Clinical Cancer Investigation Journal-ISSN: 2278-0513

Depletion of the ozone layer

Abstract

Like a shell, the stratosphere's ozone layer shields Earth from ultraviolet radiation that would otherwise be fatal to biological life. Ozone is a basic molecule made up of three oxygen atoms. Although the presence of this substance enables the growth and flourishing of living organisms, at the same time, it is a poisonous gas that causes painful irritation and inflammation of the respiratory system. But what is known as the ozone layer, the major volume of ozone is located 25-30 km above the surface of the Earth. As a protective shield, this layer protects plants, animals, and humans from the sun's ultraviolet radiation and prevents its deadly wavelengths from hitting the surface of the Earth. The radiation absorbed in these wavelengths is the cause of sunburn, skin cancer by modifying DNA, cataracts, and can weaken the human immune system and reduce its resistance. According to studies by the United Nations Environment Program, a 10% decrease in the amount of ozone in the atmosphere can cause an increase in skin cancers by 26%. In addition, ultraviolet rays can slow down the growth of plants and damage the genetic structure of living organisms.

Keywords: *Atmospheric layers, Earth's atmosphere, solar ultraviolet rays, ozone layer, destruction, halogens, refrigeration*

Babak Mohri[a]
Darya Sedaghat[b]
[a]Bachelor of Fluid Mechanics, Amir kabir University, Iran, Tehran
Master's student of Dramatic Literature and Fine Arts, University of Iran, Tehran
[b]Graduate Diploma in Fluid Mechanics, Amirkabir University, Iran, Tehran
Student of Fine Arts Acting Essentials of Iran, Tehran University
**Correspondence author:*
Email: b_mohri@yahoo.com
Email: Darya_sedaghat@yahoo.com

Introduction

Congress added measures to safeguard the ozone layer to Title VI of the Clean Air Act in 1990. The EPA must create and implement regulations for the management of ozone-depleting substances (ODS) in the US following these revisions. Additionally, they guarantee America's dedication to carrying out the Montreal Protocol. The EPA collaborates with stakeholders to protect the ozone layer. Under this authority, the EPA has established several regulatory programs, including:

1. ODS Phaseout, which prohibits the production and import of Class I ODS and stops the production and import of Class II ODS.
2. Destruction of ODS, which establishes acceptable practices for the disposal of ODS in the United States.[1]
3. Refrigeration and fixed air conditioning, which establishes service practices, technician certification programs, sales restrictions, and other requirements for these devices and systems, etc.[1]

The "sunscreen" of Earth is the stratospheric ozone layer, which protects organisms from the sun's intense ultraviolet rays. But through domestic and international measures, it is improving and should have completely recovered by 2065.[1]

Text

Two French scientists, Charles Fabry and Henri Boisson, discovered the ozone layer, or ozonosphere, in 1913. It is situated 20 to 30 kilometers above the surface of the Earth. Its 300 Dobson thickness, with a high concentration of the ozone molecule (O_3), varies depending on seasonal and weather conditions and is equivalent to 3 mm in the stratospheric layer. By absorbing 95-99.9% of the sun's ultraviolet rays, this layer allows life to continue on the planet. The ozone layer absorbs high-energy ultraviolet rays and transforms them into infrared rays prior to letting them through to the Earth's surface.[1]

All life on Earth is shielded from the sun's damaging radiation by the ozone layer, but human actions, such as the release of greenhouse gases, can also deplete or weaken the ozone layer.1. Recent research has revealed that people live in the troposphere, the lowest layer of the Earth's atmosphere, where temperatures are rising due to global warming. But at the same time, it cools the stratosphere, which is located between 18 and 50 km above Earth's surface. This layer's cooling serves as the foundation for the development of polar stratospheric clouds, which further depletes the ozone layer.[1]

Less protection from the ozone layer against ultraviolet (UV) radiation damages crops over time and leads to higher rates of skin cancer and cataracts. [1]

Ozone (O_3), is a relatively unstable molecule made up of three oxygen (O) atoms, the accumulation of which forms the ozone layer. Although this layer only covers a small part of the atmosphere of Earth, it holds significant importance and allows for life to continue on Earth. This molecule is formed from the reaction between the oxygen molecule with the chemical formula O2 and sunlight. This is the most effective process that occurs in the stratosphere layer at an altitude of 15-50 km above the Earth's surface.[1]

Ozone molecules are destroyed by atoms of chlorine and bromine coming into collision with them in the stratosphere.

