR directly affects the generation of skin cancer. Therefore, our study demonstrates that the relationship between the ozone layer and UVR exposure is vital to preventing skin cancer.

Introduction

Skin cancer is one of the most common cancers in the world. It is an intimidating disease that can cause symptoms such as itches, burns, and bleeding. Sunburns are very frequent, and continued sun exposure can eventually lead to skin cancer. Although the survival rate for skin cancer is relatively high, skin cancer diagnoses will continue to increase, causing distress worldwide. Thus, factors that cause skin cancer must be recognized and obstructed. However, the ozone layer, which lies thousands of meters above the earth's surface, is the main factor limiting skin cancer. The leading cause of this formidable disease can be linked to a combination of genetic and non-genetic factors. Of all the non-genetic elements, exposure to ultraviolet radiation - commonly known as UVR - has the most significant contribution to damaging skin cells. UV radiation damages the DNA and causes genetic mutations in skin cells, generating skin cancer. Therefore, exposure to UV radiation must be prevented to limit the growth of this disease. However, most of the ultraviolet radiation that is emitted from the sun does not reach the earth. The ozone layer blocks almost the entirety of the ultraviolet emitted from the sun. Its role in protecting against skin cancer is crucial. Due to its protection from UV radiation and skin cancer on the earth, the ozone layer must be preserved and protected.

This research paper presents an alternative view of the relationship between UV radiation and skin cancer, presenting the data and statistics through graphs to show the link between the ozone layer, UV radiation, and skin cancer. It provides a better statistical understanding of the causation relationship between factors that cause skin cancer on top of the chemical and biological information provided by previous research. It provides graphs and statistical analysis demonstrating the relationship between the ozone layer, UV radiation, and skin cancer. It also includes information about how the different factors interact biologically and chemically in a way that prevents or causes skin cancer. This paper aims to answer how the ozone layer affects skin cancer through biological, chemical, and statistical methods.

The Ozone Layer

The ozone layer, which lies mainly in the stratosphere, plays an essential role in protecting the earth from its exposure to UV radiation. It is an invisible, thin layer made up of ozone molecules. Ozone is a molecule made out of 3 oxygen atoms. Ozone molecules are constantly destroyed and recreated in this layer. Stratospheric ozone is formed by a chain of reactions involving UV radiation and atmospheric oxygen molecules (Rowland, 2006). As shown in Figure 1, oxygen molecules in the atmosphere react with UV radiation, separating them into two monoatomic oxygen atoms. Then, other oxygen molecules react with the separated oxygen atoms to form ozone. Therefore, the stratosphere, penetrated by UV radiation and filled with oxygen molecules, is suitable for holding most of the ozone layer.

1. O_2 + UV Radiation $\rightarrow O + O$
2. $O + O_2 \rightarrow O_3$

   $O + O_2 \rightarrow O_3$

Figure 1. The production of ozone in the atmosphere

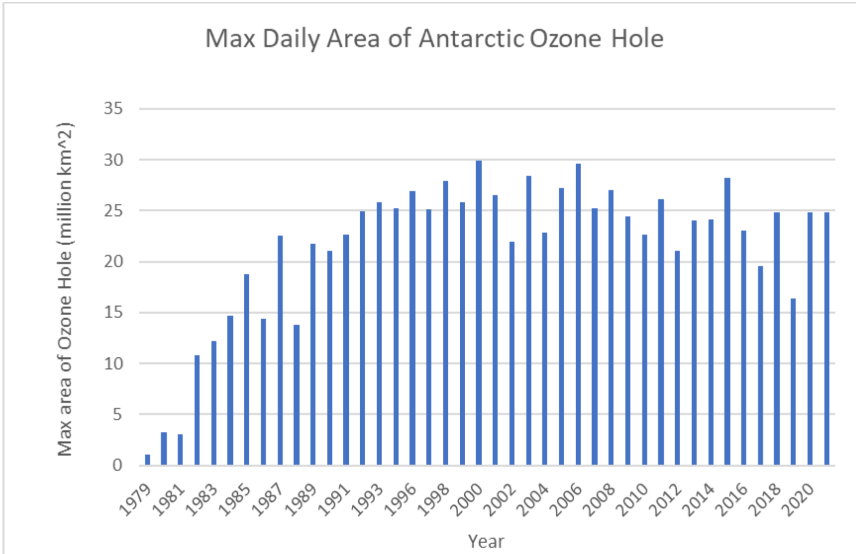
How the ozone layer has changed over time

