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Discovery of the hole in the ozone layer: environmental awareness and fighting scientific fake news

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ABSTRACT: In the 1970s, the discovery of the problem of the hole in the ozone layer represented a crucial milestone in the history of science and the environment. Scientists such as Mario Molina and F. Sherry Rowland revealed that chlorofluorocarbons (CFCs), previously thought to be harmless, could destroy the ozone layer, leading to global awareness of environmental protection. However, they faced resistance from industry and misinformation. Confirmation of the problem came with Jonathan Shanklin's work in Antarctica. The effects of ozone depletion, such as increased skin cancer, were documented, and humanity reacted with the Montreal Protocol, phasing out harmful substances. Furthermore, the link between the historical success of science-based environmental actions and the modern challenges posed by misinformation should be emphasized, especially considering the rise of digital platforms as both tools and threats to public understanding. Today, tackling disinformation in global environmental problems represents a substantial challenge, requiring science education, raising awareness on social media, valuing traditional sources, training in source verification, recognizing science as a reliable source, and tackling environmental challenges based on science. This article proposes actionable solutions such as integrating critical media literacy into education, establishing international regulations to curb disinformation, and leveraging collaborative platforms to promote accurate scientific communication. It argues that strengthening international cooperation, modeled on the Montreal Protocol, is crucial to countering misinformation and fostering effective global environmental policies. The history of the Montreal Protocol highlights the importance of science, international cooperation, and determined action in protecting the environment and human health.

KEY WORDS: Ozone hole · Global environmental challenges · Public awareness · Science education · Environmental disinformation.

1. THE DISCOVERY OF AN ENVIRONMENTAL PROBLEM

In the 1970s, a pivotal moment in the history of environmental science unfolded with the identification of the ozone layer depletion issue. In 1974, scientists Mario Molina and F. Sherry Rowland hypothesized that chlorofluorocarbons (CFCs), widely used industrial compounds, were capable of destroying ozone molecules in Earth's stratosphere (Molina & Rowland 1974). Their seminal work demonstrated the catalytic destruction of ozone molecules by chlorine atoms released from CFCs, emphasizing the fragile balance of atmospheric chemistry.

Molina and Rowland's work marked a turning point, linking industrial activities to significant environmental harm and catalyzing a new wave of scientific focus on human-induced atmospheric changes (Rowland & Molina 1975). The global nature of their discovery underscores the necessity of international

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collaboration in addressing shared environmental challenges. Despite resistance from industries reliant on CFCs, which questioned the validity of the research and promoted skepticism, Molina and Rowland's findings persisted. Initial opposition, including claims that ozone depletion was exaggerated or would take centuries to manifest, underscored the early clash between scientific discovery, economic interests, and public perception (Morrisette 1989). To address these challenges today, implementing tools such as systematic fact-checking platforms, artificial intelligence (AI)-driven misinformation detection systems, and public education programs to disseminate validated scientific knowledge could mitigate the impact of disinformation. This historical resistance mirrors contemporary challenges of combating misinformation, highlighting the need for policies that ensure accountability for industries and platforms spreading disinformation.

The emergence of misinformation around these findings, akin to early forms of scientific fake news, sought to undermine the gravity of their discovery (Falkner 2008). Nevertheless, responsible media and scientific journals played a critical role in upholding the integrity of peer-reviewed research, fostering public awareness, and rejecting misleading narratives (Dove 1996).

1.1. Confirmation and the difficulty of disputing scientific data

In the late 1970s, meteorologist Jonathan Shanklin of the British Antarctic Survey played a pivotal role in confirming the existence of the ozone layer hole. His analysis of data from the Antarctic, particularly from Halley's Bay, was crucial in identifying long-term ozone trends (Shanklin 2010). Shanklin oversaw the digitization of historical records, allowing for more advanced data analysis and global comparisons using Dobson spectrophotometers (Kravchenko et al. 2009). By 1984, he discovered a significant thinning of the ozone layer over the British Antarctic station, with levels reduced by one-third compared to previous decades (Solomon 1988). This empirical evidence validated Molina and Rowland's theoretical models and prompted both scientific and political action to address ozone depletion (Klekociuk et al. 2020). These developments highlight how robust empirical evidence can counter misinformation, a lesson relevant in today's fight against science denialism in environmental and other global issues. Adopting scientific methodologies such as meta-analyses, open-access data repositories, and transparent peer-review systems can ensure credibility and counter fake narratives effectively.

