UNSEEN CULPRIT: THE SILENT THREAT OF METHANE

ANANTHAKRISHNAN S*, REWANGINI RANJHA

Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

*Corresponding Author, E-mail: ananthakrishnan003@gmail.com

In the complex story of climate change, where carbon dioxide (CO_2) often takes center stage, there exists an unseen and potent player quietly shaping the destiny of our planet – methane (CH_4). Despite its significant heat-trapping properties, methane frequently receives limited attention in environmental discussions. As we deal with the consequences of a changing climate, it is important to recognize the significance of methane emissions. With a heat-trapping capacity over 25 times that of CO_2 in the atmosphere over a 100-year period, understanding of methane emissions is crucial for comprehending and addressing its impact on our planet. The atmospheric concentration of methane has surged by 2.5 times since the pre-industrial era. Recent studies have highlighted a concerning increase in atmospheric methane levels, prompting a revaluation of our understanding and underscoring the necessity for a thorough investigation into its origins and impacts. This article seeks to delve into the dimensions of the methane challenge, encompassing both natural and anthropogenic origins. Recent research underlines the link between climate change, wetlands, and methane emissions, stressing the need for enhanced policies to address this potent greenhouse gas.

SOURCES OF METHANE LEAKS

Methane leaks, whether from natural or human-induced origins, play a pivotal role in the global methane budget (Figure 1). In addition to the well-known sources such as wetlands, termites, and wildfires, recent events, such as the alarming methane well blowout in Kazakhstan, underscore the significant contribution of human activities to methane emissions.

Anthropogenic methane emissions contribute to approximately 30% of the global warming observed since the pre-industrial era. Human-induced sources of methane include the extraction and transportation of fossil fuels, particularly evident during the production of oil and natural gas (Figure. 2). The recent incident in Kazakhstan serves as a stark example, where a blowout during exploration drilling led to the release of an estimated 140,000 tons of methane into the atmosphere over 205 days, ranking it among the world's worst-ever blowouts. Landfills, another anthropogenic source, are notorious for emitting substantial amounts of methane as organic waste undergoes anaerobic decomposition. Livestock digestion, particularly in large-scale farming operations, is also a major contributor to methane emissions. The decomposition of organic matter in rice paddies under anaerobic conditions further adds to the methane released into the atmosphere.

A comprehensive analysis of methan" flu'es from various aquatic ecosystems, revealed that aquatic ecosystems contribute significantly, constituting 41% (median) to 53% (mean) of total global methane emissions from both anthropogenic and natural sources (Rosentreter et al., 2021). These increased aquatic emissions are due to urbanization, eutrophication, and climate feedbacks, suggesting changes in land-use management as potential mitigation strategies to reduce aquatic methane emissions. The diverse sources of methane leaks underscore the complex task of reducing emissions. While natural sources contribute, the significant impact of human necessitates comprehensive strategies to tackle both established and emerging methane sources, ensuring environmental protection against the harmful effects of this potent greenhouse gas.