However, the ozone layer has changed over time. Older products in the twentieth century, such as refrigerators, air-conditioners, and insulation foam, released a chemical in the air called CFCs, short for chlorofluorocarbons. Once CFCs enter the atmosphere, the molecules are broken by UV radiation. As a result, Cl is released from the structure of the molecule. Then, as shown in Figure 2, the released chlorine reacts with ozone to form chlorine monoxide and an oxygen molecule. Then, the chlorine monoxide reacts with a singular oxygen atom that has been previously separated to form chlorine and an oxygen molecule. The chlorine molecule again starts this cycle, reacting with ozone. Over time, the ozone layer is depleted. As a result, the ozone hole's size has remained an issue for the past 50 years.

1. $Cl + O_3 \rightarrow ClO + O_2$
2. $ClO + O \rightarrow Cl + O_2$
3. Net Reaction: $Cl + O_3 + O \rightarrow ClO + 2\ O_2$

Figure 2. Ozone depletion by released chlorine atoms from chlorofluorocarbons

As shown in Figure 3a, after the production of CFCs throughout the atmosphere, the area of the Antarctic ozone hole rapidly increased starting in the 1980s. The ozone hole is a region of the ozone layer where the ozone concentration is thinner than usual. The size of the ozone hole is calculated in terms of million kilometers squared. As the ozone hole increases, less UV radiation is absorbed by the ozone layer, exposing the earth to the harmful effects of UV radiation. As shown in Figure 3b, the minimum value of ozone in the Antarctic varies inversely with the size of the hole. When the size of the hole increases, the concentration of ozone decreases. When the size of the hole decreases, the concentration increases. The value of ozone in the Antarctic is calculated in terms of Dobson Units. One Dobson Unit is the number of ozone molecules to create a layer of pure ozone 0.01 millimeters thick at standard temperature and pressure. An ozone concentration of 1 Dobson Unit for a column would contain about 2.69×10^{16} ozone molecules for each square centimeter of its base (NASA Ozone Watch, 2018). Thus, the ozone hole suddenly surged due to increased CFCs and decreased ozone concentration. Despite efforts to slow ozone depletion, including banning CFC products, the ozone layer's recovery has been slow. As a result, ozone depletion remains a significant problem.



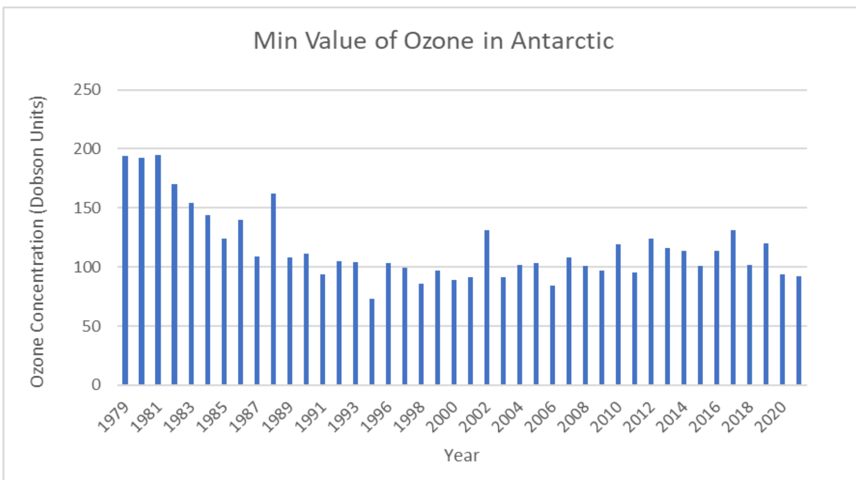


Figure 3. Changes in the Antarctic ozone layer from 1979 to 2022 (Data Source: NASA Ozone Watch. Available at https://ozonewatch.gsfc.nasa.gov/).

