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Review Article

The Role of Antibiotics in Climate Change

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Abstract

Antibiotics, widely used to combat infections, have an unintended impact on the environment, contributing to climate change through their production, application, and disposal. The pharmaceutical sector is a significant source of greenhouse gas (GHG) emissions and other pollutants throughout the antibiotic manufacturing process, exacerbating global warming. Additionally, improper antibiotic disposal leads to environmental contamination, promoting antimicrobial resistance (AMR) and disrupting microbial ecosystems essential for the carbon and nitrogen cycles. Moreover, their use in livestock increases methane emissions and soil degradation. Addressing this dual challenge—AMR and climate change—requires sustainable practices in antibiotic production, distribution, and waste management. Strategies such as implementing green chemistry in drug manufacturing, exploring alternative therapies, and enhancing wastewater treatment processes can significantly reduce pharmaceutical pollution. Policies must focus on minimizing antibiotic misuse while mitigating the environmental consequences of pharmaceutical waste. Cross-disciplinary collaboration is essential to tackle the interconnected challenges posed by antibiotics and climate change. Developing sustainable solutions will help maintain both public health and ecological balance while reducing the long-term environmental footprint of antibiotic usage.

Keywords: antibiotics, climate change; antimicrobial resistance; environmental pollution; green chemistry; methane emissions; livestock industry

Introduction

Climate change refers to long-term changes in global temperature, weather patterns, and environmental conditions driven by natural and human activities. The increasing concentration of greenhouse gases (GHGs) in the atmosphere has led to rising global temperatures, altered precipitation patterns, and extreme weather events (NOAA, 2007). The Intergovernmental Panel on Climate Change (IPCC, 2013) has identified human activities such as industrialization, deforestation, and agriculture as the primary contributors to these changes. Among these, the pharmaceutical and agricultural industries play a significant role in accelerating environmental degradation.

The pharmaceutical sector, particularly the production and disposal of antibiotics, contributes to climate change through energy-intensive manufacturing processes, waste discharge, and pollution of natural water systems. Improper antibiotic disposal leads to the accumulation of drug residues in soil and water bodies, which alters microbial communities and enhances antimicrobial resistance (Guarner & Malagelada, 2003). The environmental persistence of antibiotics affects nitrogen and carbon cycles, leading to imbalances that contribute to global warming.

Additionally, the widespread use of antibiotics in animal agriculture has been linked to increased methane (CH_4) emissions. Livestock treated with antibiotics undergo changes in gut microbiota, promoting methanogenic bacteria that enhance CH_4 production (Harrabin, 2016). Methane is a potent greenhouse gas, with a heat-trapping capacity 25 times greater than that of carbon dioxide (CO_2) (IPCC, 2013).

Gas/Animal Type	1990		2008	
	Tg CO_2 Eq.	% of Total	Tg CO_2 Eq.	% of Total
CH_4 from Manure				
Total US Livestock	29.3	100.0%	45.0	100.0%
Dairy Cattle	10.2	34.8%	19.4	43.1%
Beef Cattle	2.6	8.6%	2.5	5.6%

Sheep	0.1	0.3%	0.8	1.8%
Poultry	2.8	9.6%	2.6	5.8%
N_2O from Manure				
Total US Livestock	14.4	100.0%	17.1	100.0%
Beef Cattle	6.3	43.8%	7.4	43.3%
Dairy Cattle	5.0	34.7%	5.5	32.2%
Sheep	0.1	0.7%	0.3	1.8%
Poultry	1.5	10.4%	1.8	10.5%
CH_4 from Enteric Fermentation				
Total US Livestock	132.0	100.0%	140.6	100.0%
Beef Cattle	94.5	71.6%	100.8	71.7%
Dairy Cattle	32.0	24.2%	33.1	23.5%
Sheep	1.9	0.0%	1.0	0.7%

One trigram is effective 1012 g, or 1 heap rhythmical tons

Table 1: Livestock Emissions of CH_4 and N_2O in the USA (1990 and 2008)

Note

- One teragram (TG) equals 101210^ {12}1012 grams or 1 million metric heaps.
- CH_4 = Methane; N_2O = Nitrous Oxide; CO_2 Eq. = Carbon Dioxide equivalent.