Over 100 thousand ozone molecules can be destroyed by a single chlorine atom before they are expelled from the stratosphere. Ozone can be lost more quickly than it can be naturally generated.[1]

When some substances are exposed to strong ultraviolet radiation in the stratosphere, they can emit bromine or chlorine. These chemicals contribute to the ozone layer's depletion as ozone-depleting substances (ODS). Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), carbon tetrachloride, and methyl chloroform are examples of ODS that release chlorine. Methyl bromide and halons are examples of ODS that release bromine. ODS releases at the Earth's surface, but it takes two to five years for it to finally enter the stratosphere. [1]

Many nations, including the US, outlawed the use of chlorofluorocarbons (CFCs) as aerosol propellants in the 1970s due to worries about the impact of ODS on the stratospheric ozone layer. Nonetheless, when new applications for CFCs and other ODS were discovered in the fields of floor insulation, firefighting, refrigeration, and other areas, their production worldwide continued to expand quickly.

Large volcanic eruptions are one example of a natural event that may indirectly affect ozone levels. For instance, the 1991 eruption of Mount Pinatubo released a significant number of small particles known as aerosols, which are distinct from the aerosols found in consumer goods. However, it had little effect on the concentration of chlorine in the stratosphere. These particulates in the air make chlorine more efficient at destroying ozone. Ozone can be destroyed by CFC-based chlorine on a surface created by particulate matter in the stratosphere. Nevertheless, the impact of volcanoes is short-lived.[1]

The depletion of the ozone layer is not caused by all sources of bromine and chlorine. For instance, researchers have discovered that the stratosphere is not reached by chlorine originating from industrial facilities, swimming pools, sea salt, or volcanoes. ODS, on the other hand, are highly sturdy and do not break down in the rain. Thus, ODS is not eliminated from the lower atmosphere by natural processes.[1]

The yearly ozone "hole" above Antarctica that has been present in the Antarctic spring since the early 1980s is one illustration of the degradation of the ozone layer. It is a sizable area of the stratosphere with extremely low ozone levels, rather than a hole through the ozone layer. The area over Antarctica is not the only place where the ozone layer is being destroyed. Ozone depletion is seen in latitudes that encompass North America, Europe, Asia, and much of Africa, Australia, and South America, according to research. The UN Environment Programme's 2018 Scientific Assessment on Ozone Depletion has further details on the pace of ozone depletion worldwide.[1]

Health and Environmental Effects of Ozone Layer Destruction[2]

1. The relationship between the destruction of the ozone layer and UVB rays

Less protection from solar radiation and increased exposure to ultraviolet B radiation occur at the Earth's surface due to ozone depletion brought on by ozone layer degradation. Research has indicated that during Antarctica's yearly ozone hole event, the quantity of UVB detected at the surface might double.

2. Effects on human health

The quantity of UVB that reaches the Earth's surface rises with ozone layer degradation. According to epidemiological and laboratory research, UVB contributes significantly to the development of malignant melanoma and causes non-melanoma skin cancer. Furthermore, UVB has been linked to cataracts, which are clouding of the lens of the eye. Even in situations where stratospheric ozone levels are normal, sunlight contains some UVB radiation; therefore, it's crucial to protect your skin and eyes from it.

In order to calculate the health advantages of enhanced ozone protection under the Montreal Protocol, the EPA used the Atmospheric Health Effects Framework model. This 2015 study, Improving Ozone Estimates and Emission Profiles for Use in the Atmospheric Health Effects Framework Model, provides updated data on the advantages of the EPA's efforts to mitigate ozone depletion.

3. Effects on plants

Plant growth and physiological activities are impacted by UVB radiation. The growth of plants can be directly impacted by UVB radiation, even if there are ways to mitigate or repair the impacts and the capacity to adapt to higher UVB levels.

UVB may induce indirect effects as well as direct ones, sometimes much more so. Examples of these indirect impacts include changes in plant form, nutrient distribution within the plant, timing of development phases, and secondary metabolism. Plant competitive balance, herbivory, plant diseases, and biogeochemical cycles may all be significantly impacted by these changes.