The impact of the ozone layer on UV Radiation exposure

The ozone layer absorbs UV radiation, protecting the earth from exposure to UVR. Ozone completely absorbs low wavelength UVR (100 to 280 nm), mostly absorbs moderate wavelength UVR (280 to 315 nm), and does not absorb high wavelength UVR (315 to 400nm) (Watson et al., 2016). As shown in Figure 4, the ozone molecule absorbs UV radiation to break down into an oxygen molecule and a monatomic oxygen atom. However, the oxygen molecule and atom bond later to form ozone again. Therefore, the destruction and recreation of ozone is a constant cycle involving UV radiation's penetration.

1. O_3 + UV Radiation → O_2 + O

2. O_2 + O → O_3

Figure 4. Absorption of UV radiation by ozone

Emission of UV Radiation

Ultraviolet is a specific type of electromagnetic radiation between 10 and 400 nm wavelengths (Watson et al., 2016). UV radiation is not visible to the human eye. Although it is not visible, UV radiation still significantly impacts life on earth. While UV radiation is necessary for mediating Vitamin D and endorphin synthesis, excessive exposure to UV radiation presents extreme problems such as wrinkling, atrophy, and pigmentary changes (D'Orazio, 2013). Thus, exposure to the right amount of UVR is essential to a healthy lifestyle. Excessive or insufficient UV radiation can have negative repercussions.

Types of UV Radiation

As shown in Table 1, there are three different types of UV radiation: UVA, UVB, and UVC. The three types are classified based on their wavelength, ability to pass the ozone layer, and effects. UVA has a wavelength from 315 to 400 nm. It has the lowest energy. UVA is not absorbed by the ozone, so 90 to 99 percent reaches the earth's surface. However, out of the three, UVA has the least harmful effects. Exposure to UVA for an extended period can develop skin aging and indirect DNA damage (Narayanan et al., 2010). UVB has a wavelength from 280 to 315 nm. UVB is mostly absorbed by the ozone, and 1-10 percent reaches the earth's surface. Extended exposure to UVB can cause tanning, which indicates damage to the skin (Watson et al., 2016). It can also cause sunburns, wrinkling, and structural DNA damage (Narayanan et al., 2010). Finally, UVC has the most dangerous effects, but the ozone layer completely absorbs it. It can cause skin burning and cancer (Narayanan et al., 2010). However, all wavelengths can cause DNA damage, ultimately leading to the formation of cancerous cells.

Table 1. The different types of UV radiation characterized by wavelength, ability to pass the ozone layer, and effects

Type	Wavelength (nm)	Ability to pass the ozone layer	Effects
UVA	315 to 400	Not absorbed by the ozone layer 90 to 99% reaches the earth's surface	- Harmful if exposed to for an extended period - Causes skin aging - Penetrate deep into the skin through the epidermal junction - Causes Indirect DNA damage
UVB	280 to 315	Mostly absorbed by the ozone layer 1 to 10% reaches the earth's surface	- Directly absorbed by DNA, causing structural DNA damage - Causes sunburns, wrinkling, tanning - Overexposure can cause swelling, pain, erythema - Can cause skin cancer
UVC	100 to 280	Completely absorbed by the ozone layer	- Causes skin burning, aging, wrinkling - Can cause skin cancer