1.2. The effects are evident

The effects of ozone layer depletion are widely recognized as a legitimate concern, with significant consequences for both humans and the environment. One of the most evident impacts is the rise in skin cancer rates, as UV-B radiation, which penetrates more deeply due to ozone depletion, causes direct DNA damage that can lead to mutations and skin cancer (Kripke 1988). A mere 1% loss of ozone correlates with tens of thousands of new skin cancer cases worldwide (Amron & Moy 1991). Additionally, UV-B radiation contributes to cataracts, macular degeneration, and premature skin aging (Roberts 2011, Kohl et al. 2011). In Brazil alone, this increased UV-B exposure is linked to over a thousand new cases of skin cancer annually (Corrêa et al. 2003).

Beyond human health, UV-B radiation also negatively impacts ecosystems. Aquatic life, such as fish and crustaceans, is vulnerable, with UV-B inhibiting development and reducing productivity in phytoplankton and plants, disrupting food chains (De Mora et al. 2005, Llabrés et al. 2013). This depletion of primary producers affects biodiversity and ecosystem services. Thus, the consequences of ozone depletion extend beyond humans, threatening ecosystems and biodiversity globally (Caldwell et al. 1998). Addressing these impacts is crucial for protecting the planet and mitigating the risks of UV-B radiation exposure (Paul et al. 2012).

1.3. Humanity reacts

Humanity's response to the discovery of the ozone hole marked a critical moment in environmental awareness and international cooperation (Andersen & Sarma 2012). The adoption of the Montreal Protocol on 16 September 1987 was a key milestone, illustrating the effectiveness of global collaboration in addressing environmental issues (Albrecht & Parker 2019).

Following scientific warnings about the risks of ozone depletion, the world acted swiftly. The 1985 Vienna Convention laid the groundwork for the Montreal Protocol, which aimed to phase out ozone-depleting substances such as CFCs (Brack 2017). Entering into force in 1989, the Protocol achieved universal ratification by 2008, becoming the only UN environmental agreement endorsed by every nation (Velders et al. 2012).

The United Nations Environment Program was instrumental in this process, supporting the Vienna

Convention and managing the Ozone Secretariat (Wettestad 2001). The Montreal Protocol exemplifies the power of multilateralism supported by strong scientific evidence, demonstrating that global environmental challenges can be successfully addressed through international cooperation (Gonzalez et al. 2015). To replicate this success in combating misinformation, coordinated global frameworks should be established, including mandatory reporting standards for scientific data and collaborative efforts between governments, scientific institutions, and media organizations to counter false narratives.

The Montreal Protocol serves as a prime example of how global environmental challenges require concerted international efforts to achieve meaningful and lasting solutions. It highlights that effective policies are often driven by unified action and trust in scientific evidence.

1.4. The results appear

Humanity's actions to address ozone layer depletion have yielded significant results, demonstrating the power of global collaboration in environmental protection (Kuttippurath & Nair 2017). Nearly 99% of harmful substances have been phased out, and the ozone layer is recovering, with the hole over Antarctica expected to close by 2060 (Polvani et al. 2011). This progress has saved an estimated 2 million lives annually from skin cancer and reduced other health issues, such as cataracts and immune suppression, while also mitigating climate change, as many ozone-depleting substances are potent greenhouse gases (Bais et al. 2018).

Without the Montreal Protocol's ban on CFCs, global warming could have been 0.5 to 1.0°C higher due to reduced carbon accumulation in plants and soils (Williamson et al. 2014, Häder et al. 2011). Although the Protocol has been a critical success, ongoing monitoring and adaptation remain crucial. Recent illegal CFC-11 emissions underscore the need for vigilant enforcement (Dhomse et al. 2019), and scientists continue to assess new challenges and potential effects of rising polar temperatures on ozone (Stone et al. 2021).

