The Net Environmental Impact of Preventative Healthcare – Vaccination's Role in the Fight Against Climate Change

EPH-170

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INTRODUCTION

- The adverse effects of climate change on human health and the pharmaceutical industry's environmental footprint have been extensively studied; however, not all healthcare interventions share the same environmental consequences
- While research, manufacturing, distribution, utilization, and disposal of pharmaceuticals contribute to environmental degradation, preventive treatments may offer a counterbalance by averting future illnesses, lessening severity, and reducing resource-intensive healthcare demands[5,6,7]
- Vaccination, a cornerstone of prophylactic medicine, is recognized for its cost-effectiveness due to disease prevention, but its environmental implications remain underexplored and under-quantified[10, 23]
- Understanding the net environmental impact of vaccination is crucial for making informed decisions about public health interventions and advancing sustainable healthcare practices

OBJECTIVES

- This literature review aims to evaluate the existing peer-reviewed, academic research assessing the net environmental impact of vaccination, considering the negative environmental footprint across various stages of the vaccine lifecycle vs. the potential positive impact of disease avoidance and severity reduction
- Additionally, it investigates the methods behind industry-sponsored studies of vaccines' net environmental impact, to understand current levels of rigor and standardization

METHODS

- A targeted literature search was performed across multiple databases, including PubMed, ISPOR archives, and Google, encompassing materials published between 2019 and 2023
- The search was conducted using tailored search strings aimed at capturing relevant literature pertaining to vaccination and its impact on the environment
- Key search terms (alone or in combination) included "vaccination", "environmental impact", "climate change", "pollution", "waste", "carbon", "emissions", etc.
- Hand searching was also conducted to include relevant articles and grey literature (presentations, whitepapers, online reports, and articles) that met eligibility criteria for relevance
- Both peer-reviewed publications and grey literature sources were included to ensure a comprehensive review; this systematic approach allowed for the identification and retrieval of pertinent publications, contributing to a thorough exploration of the topic

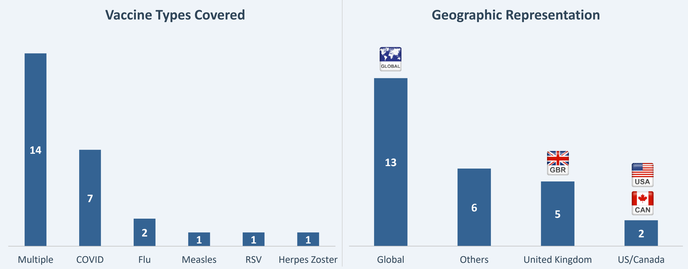
Search Strategy

Sample Search Terms	Vaccine, vaccination, environmental impact, climate change, pollution, waste, carbon, emissions
Filters	2019-2023, Abstract Available, English
Refinement	1,692 sources accessed, reduced to 36 based on keyword refinement and title review
Relevant Results (N)	26 publications ultimately referenced for data extraction

RESULTS

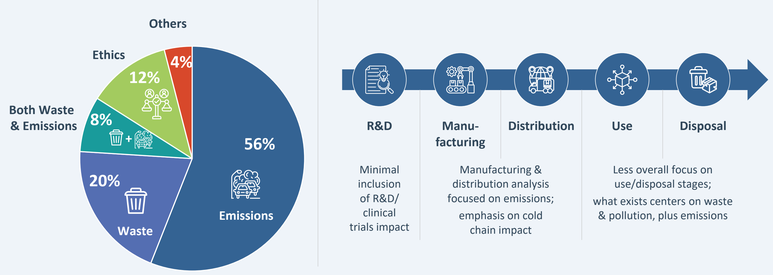
Negative Environmental Impacts of Vaccines: *Peer-Reviewed Academic & Grey Literature (n=26)*

Figure 1 | Vaccine Types & Geographic Representation[1-26]



- Publications covering multiple Vaccine types were more general and less quantitative in their findings, or focused on only one segment of product life cycle
- The recent proliferation of COVID-specific research may be reflective of post-pandemic research funding priorities coinciding with increasing interest in environmental impact analyses
- The UK has disproportionate representation globally, potentially resulting from the NIH's leadership in net zero and sustainability goals

Figure 2 | Types of Impact Assessed & Product Life Cycle Stage Inclusion[1-26]



- Most publications focus only on emissions, primarily examining CO_2 equivalents
- Significantly less attention is given to waste and pollution, and no publications covered water use/contamination or raw materials and other resource use in the context of a vaccine's life cycle
- Ethical considerations were also included as an impact in some publications, but not quantified
- Overall, there is incomplete consideration of impact across the product life cycle – studies mostly focused on distribution & use/disposal; manufacturer-gated data also limits researchers' ability to holistically quantify