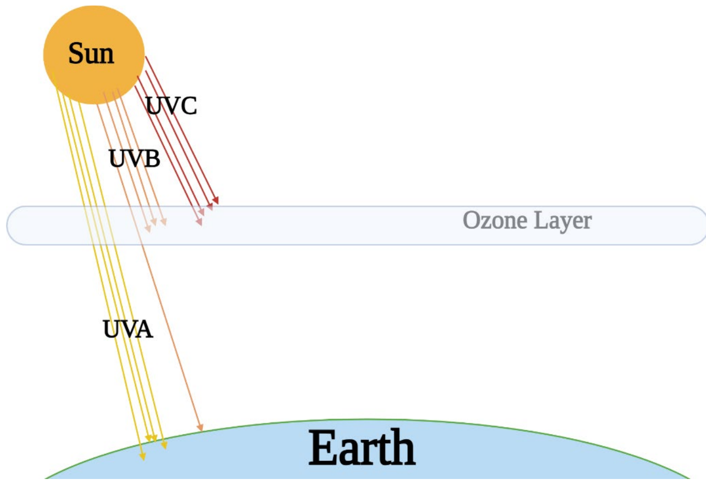


Figure 5. The ability of UVA, UVB, and UVC to pass the ozone layer to reach the earth

Factors that affect exposure to UVR

Several factors affect one's exposure to UV radiation. Since UV radiation comes from the sun, individuals who have extended exposure to the sun or more likely to have exposure to UV radiation. Factors that influence the amount of sun exposure include location on earth, occupation, and the time of year or day. Location on earth heavily impacts exposure to the sun. Since solar radiation travels a smaller distance to reach the equator, people living near the equator are exposed to much more radiation. UV rays travel a shorter distance at latitudes near the equator, so more UV radiation is emitted near the equator. In addition, outdoor occupations require extended exposure to sunlight compared to indoor occupations. This puts outdoor occupations more susceptible to harmful amounts of exposure to UV radiation. Lastly, the sun's rays have the least distance to travel from 10 AM to 4 PM. Also, the UVB levels are at their peak at this time. So, from 10 AM to 4 PM, UV radiation levels are at their highest daily. On an annual level, UV intensity tends to be highest during summer. Figure 6 displays the disparity in UV index during the seasons for five major United States cities. The UV index measures the amount of UV radiation that reaches the earth's surface. The UV index goes from 1 to 11 and above. 1 to 2 on the UV index scale is low; 3 to 5 is moderate; 6 to 7 is high; 11 and above is extreme. While the average UV index is from low to high during the summer, the average UV index during the winter is from high to extreme.

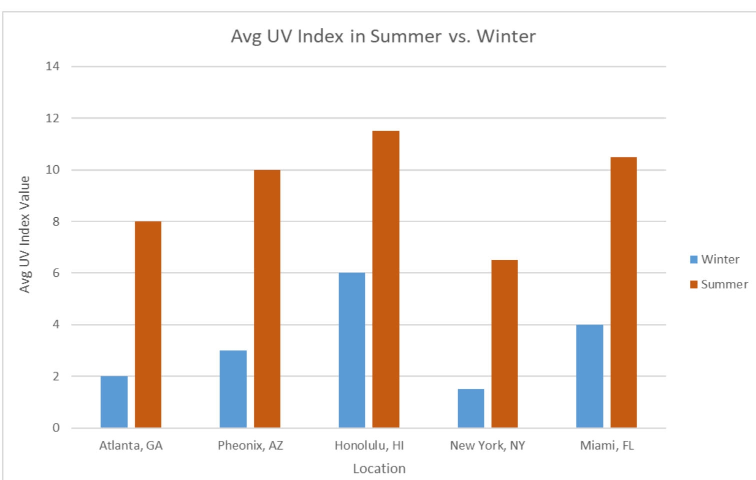


Figure 6. The average UV index difference between winter and summer (Data Source: Office of Air and Radiation, 2004. Available at https://www.epa.gov/sites/default/files/documents/uviguide.pdf).

UV radiation causes skin cancer

As shown in Figure 7, UVB penetrates the epidermis while UVA penetrates deeper into the dermis. In the epidermis, the UVB reaction leads to DNA lesions, DNA molecule sections containing a primary damaged site. Skin cells can repair this damage. However, if enough DNA damage accumulates over time, the repair process can eventually form mutations that cause skin cancer. However, in most cases, skin cells in the epidermis called melanocytes produce melanin to combat the damage to skin cells. Melanin can absorb UV light to some extent, but not completely. Therefore, UVB usually causes skin burning and tanning (Rastogi et al., 2010). UVA contributes to skin aging and wrinkles. UVA damages the scaffolding in the skin, making it more prone to wrinkling and aging.