The Montreal Protocol's legacy highlights how international cooperation, science, and proactive policy can effectively address environmental issues, but continuous commitment is necessary for long-term success (Barnes et al. 2021). These successes underline the importance of reinvigorating global cooperation as a core strategy for addressing not only ozone depletion, but also contemporary challenges exacerbated by misinformation. The success of the Montreal Protocol underscores the importance of embedding monitoring mechanisms and adaptive policies in international agreements. Future efforts should include protocols to address disinformation and ensure transparent communication of environmental data.

2. WOULD SUCH A RESULT BE POSSIBLE TODAY (IN 2025) IN RELATION TO A GLOBAL-SCALE ENVIRONMENTAL PROBLEM?

The lessons from the successful global response to the ozone layer crisis provide a blueprint for tackling misinformation today, although the current digital landscape presents unprecedented challenges. The current era is often referred to as a 'post-truth' society, where subjective beliefs and emotions increasingly overshadow objective facts and scientific evidence (McIntyre 2018, Farkas & Schou 2019). This shift, combined with the pervasiveness of digital platforms, enables the rapid spread of misinformation. While fake news is predominantly harmful due to its ability to undermine scientific consensus and trust, some argue that it exposes weaknesses in communication systems and can encourage scientists and policymakers to improve public engagement strategies (Lazer et al. 2018). The possibility of reacting and achieving effective results against the hole in the ozone layer in a world affected by scientific fake news and disinformation represents a substantial challenge. The rampant dissemination of misinformation and conspiracy theories in an environment where many individuals obtain information mainly through social media makes combating the environmental problem even more complex (Silva 2022b). To mitigate this, governments could collaborate with social media platforms to establish misinformation tracking systems, while educators integrate critical media literacy programs to empower citizens in identifying credible sources. Implementing evidence-based strategies, such as developing AI algorithms to flag disinformation, creating international fact-checking consortiums, and establishing research funding for digital media literacy studies, would provide structured methodologies to combat fake news. Unlike during the ozone crisis, when scientific evidence guided global action, today's fragmented information landscape poses a significant barrier to fostering the trust and unity necessary for collective action. Nevertheless, understanding why fake news spreads is cru-

cial. Its prevalence is often linked to psychological factors, such as cognitive biases and confirmation bias, which drive individuals to accept information that aligns with pre-existing beliefs. Moreover, fake news, although unethical, can sometimes prompt critical discussions that compel institutions to clarify scientific uncertainties and improve transparency (Lazer et al. 2018, McIntyre 2018). Ethical considerations in communication, combined with strategies for better science dissemination, can thus help mitigate the harm caused by misinformation.

The spread of misinformation about scientific issues such as the hole in the ozone layer is an obstacle not only to public awareness, but also to the very construction of effective environmental policies (Gertrudix et al. 2024). Fake news often flourishes in environments where scientific literacy is limited and ethical boundaries in media dissemination are unclear (Frankfurt 2005). Ethical questions arise when misinformation is deliberately crafted to serve economic, political, or ideological agendas (Silva 2022a). This highlights the need for ethical frameworks that govern information sharing, especially in the digital age, where algorithms prioritize engagement over accuracy. The digital age exponentially increases the spread of fake news, and in the case of complex environmental problems, a lack of sound scientific understanding can lead to inadequate measures or government inaction. It is essential to recognize that disinformation campaigns, amplified by social media, can dilute the sense of urgency needed to mitigate the impacts of ozone depletion, undermining global efforts to address this problem.

In this scenario, where a significant portion of the population is connected to social networks, addicted to inaccurate information, and little exposed to traditional and reliable sources of knowledge, the battle for awareness and action on the hole in the ozone layer would be undermined. Disinformation often finds fertile ground, undermining public understanding of the problem and the will to take action (Silva 2021).

Additionally, the failure to adequately educate the public about the severity of the damage to the ozone layer could lead to a self-reinforcing cycle of disinformation, in which people exposed to fake news continue to be fed incorrect information due to the algorithms of digital platforms (Crinnion et al. 2024). This phenomenon, known as the 'echo chamber', hinders access to correct information, reinforcing mistaken beliefs about the causes and environmental consequences of the phenomenon. In the long term, misinformation can prevent the adoption of preventive and corrective measures, such as support for stricter legislation against ozone-depleting substances.