4. Effects on marine ecosystems

Aquatic food webs are based on phytoplankton. The aphotic zone, or upper layer of the water column, where enough sunlight is present to sustain net production, is the only place where phytoplankton productivity can be found. It has been demonstrated that exposure to solar UVB radiation alters phytoplankton's orientation and movement, which lowers the organism's survival rate. Researchers have demonstrated a clear correlation between higher UVB levels linked to ozone depletion and a decrease in phytoplankton output. It has been shown that UVB rays harm fish, shrimp, crabs, amphibians, and other marine animals during their early stages of development.

Reproductive capacity decline and disturbance of larval development are the most severe impacts. Little increases in UVB radiation have the potential to cause small marine creature populations to decrease, which would have an impact on the marine food chain overall.

5. Effects on biogeochemical cycles

Increased ultraviolet B radiation has the potential to impact both terrestrial and aquatic biogeochemical processes, therefore modifying the origins and destinations of chemically significant greenhouse and trace gases, including carbon dioxide, carbon monoxide, carbonyl sulfide, ozone, and maybe additional gases. These possible alterations support feedback between the biosphere-atmosphere that either raises or lowers the amounts of these gases in the atmosphere.

6. Effects on materials

UVB radiation affects materials of commercial relevance, as well as synthetic polymers and natural biopolymers. Today's materials have special additives that provide limited UVB protection. However, increased ultraviolet (UV)B levels accelerate degradation and reduce usability outdoors.

7. Effects on animals

Whales off the coast of California have shown a substantial enhancement in sun damage, based on a study performed in November 2011 by researchers from the Zoological Institute of London. The scientists "fear that the thinning ozone layer is to blame." Over 150 whales were photographed in the Gulf of California for the investigation. and used a sample to discover cells that are created when UV radiation damages DNA, as well as "extensive proof of epidermal damage typically associated with acute, severe sunburn." The research indicates that "increased UV levels have been observed as a result of ozone depletion causing skin damage, just as human skin cancer rates have increased in recent decades." They experience the same detrimental impacts of increasing UV-B radiation as dogs, cats, sheep, and terrestrial ecosystems.

Environmental Assessment of The Destruction of the Ozone Layer Due to the Manufacture of Plastic Bags

This report presents the findings of a quantitative investigation of the possible environmental consequences of ozone depletion caused by plastic bag manufacturing in a facility located in northern Colombia. Measured in kilos, the released gases must be identified in order to ascertain their role in the ozone layer's depletion. CFC-11 equation using SimaPro and LCA software. The objectives, parameters, and constraints of the production system are specified, and the assessment criterion is founded on the life cycle analysis approach. Based on this data, an inventory was created, with its primary component being the quantitative assessment of the flow of materials and energy for all inputs and outputs of the manufacturing process. Based on information on the identification, description, and evaluation of the environmental effects of global warming related to the production of plastic bags, it was possible to conclude that extrusion is the method that produces the greatest pollution, followed by printing.

One of the primary polymer types—polyethylene, high-density polyethylene (HDPE), low-density polyethylene (LDPE), or linear low-density polyethylene (LLDPE)—is used to make plastic bags. HDPE is typically used to make plastic grocery bags. Plastics by themselves don't pose a harmful or toxic threat. However, throughout the manufacturing process, both organic and inorganic additives such as metals, stabilizers, softeners, antioxidants, and dyes and pigments are used.[3]

The heavy metals lead and cadmium included in pigments used in the manufacture of plastic bags, as well as organic and inorganic substances referred to as stabilizers and antioxidants, guard the material from thermal deterioration. These industrial chemicals are thought to be a major source of pollutants in the atmosphere since they may produce molecules including sulfides, oxides, and chlorides, all of which make significant contributions to the depletion of ozone.

Roland-Molina hypothesis

The behavior of long-lived organic halogen compounds, like CFCs, might be analogous to what Kratzen proposed for nitrous oxide, according to Frank Sherwood Rowland, a chemistry professor at the University of California, Irvine, and his postdoctoral researcher Mario J. Molina's 1974 suggestion. Nearly every CFC chemical created since its inception in 1930 was still present in the atmosphere, according to research done by James Lovelock in 1971 while on a South Atlantic cruise.

Similar to N2O, Molina and Rowland determined that CFCs reach the stratosphere, where UV radiation dissociates them, releasing atoms of chlorine. It was demonstrated a year prior by Richard Stolarski and Ralph Cicerone of the University of Michigan that chlorine was an extremely effective catalyst for the degradation of ozone compared to nitrogen oxide. Harvard University's Steven Wofsey and Michael McElroy came to identical conclusions. Neither group, however, was aware that CFCs may be a significant source of stratospheric chlorine. Rather, they were looking into the impacts of the considerably smaller space shuttle's HCl emissions.