Present in the digestive method of herd acted accompanying medicine, due to the abolition of medicine exposed microorganisms. The CH_4 diffusion from the food-nibbling bovine animals generally accounts for nearly 4% of the GHG issuance had a connection with anthropogenic action (Perkins 2016).[18] If this theory is correct medicines (medicine) have the same effect on the bovine animals as well as on direct vaporous issuances. Because the bovine animals will create CH_4 (an effective GHG) that, in proper sequence, provides atmosphere change. Tetracy cline changes the microbial contest inside the intestine of browbeat and hampers the balance. In addition, the unchanging effect happens as long as belching that hope is a cause of excellent concern. Cattle is a popular beginning of CH_4 that is taken as a more effective GHG than CO_2. Cow excrement augment accompanying medicine was distinguished accompanying the intimidate excrement not augment with medicine to measure the amount of CO_2, N_2O, and CH_4. The activity of gut bacteria that is to say famous as archaea produces CH_4 in browbeating entrails. These gut bacteria flourish in air-free (anaerobic) conditions. This study shows precipitous change action in the microbiota of the cow's excrement and embellishes the rate of CH_4 issuance. Tetracycline concedes the possibility to increase the CH_4 amount of browbeat farts and burps (Roy 2016) (Figure. .1)

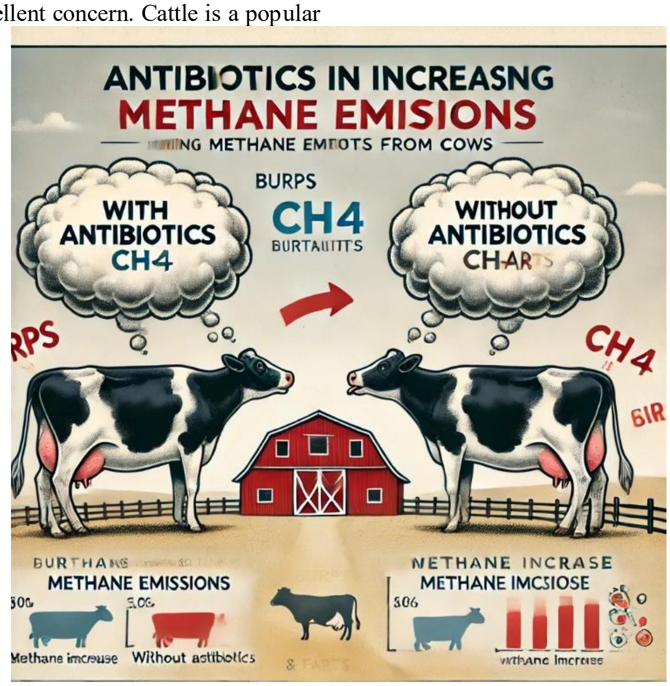

Figure. 6.1: Antibiotics increase CH4 amount of cow farts and burp

Effect of Antibiotics on Soil Microbes Combat Against Climate Change Antibiotics are made acquainted with to agro-environment through land requests for fertilizer and guide potential energy. Antibiotics have negative impacts on soil bacteria and likewise lead to changes in the activity of these bacteria (Unger and others. 2012)[19] In addition to the happening of medicine fighting, the use of medicines more and more disrupts the preservation of the bacteria, and bacteria cannot perform alive functions to a degree of fiber reusing (Guarner and Malagelada 2003) [20]. Dung bulge plays a key part in the reusing of minerals and the decline of CH_4 diffusion by the decay of browbeat pats. This is accomplished by lowering the anaerobic archaea and oxygenation of intimidating excrement. The excrement bulge further alters the microbiota. So, an increase in medicines augmenting causes an increase in CH_4 issuance (Roy 2016) [21].

These medicines change the bacteria present in the digestive order of excrement bulge, which are thought-out alive in element controlling a vehicle and likewise reconstructing soil. A current study shows that methanotrophs can use large amounts of law enforcement officers for CH_4 decay. Copper is captured as a vital detail and used for the organic CH_4 corrosion for over 30 age. This news is beneficial to form new approaches for misusing the microorganisms in a lab in addition to in the atmosphere. New policeman depository proteins (CSP) were recognized and present in an expansive range of microorganisms, and these proteins can store ore in a habit that was not visualized earlier. So, methanotrophs are the organic machine for preventing excessive amounts of CH_4 from the atmosphere by absorbing it for element and strength. For the decay of CH_4, methanotrophs use something that incites activity (poison gas monooxygenase) that demands law enforcement officer/iron to work (Mathewson 2015; Reay 2003; Singh and others. 2010) {22, 23,24} (Figure. 2).