Collaboration between governments and scientific institutions is essential to deal with an environmental problem of this magnitude. However, in a scenario where some governments would deny or minimize the existence of the hole in the ozone layer based on fraudulent scientific news, it would be difficult to establish effective policies that take environmental and climate issues into account. These policies could be key to phasing out ozone-damaging substances such as CFCs. An example that demonstrates that this scenario is not unlikely has recently occurred in the governments of Brazil (Jair Bolsonaro) (Araújo 2020) and the USA (Donald Trump) (Selby 2019), who have denied the occurrence of climate change, despite solid evidence that this phenomenon is taking place.

In this context, an effective global response would require not only collaboration between governments and scientists, but also the active participation of traditional media in disseminating accurate and accessible information (Silva 2024a). The press plays a crucial role in filtering scientific information and transmitting data validated by the academic community. However, the media's efforts to educate the population can be undermined by the growing mistrust that part of the public has for sources of information that are considered 'mainstream'. In many cases, this distrust stems precisely from disinformation campaigns that associate the mainstream media with hidden interests, diverting the focus from the real environmental threats.

The existence of digital communities that point out supposed flaws in studies on the hole in the ozone layer, and spread these unfounded allegations, would contribute to fueling distrust of the academic community. This would make it even more difficult to disseminate accurate and reliable information about, for example, the consequences of ozone depletion, such as the increase in the number of cases of skin cancer.

Furthermore, the proliferation of 'fringe scientists', who publish in low-credibility journals or outlets without a peer-review policy, compounds the problem (Silva 2024b). Pseudoscience often uses anti-establishment rhetoric to gain popularity among certain groups, which undermines public understanding of highly relevant issues such as ozone depletion. These 'researchers' may reinforce conspiracy theories, claiming that the mainstream scientific community is acting in collusion with economic or political interests, fueling distrust of solid scientific data.

The algorithms of digital platforms could exacerbate the problem by prioritizing the display of fake news and misleading information to unsuspecting users to gain the greatest engagement from these users (Zarocostas 2020). It would create a vicious cycle in which misinformation spreads widely, undermining efforts to educate the public and favoring public policies that would negate any rational action against the serious environmental problem.

The existence of marginal scientists who support the denial of the hole in the ozone layer, publishing only in questionable and marginal scientific journals, would be an example of how pseudoscience can find a platform to spread. It would feed the conspiracy theory that academia is involved in a shady scheme to deceive the population and persuade the industry into favoring certain groups without proof. However, after much dissemination, these daydreams would appear to be true, as is the case with many fake news and conspiracy theories today.

2.1. Dealing with this perspective of denial towards environmental problems

In a hypothetical situation in which the denial of environmental problems, including that of the hole in the ozone layer, represented a significant challenge, some strategies could be adopted to confront this perspective of denialism. Addressing denialism requires acknowledging the ethical dimensions of misinformation and its societal impacts. Combating post-truth narratives involves understanding the political, economic, and technological factors that enable their spread (Farkas & Schou 2019). Thus, any strategy must combine ethical guidelines, technological tools, and improved communication frameworks. Education could play a central role in this effort. Building on past successes, such as the dissemination of accurate information about the ozone hole, offers valuable strategies. However, adapting these to counter the rapid spread of digital misinformation is essential. Education initiatives should not only combat misinformation, but also emphasize the importance of international partnerships in addressing global challenges, drawing lessons from the Montreal Protocol.

2.1.1. Promoting science education

One of the key ways to combat denialism is to invest in education, especially science education. Formal education, including science classes and related subjects, should address scientific fake news. Students should be taught how to recognize, deconstruct, question, and react to false information and how to seek out reliable sources of information. A critical addition to science education is the integration of ethical discussions around misinformation. Teaching students about the ethical consequences of fake news, including its role in undermining democratic processes and scientific progress, can foster a sense of responsibility when engaging with information. Governments should mandate digital literacy curricula in schools, focusing on the analysis of online content and the identification of misinformation. In addition, curricula should include exercises such as case studies on historical misinformation (e.g. climate change denial or the ozone layer controversy) and hands-on training in tools such as browser plugins for fact-checking. Public awareness campaigns could complement these efforts by targeting adults and marginalized populations who may not have access to formal education.