According to a quote from the head of Aerosol and Halocarbon Industries, DuPont, "The theory of ozone depletion is science fiction...a load of garbage...nonsense." Six The president of Precision Valve, Robert Abplanalp (who also invented Practical Aerosol, the first spray can valve), complained in writing to the UC Irvine chancellor about Rowland's remarks made in public. 7. However, within three years, direct observations in the stratosphere and laboratory measurements verified the majority of Rowland and Molina's fundamental hypotheses. The main source of stratospheric chlorine is, in fact, CFCs, and nearly all released CFCs ultimately end up in the stratosphere, according to measurements of source species

(CFCs as well as associated chemicals) and sink species (HCl and ClONO) of chlorine carried out throughout the stratosphere.

James J. Anderson and associates' findings of chlorine monoxide (ClO) in the stratosphere were much more convincing. When chlorine and ozone combine, ClO is created. The discovery illustrated that chlorine radicals are not only found in the stratosphere but also contribute to the depletion of ozone. In addition to demonstrating that bromine atoms are much more potent ozone loss catalysts than chlorine atoms, McElroy and Wofsey expanded on the research of Rowland and Molina by arguing that the brominated organic molecules known as halons, which are often found in fire extinguishers, are mostly found in the stratosphere.

Brehm stated that there was substantial scientific evidence to support the ozone depletion theory in a 1976 study issued by the US National Academy of Sciences. As a result, in 1978, the use of CFCs in aerosol spray cans was outlawed in the US, Canada, and Norway. According to early predictions, the total amount of atmospheric ozone would reach a stable state almost a century later, 15–18% below normal, if CFC production persisted at 1977 levels. his prediction was changed to a steady-state decline of 5–9% in 1984 once further information about critical reaction rates became available.[9] Kratzen, Molina, and Rowland's research on stratospheric ozone earned them the 1995 Nobel Prize in Chemistry.

Arctic Ozone "Mini Hole".

The unusually large 2004 Arctic ozone hole was linked to solar wind activity, according to a March 3, 2005, paper published in Nature.[10]

A record amount of ozone was lost on March 15, 2011, with nearly half of the ozone in the Arctic gone. [10.11.12] This shift, which resulted in progressively colder winters in the Arctic stratosphere at a height of around 20 km (12 mi), was linked—though the exact relationship—to changes brought about by global warming. [11]

Ozone loss, with the potential to form an ozone hole, reached its highest levels ever recorded on March 25, 2011, when compared to all prior winters.[13] In order to do this, the 250 Dobson units of ozone that were measured in Central Siberia had to drop to fewer than 200.[13] On March 30-31, the thinning layer was predicted to cover portions of Eastern and Scandinavian Europe.[13]

Around 20 kilometers (12 miles) above the surface, up to 80% of the ozone in the atmosphere was lost between December 2010 and March 2011, according to research published in Nature Magazine on October 2, 2011. It was comparable to the Antarctic ozone hole, which emerges every winter, according to scientists, because of its intensity.[14] According to the study, "for the first time, there was enough loss to reasonably be described as an Arctic ozone hole." [14] This study discovered that there was more ozone depletion than normal after analyzing data from the Aura and CALIPSO satellites. It was brought on by an extended stretch of very cold air in the Arctic—roughly 30 days longer than typical—which promoted the formation of more ozone-depleting chlorine compounds.[15]

Clouds and aerosol particles with chlorine compounds found on them "were abundant in the Arctic as late as mid-March 2011—much later than usual—with moderate amounts at some altitudes similar to those observed in Antarctica and significantly larger than the near-zero values observed in March during most arctic winters," according to Lamont Poole, one of the study's authors.[15]

After examining the data, scientists concluded in 2013 that the Arctic event of 2010–11 did not deplete the ozone layer to the point where it could be considered a true hole. Generally speaking, an ozone hole is defined as 220 Dobson units or fewer; [16] That low level is not approached by the Arctic Hole. [17] Since then, it has been designated as a "minor hole."[18]

Following the ozone depletion between 1997 and 2011, weather balloons above the Arctic recorded a 90% decrease in ozone in March 2020. This was calculated because the balloons typically recorded 3.5 parts per million ozone equivalents, although, in reality, the decline was only around 0.3 parts per million. The strongest polar vortex in history, which permits pollutants like chlorine and bromine to wash away, combined with the lowest temperatures recorded since 1979.[19] 2020, saw the study of a unique hollow caused by exceptionally low temperatures in the upper Arctic atmosphere. [20, 21]