Positive Environmental Impacts of Vaccines: *Industry-Sponsored Studies (n=3)*

Figure 3 | Summary of Findings from Industry-Sponsored Studies

Sponsor	Vaccine Type	Region	Study Population	Impact Type	Units	Findings
sanofi AstraZeneca	Respiratory Syncytial Virus (RSV)	GBR	Infants	Averted Healthcare Resource Utilization	Kt CO_2 eq., over entire UK infant population	• A universal RSV immunization program using nirsevimab was found to avoid substantial carbon emissions, amounting to a net avoided ~22 kilotons (kt) of CO_2 eq. per year for the study pop[1] • RSV vaccine use for this population is estimated to contribute annual emissions of .02 kt CO_2 eq. emissions, though data are not public and notably this does not include the impacts from manufacturing, distribution, disposal, etc., so should be considered a partial figure[1]
GSK	Herpes Zoster	USA	Adults 50+	Averted Healthcare Resource Utilization	Kt CO_2 eq., per 1 Million adults 50+	• Resulted in carbon savings of 18% (4.5k tons of CO_2 eq. for every 1 million individuals vaccinated) due to avoided hospitalization and care visits[2] • The study does not include direct quantification of negative environmental impact, but notes that "internal company data" was used to compare the emissions from vaccination to those from averted hospital admissions and care[2]
AstraZeneca	Seasonal Influenza	GBR	General Population	Averted Healthcare Resource Utilization	Kg CO_2 eq., per flu patient/case	• Treating one case of seasonal flu emits equivalent CO_2 to administering ~14.5 vaccines[3] • AZ's flu vaccine was shown to have a global warming impact of 1.52 kg CO_2 eq. per dose administered (data not public)[3] • Treating one average flu case in the UK emits 22.1 kg CO_2 eq (including multiple steps along the patient care pathway, e.g., self-care, primary care, and secondary care)[3]

ANALYSIS

- Publications focus on the UK, US, and select other countries (e.g., Bangladesh), which may be reflective of regional priorities and local data/funding availability
- Few vaccine-specific publications exist beyond COVID, representing potential for future research
- The current focus on only emissions misses the bigger picture of holistic environmental impact, which can vary significantly by metric and region of interest
- Inconsistent data availability raises issue of highly limited publicly-available sources and manufacturer ownership of most impact data across the product life cycle

- Industry-sponsored studies focus on averted healthcare resource utilization (HCRU), and have limited inclusion of negative upstream effects
- Methodologies are not consistent, though all use a patient care pathways approach, championed by the Sustainable HC Coalition
- Measurement of outputs and study populations are also inconsistent, so studies are not comparable
- Data leveraged in these studies is non-public (typically manufacturer-owned) and their results have not been peer-reviewed
- Geographies are limited to the US and the UK

DISCUSSION & CONCLUSION

Discussion:

- **Academic Focus on Negative Upstream Effects:** Peer-reviewed publications have predominantly examined the negative upstream effects of vaccines, shedding light on environmental concerns associated with vaccine production and distribution across the product life cycle
- **Industry Focus on Averted HCRU**: Manufacturers are using a patient care pathways approach to quantify the positive environmental impact of vaccination through removing the need for care, though their analyses stop short of holistically comparing upstream and downstream effects
- **Lack of Data Availability:** Little publicly-available data exists on the quantification of either upstream or downstream effects; therefore, many studies either omit portions of the product/use lifecycle or rely on unpublished sources
- **Inconsistent Methodologies:** Analyses are not standardized, and outputs are not presented in consistent units or populations

Conclusions:

- **Inconclusive Evidence on Net Environmental Impact**: Despite these efforts, the hypothesis that vaccination may have a net positive environmental effect cannot be confirmed or refuted based on current evidence
- **Need for Continued Research:** There is a pressing need for continued research in this area to build a base of publicly-available data to be leveraged in quantification, and for academic & professional society leadership to develop standardized methodologies for assessing the environmental impact of vaccines; this can help prevent greenwashing and ensure accurate and transparent reporting
- **Future Analyses:** Conversion of environmental impact to economic impact and the effect of alternative options (e.g., oral vaccines and microneedle patches) should also be explored; quantification can extend to other types of healthcare and behavioral interventions
- **Impact of Successful Quantification:** Understanding the true net impact of vaccines can help inform policy and manufacturing / product development decisions, leading to a more sustainable future of healthcare

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Disclosures: All the authors are employees of Trinity Life Sciences (Waltham, MA); LH and MOH hold equity in Trinity Life Sciences