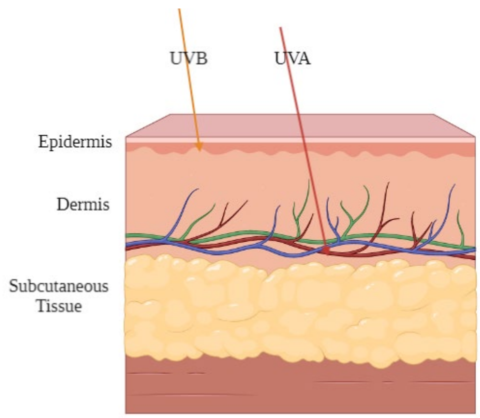


Figure 7. The penetration of UVA and UVB into the skin

Locations with skin cancer

Locations with some of the highest percentages of cancer attributable to UV radiation include New Zealand, Australia, Norway, Denmark, and Sweden. For all the countries listed and more, more than 90% of cancers are attributable to UV radiation (Arnold et al., 2018). The five countries listed are in similar regions. New Zealand and Australia reside in the Australasia region. Norway, Denmark, and Sweden reside in Scandinavia. Australasia exhibits high amounts of UV radiation, with a tendency for outdoor activities. As a result, many people in Australia and New Zealand are susceptible to cancer from UV radiation. Scandinavia has a practice of indoor UV tanning. As a result, people in this region are exposed to extended periods of UV radiation. Due to this practice, this region has a high ratio of cancers attributable to UV radiation.

Types of skin cancer

There are two types of skin cancer- melanoma and nonmelanoma. Melanoma cancer develops in the skin's melanocytes. It is less common than nonmelanoma cancers. Melanocytes, found in the upper layer of skin, produce melanin that gives color to one's skin. UV radiation causes skin damage, triggering melanocytes to produce eumelanin. Eumelanin is a type of melanin that darkens the skin to protect it from more UV damage. However, DNA damage caused by UV radiation can cause mutations in the melanocytes. Mutations can stimulate new cells to grow out of control, forming cancerous cells (Narayanan et al., 2010). To educate physicians and the public about diagnosing melanoma, the "ABCD" criteria were developed in 1985. It stands for Asymmetry, Border irregularity, Color variegation, and Diameter greater than 6 mm (Rastrelli et al., 2014). These are some common attributes for diagnosing melanoma cancer. The two main types of nonmelanoma skin cancer are basal cell carcinoma (BCC) and squamous cell carcinoma (SCC). BCC is the most common skin malignancy in the world. It originates from basal cells in the epidermis. DNA damage causes uncontrolled cellular growth in these cells. It appears shiny and glossy (Dika et al., 2020). Lastly, SCC originates from the squamous cells. Squamous cells are located near the surface of the skin. DNA damage triggers changes in the squamous cells, causing SCC. It appears crusty and scaly (Corchado-Cobos et al., 2020).

Conclusion

In summary, skin cancer presents a significant, deleterious problem to society. While exposure to sunlight is necessary, extended exposure can result in important issues such as skin cancer. Sunlight contains UV radiation, which is not visible to the human eye. UV radiation has three types- UVA, UVB, and UVC. However, the ozone layer can block earth's life completely from UVC and mostly from UVB. The ozone layer, a thin layer of ozone molecules, absorbs UV radiation by destroying and recreating ozone molecules. Therefore, the ozone layer plays a vital role in protecting life on the earth. However, during the late 1970s, a large portion of the ozone layer was depleted, making protection from UV radiation a significant issue. UV radiation causes cancer by penetrating the skin, causing DNA damage to a particular cell. DNA damage causes uncontrolled cellular growth, leading to the formation of cancerous cells in the skin. Thankfully, the mortality rate for skin cancer is relatively low. However, skin cancer is still marked by painful symptoms such as rashes, burns, spots, and itches. Thus, skin cancer must be prevented. The relationship between the ozone layer and UV radiation is a significant factor in limiting skin cancer.

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