Ozone Hole in Tibet

An ozone hole occasionally arises above Tibet due to the region's greater vulnerability to winter cold. The Tibetan region was found to have an ozone hole in 2006, spanning 2.5 million square kilometers.[22] There was also an unprecedented hole over the North Pole in 2011 and an ozone hole over the mountainous areas of Tibet, Xinjiang, Qinghai, and the Hindu Kush; however, the Tibetan hole's severity was far lower than that of the holes over the North and South Poles.[23]

World Ozone Day

The International Day for the Protection of the Ozone Layer, or "World Ozone Day," was established by a decision of the UN General Assembly in 1994.[14] This name honors that date in 1987 when the Montreal Protocol[16] was signed.[16]

Conclusion

UVB radiation that touches the Earth's surface increases when the ozone layer thins. Studies in laboratories and epidemiology demonstrate that UVB is a major factor in the formation of malignant melanoma and causes skin cancer that is not melanoma. The mass and energy levels needed for inventory analysis and potential environmental effect evaluations were created using production data from January 2014 to June 2015. Extrusion, printing and sealing, and the recovery of plastic waste are the main processes utilized in the production of high-density polyethylene (HDPE) plastic bags[16] as shown in Figure 1. Solid waste is generated during the bag printing process and is handled by the recovery subprocess (agglutinate), which consists of two binding and pelletizing stages.

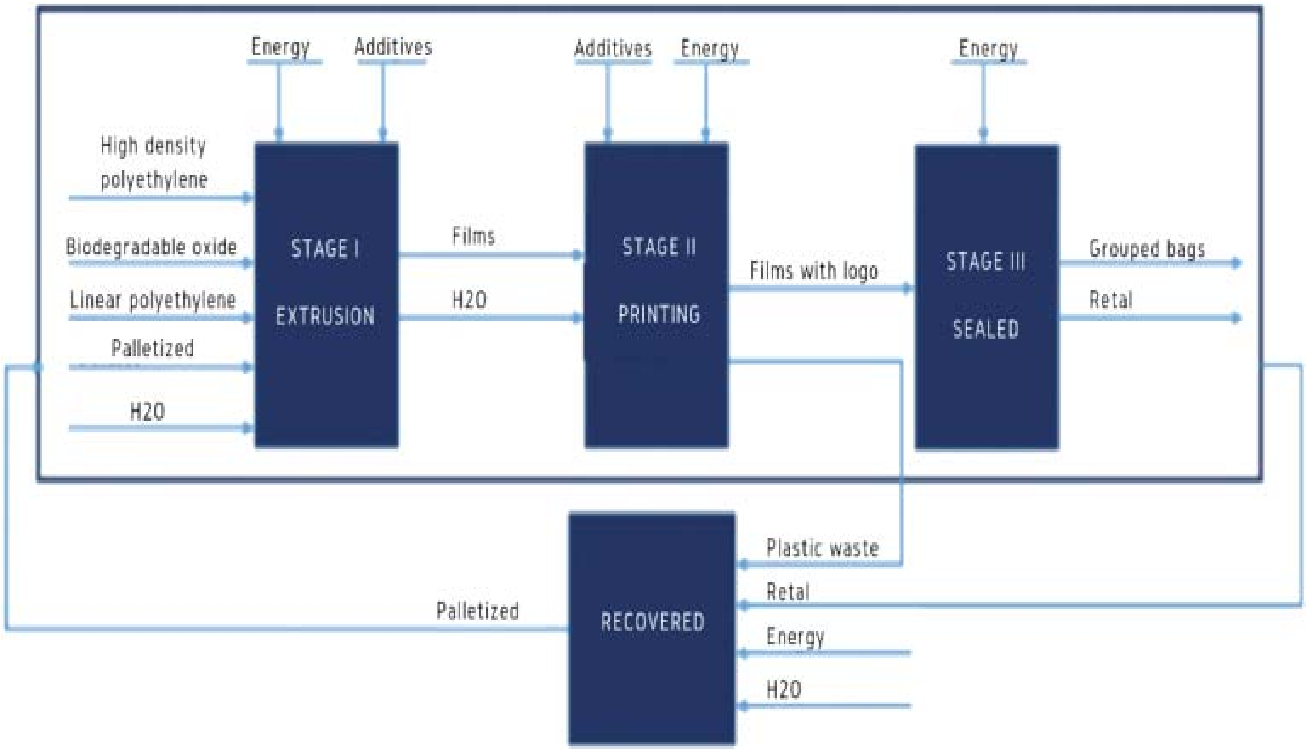

figure 1
Recovery Subprocess (Agglutinin)