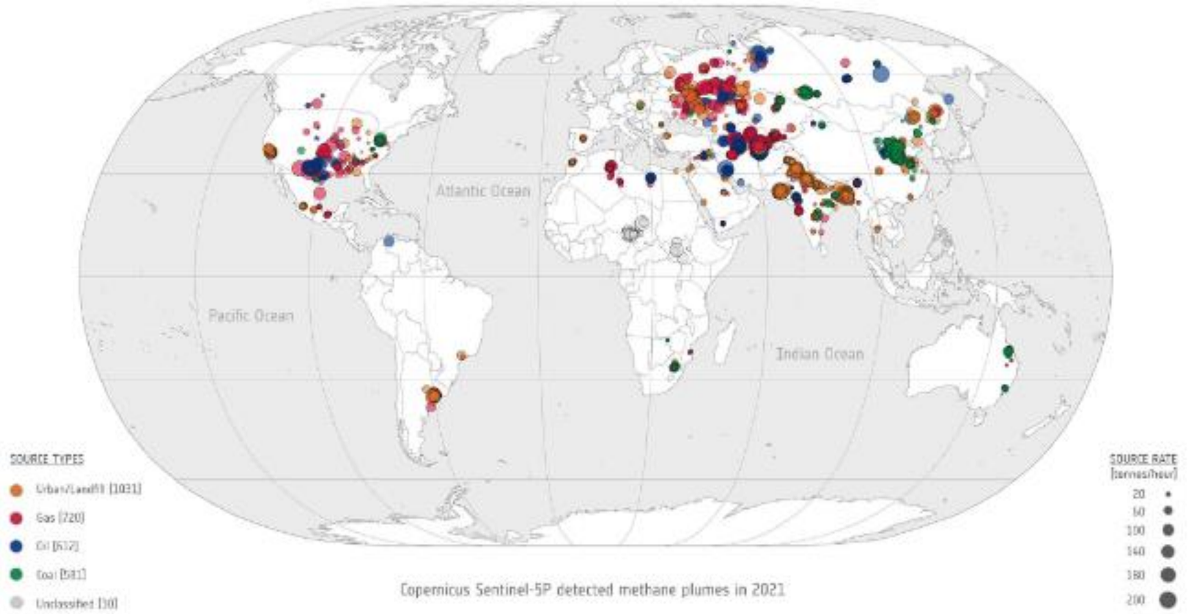

Figure 1: Global overview showing the location and magnitude of 2974 methane super-emitter plumes detected in 2021 using the Copernicus Sentinel-5P Tropomi instrument (Source: Trio of Sentinel Satellites Map Methane Super-emitters, 2023).

Figure 2: Methane super-emitter plumes detected in a cluster of detections at an oil exploitation site in Libya, as observed by Copernicus Sentinel-5P on 26 July 2021 (Source: Trio of Sentinel Satellites Map Methane Super-emitters, 2023)

IMPACTS ON CLIMATE CHANGE

Methane's potency as a greenhouse gas makes it a key player in global warming. Although it has a shorter atmospheric lifetime compared to CO_2, its heat-trapping capabilities are far more potent. Methane is responsible for approximately 16% of global greenhouse gas emissions (Chai et al., 2016). Uncontrolled methane leaks exacerbate climate change by accelerating the warming of the planet. The indirect global warming potential of methane, which includes the production of CO_2 from its oxidation, further underscores its role in climate change. The rise in CO_2 levels induced by climate change exacerbates methane emissions, as demonstrated by studies using models. Simulation results indicate that doubling CO_2 levels leads to a substantial 78% increase in methane emission (Shindell et al., 2004).

The findings by Zhang et al., (2017) underscore that, climate-change-induced feedbacks between wetlands and methane play a crucial role in radiative forcing, constituting a significant component of climate change. The study advocates for the inclusion of these climate-change and wetland methane feedbacks in policies aiming to mitigate global warming below the 2°C threshold.

ECONOMIC AND ENVIRONMENTAL CONSEQUENCES

In addition to its climate impact, methane leaks pose economic and environmental risks. Lost methane represents wasted energy resources and revenue for the fossil fuel industry. Furthermore, methane leaks contribute to ground-level ozone formation, leading to air pollution and adverse health effects for nearby communities. Owens et al. (1982) found that a doubling of ground-level methane flux could increase total ozone column by 3.5%. Field et al. (2014) further demonstrated the role of fugitive emissions from oil and gas operations in driving episodic ozone production. Kurtén et al. (2011) highlighted the potential for large methane releases to reduce cloudiness and increase ozone. These studies collectively underscore the need for effective methane leak detection and emission control measures to reduce their contribution to ground-level ozone formation.

Methane emissions also harm ecosystems and aquatic life when released into water bodies. It can warm water bodies affecting species distribution and ecosystem dynamics. A study conducted by Gonzalez-Valencia et al. (2014) investigated methane emissions from lakes, polluted by anthropogenic carbon and nutrient inputs, finding wide-ranging fluxes strongly correlating with water quality indexes.

DETECTION AND MONITORING

Detecting methane leaks is challenging as it is colorless and odorless in nature. Advanced technologies, such as satellite imaging, drones, and infrared cameras, have been used to identify and monitor methane emissions. Short wave infrared bands are known to provide unique fingerprints for methane. Continuous advancements in monitoring techniques are crucial to addressing leaks promptly and effectively.

MITIGATION STRATEGIES

Due to its shorter atmospheric lifespan compared to CO_2, methane presents an opportunity for prompt climate action. By lowering methane emissions, we can witness a discernible decrease in global methane levels within a decade, contributing to the mitigation of the enhanced greenhouse effect. Efforts to reduce methane leaks require a multi-faceted approach involving technology, policy, and industry. New technologies and platforms, such as drones and satellites, to enhance the effectiveness of leak detection and repair programs are necessary. However, the effectiveness of these programs is contingent on careful policy design. Implementing stricter regulations on methane emissions, improving infrastructure to prevent leaks, and adopting cleaner extraction and production methods are essential steps. Methane capture and utilization technologies, such as methane digesters in agriculture and renewable natural gas projects, also offer promising solutions.

CONCLUSION

As the world deals with the challenges of climate change, addressing methane leaks emerges as a critical component of mitigation efforts. Understanding the sources and impacts of methane, and implementing effective solutions to reduce its emissions is paramount for a sustainable and resilient ecosystem. The collective action of industries, governments, and communities is essential in curbing methane leaks and safeguarding the planet from the threat of climate change.

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