In addition to promoting scientific education in schools, it is essential that public policies encourage continuing education programs for the general population (Schneegans & Nair-Bedouelle 2021). Programs focused on scientific and technological literacy can reach different age groups and social contexts, especially in regions where access to formal education is limited. Promoting workshops, lectures and awareness campaigns in communities can help reduce the impact of environmental misinformation by empowering citizens to discern between reliable sources and fraudulent content.

2.1.2. Social media awareness

Students must understand the risks and consequences of excessive use of social media. It involves an in-depth understanding of how the algorithms of social media platforms direct and amplify fake news and conspiracy theories. Education in this regard is essential to help young people navigate digital platforms more critically and informedly on social media. Regulators should develop global frameworks requiring social media companies to flag and limit the spread of unverified scientific claims. Practical initiatives, such as workshops for creating critical-thinking toolkits and collaborations with tech companies to improve misinformation algorithms, could be systematically introduced to promote social media awareness. Collaborative initiatives such as fact-checking

partnerships could serve as a model for ensuring scientific accuracy.

Raising awareness about the use of social media should also include the creation of regulatory mechanisms that oblige digital platforms to control the dissemination of fake news (Schneider 2016). While freedom of expression is a valuable principle, accountability for the veracity of information published en masse on social media needs to be better regulated. Some international initiatives have discussed the creation of legal frameworks that impose sanctions on technology companies that profit from the spread of fake news, especially those that impact public health and the environment.

2.1.3. Valuing traditional media

It is important to restore the value of traditional media, such as newspapers, TV news, magazines, and books, among others. Students and the general population should be encouraged to seek information from traditional sources, which often follow rigorous standards of verification and responsibility, in which it is possible to verify who produced the content and its sources, and assign consequences for its dissemination. Public subsidies or grants for independent investigative journalism could strengthen the role of traditional media in disseminating accurate scientific information. Media organizations should also invest in accessible formats, such as podcasts and infographics, to appeal to diverse audiences.

The revitalization of traditional media also depends on a greater appreciation of scientific journalism (Nielsen 2015). Investing in science and environmental journalists who can translate complex findings into clear and accessible texts is crucial to rebuilding public trust in traditional media outlets. In addition, traditional media outlets can adopt new technologies and formats, such as podcasts and short videos, to reach younger audiences who are accustomed to consuming information on digital platforms.

2.1.4. Source verification training

Students (and the general population) should learn to evaluate and identify reliable sources on the internet. This includes using news verification sites and distinguishing between reputable sources and dubious information. It should always be emphasized that there should be no rejection of the internet; it can be a very important tool for searching for information, but it is a tool that should be given much attention and much caution, in order to prioritize it as a source of research. Governments and NGOs could develop free, open-source tools for real-time fact-checking and source verification, which could be integrated into search engines and social platforms.

2.1.5. Research and analysis of the scientific fake news phenomenon

Promoting the study, research, and analysis of the phenomenon of disseminating fake science news is essential. Developing quantitative models to track the spread of misinformation, analyzing user engagement patterns, and publishing regular scientific reports could serve as effective methodologies for understanding and combating scientific fake news. A thorough understanding of this modern problem is crucial to developing innovative strategies to combat it and promote scientific literacy. Digital media could be used as tools for combating fraudulent news, and there will probably have to be some accountability for the big internet platforms and social networks, which profit handsomely from the spread of fake news.

2.1.6. Recognition of science as a reliable source

Science must be valued as a reliable source of knowledge. Students, politicians, and the general population must recognize science as an essential guide to understanding environmental problems and their solutions. This implies supporting policies based on scientific evidence. A key example is how science presented possible responses to the COVID-19 pandemic: despite the large amount of fake news that circulated about the whole crisis, it was through measures enshrined by science, such as social isolation and mask-wearing, in addition to the formidable speed of vaccine production, that the SARS-CoV-2 virus was controlled. It is also important to remember that no scientific fake news about the disease turned out to be true (Greene & Murphy 2023).