Acknowledgment:

Thank God that the speakers remain in praising Him and the enumerators do not know how to count His blessings and the strivers are not able to convey His truth. And peace and blessings be upon Muhammad and his pure family, the pure ones, those who owe our existence to them; And a continuous curse on their enemies until the Day of Resurrection...

Conflict of Interest:

Name of responsible author: **Babak Mohri**	Email: **b_mohri@yahoo.com**
Organizational affiliation: **Chagalesh Consulting Engineers**	Phone**: 0912 15 40 884**
Title : **Wind energy and analysis of its applications**	

Did the authors or the relevant institution receive funds from a third party (government, commercial, private foundation, etc.) for any part of the submitted article (including financial assistance, data monitoring, study design, article preparation, analysis and has it received statistical analysis and...?

No ●	Yes ○

Do the authors have any pending, pending, or registered patents related to this work?

No ●	Yes ○

Are there any other access ways that readers can get additional information about the said work from the authors of the article?

No ●	Yes ○

Is there any aspect of this work related to experimental animals or specific human diseases that needs to be declared and approved by publishing ethics?

No ●	Yes ○

Name of responsible author: **Babak Mohri** Date: **1402/11/29** Signature:

Name of responsible author: **Darya Sedaghat**	Email: Darya_sedaghat@yahoo.com
Organizational affiliation: **Chagalesh Consulting Engineers**	Phone**:** 09128198462

Title : **Wind energy and analysis of its applications**

Did the authors or the relevant institution receive funds from a third party (government, commercial, private foundation, etc.) for any part of the submitted article (including financial assistance, data monitoring, study design, article preparation, analysis and has it received statistical analysis and...?

No ●	Yes ○

Do the authors have any pending, pending, or registered patents related to this work?

No ●	Yes ○

Are there any other access ways that readers can get additional information about the said work from the authors of the article?

No ●	Yes ○

Is there any aspect of this work related to experimental animals or specific human diseases that needs to be declared and approved by publishing ethics?

No ●	Yes ○

Name of responsible author: Darya Sedaghat Date: **1402/11/29** Signature:

Funding:

"This article was written independently and no financial support was received from any organization to write it".

Ethics statement:

1. Plagiarism: Plagiarism is the use of other people's ideas and main parts (without mentioning the source) in such a way that it is believed to be one's own. Copying even one sentence from someone else's articles and even articles that you have already published without proper citation is considered plagiarism in the view of the Journal of Transformation Management. All articles under review or published in this publication are matched with plagiarism detection software, for Persian texts with Hamiyab matching software, and the English abstract of articles with software such as iThenticate. Therefore, plagiarism is a serious violation of publishing ethics.

2. Simultaneous submission: You must be sure that your submitted article has not been published anywhere and in any other language before and that it should not be sent to other publications at the same time.

Duplicate publications: Duplicate publications occur when two or more articles use exactly the same hypothesis, data, and results without proper referencing.

3. Redundant publications: Redundant publications mean the inappropriate division of the information of a study into several articles, which often happens as a result of a person's desire to complete his academic resume.

4. Data falsification: Data falsification means that the researcher did not really conduct the study, but presented unreal and fictitious data and results, or that he conducted the experiment but deleted, manipulated, or changed the data or research results. .

5. Citation manipulation: Citation manipulation means excessive citations in the submitted article that do not contribute to the scientific content of the article and are done only to increase the citation of a particular author's work or articles published in a particular publication. This work has resulted in misrepresenting the importance of the particular

work or publication that is being referred to, and is therefore considered a form of scientific misconduct.

6. Improper Author Contribution or Attribution: All listed authors must have made a significant contribution to the research presented in the article and have confirmed all its claims. It is reminded that all people who have a significant scientific contribution, including students and laboratory technicians, should be mentioned in the list of authors.