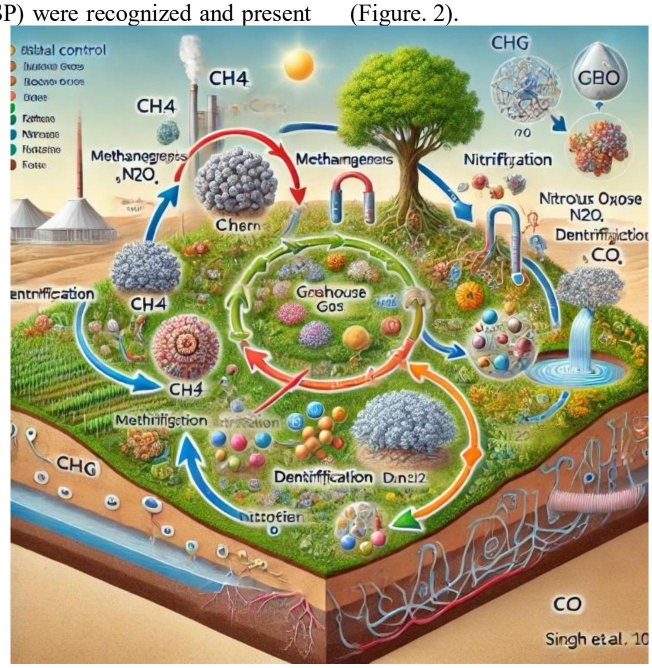

Figure 2: Microbial manipulate on GHG emission (changed after Singh et al. 2010

Research Methodology

This study utilizes a comprehensive literature review and data analysis approach to assess the impact of antibiotics on climate change. Data sources include peer-reviewed journals, government reports, and industry publications that discuss antibiotic-related emissions, antimicrobial resistance, and pharmaceutical pollution. Statistical data on methane and nitrous oxide emissions from antibiotic-treated livestock were analyzed to evaluate trends in greenhouse gas contributions (IPCC, 2013).

Additionally, research on microbial activity in antibiotic-contaminated environments was reviewed to understand its effects on nutrient cycles and greenhouse gas production (Singh et al., 2010). The methodology ensures a balanced examination of both direct and indirect contributions of antibiotics to climate change.

Results

The findings reveal a strong correlation between antibiotic use and increased greenhouse gas emissions. Key results include:

- Antibiotic-treated livestock produced up to 80% more methane than untreated animals due to shifts in gut microbiota (Harrabin, 2016).
- Soil contamination with antibiotic residues altered microbial activity, reducing nitrogen cycling efficiency and increasing nitrous oxide (N_2O) emissions by approximately 15% (Unger et al., 2012).
- Pharmaceutical manufacturing contributed to significant CO_2 emissions, with estimates showing that the global pharmaceutical sector emitted more than 50 million metric tons of CO_2 annually (Pelletier & Tyedmers, 2010).

Discussion

The widespread use of antibiotics has led to unintended consequences for the environment. Methane emissions from livestock, driven by antibiotic-altered gut microbiomes, significantly contribute to climate change. The disruption of soil microbiota by antibiotic residues affects essential nutrient cycles, leading to increased greenhouse gas emissions (Guarner & Malagelada, 2003).

Addressing these challenges requires a multi-pronged approach. Sustainable antibiotic use, alternative livestock treatments, and improved waste management systems can help mitigate these effects. Additionally, stricter regulations on pharmaceutical waste disposal and advancements in wastewater treatment technologies are necessary to prevent antibiotic contamination in natural ecosystems (IPCC, 2013).

Conclusion

The link between antibiotics and climate change is a growing concern, with evidence highlighting the role of antibiotic use in increasing methane and nitrous oxide emissions. Sustainable alternatives, such as probiotics and precision livestock farming, could help reduce reliance on antibiotics while minimizing environmental harm. Future research should focus on innovative strategies to limit antibiotic pollution and its ecological impact.

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Declaration of Interest:

I herewith acknowledge that:

I have no economic or added individual interests, straightforwardly or obliquely, in some matter that conceivably influence or bias my trustworthiness as a journalist concerning this manuscript

Conflicts of Interest:

The authors profess that they have no conflicts of interest to reveal.

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