Trust in science as a reliable source of knowledge also requires recognition of the role of scientists as communicators (Olan et al. 2024). Scientific dissemination, often neglected in academia, should be encouraged, with researchers being trained to communicate their findings in a way that is accessible to the public. This action can reduce the gap between scientific knowledge and popular understanding, strengthening the perception that science not only

reveals the truth, but also protects society from global crises such as climate change and environmental disasters.

2.1.7. Tackling environmental challenges based on science

To tackle the environmental challenges of the first half of the 21st century, it is essential to rely on scientific knowledge based on evidence. Solving climate and environmental problems requires a solid understanding of science and a population and political leaders who recognize the importance of science in identifying problems and presenting solutions, just as happened with the ozone hole phenomenon. It is important to point out to students (and society as a whole) the example of tackling the ozone hole; how suffering from skin cancer was reduced and in some cases avoided, the ecosystem effects that were lessened or avoided, and how difficult it would be to tackle this in an environment steeped in scientific fake news in a population that mostly went along with it.

2.1.8. Moral and character education

In addition to scientific education, broader moral and character education plays a fundamental role in equipping individuals with the ethical foundations necessary to discern truth, exercise sound judgment, and make decisions based on shared values of justice and human flourishing. Developing cognitive, emotional, and relational aspects of character can allow people to navigate the complexities of misinformation and resist the influence of fake news, gossip, and post-truth narratives (Athanassoulis 2024, Kristjánsson 2022). By cultivating virtues such as honesty, critical thinking, and responsibility, moral education enables individuals to act consistently with ethical principles, even when exposed to misinformation.

Furthermore, incorporating character education into curricula promotes personal development that transcends specific contexts or issues. It empowers individuals to become wise decision-makers who anchor their actions in moral systems rather than relying solely on external sources of information (De Ruyter et al. 2022). This approach can contribute to reducing the vicious cycles of misinformation by fostering communities that value ethical integrity, mutual trust, and collective well-being over divisive and sensationalized narratives.

Educational initiatives can include interactive programs, reflective exercises on moral dilemmas, and examples from historical events where ethical reasoning played a decisive role, such as the successful global response to the ozone hole crisis. These programs could be complemented by discussions on the moral responsibilities of individuals, media platforms, and governments in ensuring the dissemination of accurate information.

3. CONCLUSIONS

In this hypothetical situation, humanity's fate in relation to climate change and other environmental challenges would be influenced by the ability to promote education, scientific literacy, and public awareness. Only through critical understanding, commitment to science, and the search for reliable information can humanity take effective action to address crucial environmental issues and shape its future responsibly and sustainably. To address the intersection of environmental challenges and disinformation, this article emphasizes the need for international regulations, innovative educational tools, and partnerships between governments, educators, and media organizations. By integrating moral and character education into broader educational frameworks, societies can cultivate individuals who prioritize truth, ethical reasoning, and collective well-being. This approach provides a sustainable foundation for resisting misinformation, fostering trust, and ensuring wise actions in response to global challenges such as environmental crises and scientific denialism. By adopting these strategies, society can ensure that science and accurate information remain at the forefront of environmental policymaking. By integrating AI-driven detection systems, fostering science journalism, and introducing interdisciplinary methodologies, global efforts can overcome the challenges posed by disinformation. Ultimately, combating misinformation requires a balance between technological solutions, such as AI algorithms, and ethical approaches that emphasize truth, accountability, and public engagement. Recognizing the ethical dimensions of fake news (Frankfurt 2005, McIntyre 2018) can guide efforts to rebuild trust in science and strengthen collective action against global challenges. Such approaches, grounded in data transparency and international cooperation, are crucial for fostering informed decision-making and sustainable environmental policies. Building on the success of the Montreal Protocol, this article highlights the critical

role of international cooperation in overcoming modern environmental challenges. By fostering trust in scientific evidence and aligning global efforts, humanity can navigate the complexities of misinformation and take decisive action to protect the planet. The history of the ozone hole response serves as a powerful reminder of the impact of science-driven policies. Integrating this lesson into modern strategies can bridge the gap between past successes and present challenges posed by misinformation. As a global society, we need to rethink how we deal with information in an over-connected population, often addicted to smartphones, so that public policies and individual actions are guided by credible knowledge that can be held accountable.

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