References

1. https://www.epa.gov/ozone-layer-protection/basic-ozone-layer

2. Environmental Effects of Ozone Depletion and Its Interactions with Climate Change: 2014 Assessment

3. Martínez Flores K., Souza Arroyo V., Bucio Ortiz L., Gómez Quiroz L., Gutiérrez Ruiz M. Cadmio: efectos sobre la salud. Respuesta celular y molecular. Acta Toxicol. Argent. 2013:33–

4. Sánchez-Monedero M., Serramiá N., Civantos C., Fernández-Hernández A., Roig A. Greenhouse gas emissions during composting of two-phase olive mill wastes with different agroindustrial by-products. ScienceDirect. 2010;18–25 Obtenido de. [PubMed] [Google Scholar]

5. from the original on April 6, 2012.

6. ^Roan, Sharon (1989) Ozone crisis: The 15-year evolution of a sudden global emergency, New York: Wiley, p. 56 ISBN 0-471-52823-4

7. ^ Causes and Effects of Stratospheric Ozone Reduction: An Update. National Research Council.. p. Summary, 3. doi:10.17226/319. ISBN 978-0-309-03248-3.

8. news050228–12. doi:10.1038/news050228-12. Retrieved May 28, 2016.

9. ^ Dell'Amore, Christine (March 22, 2011). "First North Pole Ozone Hole Forming?". National Geographic. Retrieved April 6, 2011.

10.^ Jump up to a b Helmholtz Association of German Research Centres (March 14, 2011). "Arctic on the verge of record ozone loss". Science Daily. Retrieved April 6, 2011.

11.^ "The Arctic Ozone Sieve: More Global Weirding?". *Scienceblogs.com. March 25, 2011. Archived from the original on April 4, 2011*. Retrieved April 6, 2011.

12.^ Jump up to a b c "Developing ozone hole approaches Europe". *EurActiv. Archived from* the original *on April 4, 2011*. Retrieved April 6, 2011.

13.^ Jump up to a b c "Arctic ozone loss at a record level". BBC News *Online. October 2, 2011.* Archived *from the original on October 2, 2011*. Retrieved October 3, 2011.

14.^ Jump up to a b "Unprecedented Arctic Ozone Loss in 2011, Says NASA-Led Study" *(Press release). NASA. October 2, 2011*. Retrieved July 1, 2016.

15.^ *Millan, Luis; Manney, Gloria (2017-05-02).* "An assessment of Ozone Mini-holes Representation in Reanalyses Over the Northern Hemisphere". *Atmospheric Chemistry and Physics Discussions. 17 (15): 9277.* Bibcode*:*2017ACP....17.9277M. doi*:*10.5194/acp-2017-341.

16.^ *Strahan, S. E.; Douglass, A. R.; Newman, P. A. (2013).* "The contributions of chemistry and transport to low arctic ozone in March 2011 derived from Aura MLS observations". *Journal of Geophysical Research: Atmospheres. 118 (3): 1563–1576.* Bibcode*:*2013JGRD..118.1563S. doi*:*10.1002/jgrd.50181. hdl*:*2060/20120011691. ISSN 2169-8996. S2CID 128447261.

17.^ *Zell, Holly (2013-06-07).* "NASA Pinpoints Causes of 2011 Arctic Ozone Hole". *NASA*. Retrieved 2019-10-03.

18.^ *Witze, Alexandra (27 March 2020).* "Rare ozone hole opens over the Arctic — and it's big". *Nature. 580 (7801): 18–19.* Bibcode*:*2020Natur.580...18W. doi*:*10.1038/d41586-020-00904-w. PMID 32221510. S2CID 214694393.

19.^ *Harvey, Fiona (2020-04-07).* "Record-size hole opens in the ozone layer above the Arctic". The Guardian. ISSN 0261-3077. Retrieved 2020-04-08.

20.^ *Lubben, Alex (8 April 2020).* "Now There's Another Hole in the Ozone Layer. Great". Vice.

21.^ "Earth news: Chinese Scientists Find New Ozone Hole, Over Tibet". *Elainemeinelsupkis.typepad.com. May 4, 2006*. Retrieved April 6, 2011.

22.^ Schiermeier, Quirin (February 22, 1999). "The Great Beyond: Arctic ozone hole causes concern". *Blogs.nature.com*. Retrieved April 6, 2011.

23."WMO/UNEP Scientific Assessments of Ozone Depletion (Latest Report 2022)". *Chemical Sciences Laboratory, National Oceanic and Atmospheric Administration (NOAA).*