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Education Article

Environmental Sustainability of Inhaler Therapy In Respiratory Diseases: Reducing Carbon Footprints While Preserving Personalized Patient Care

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SUMMARY

Introduction: Climate change has emerged as one of the greatest threats to global health, and the healthcare sector contributes substantially to greenhouse gas emissions. In the management of respiratory diseases, pressurized metered-dose inhalers (pMDIs) are an important source of greenhouse gas emissions because they contain hydrofluoroalkane propellants with a high global warming potential.
Methodology: This review summarizes current evidence on the environmental impact of inhaler devices and evaluates the environmental, clinical, patient-related, and economic considerations that should guide sustainable inhaler prescribing for asthma and chronic obstructive pulmonary disease (COPD). A literature search was conducted in the PubMed database from inception to 1 June 2026 using the search terms „inhalation device" OR „environmental". Seventy-nine articles were identified and supplemented by relevant publications from reference lists.
Topic: Current evidence demonstrates that dry powder inhalers (DPIs) and soft mist inhalers (SMIs) have substantially lower carbon footprints than pMDIs while providing comparable clinical outcomes when appropriately selected for patients. However, inhaler choice should not be based solely on environmental considerations, as clinical effectiveness, patient characteristics, inhaler technique, patient preferences, and device availability remain essential determinants of successful treatment. Economic evaluations suggest that switching clinically eligible patients from pMDIs to lower-carbon alternatives may reduce both greenhouse gas emissions and healthcare costs in selected settings, although the financial impact depends on the replacement strategy and local pricing.
Conclusion: Overall, sustainable inhaler prescribing should integrate environmental sustainability with evidence-based clinical practice and shared decision-making to optimize patient outcomes while reducing the environmental impact of respiratory care.

Keywords: Climate Change, Greenhouse Gas Emissions, Carbon Footprint, Inhalers, Sustainable Healthcare

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INTRODUCTION

Climate change poses a significant threat to human health, especially for people with chronic lung diseases. The main driver of climate change is the emission of greenhouse gases (GHGs), among which CO_2 is the most important. These gases absorb thermal energy and slow down its release into space, thereby contributing to global warming [1]. Consequences include rising temperatures, droughts, heat waves, forest fires, and other environmental changes that adversely affect human health [1–3]. That is why many countries are implementing measures to reduce GHG emissions.

In addition to the wider impact on the environment, the pharmaceutical sector can contribute to environmental pollution throughout the life cycle of medicines, from their production and use to their excretion, transformation, and disposal. Pharmaceutical substances and their transformation products may enter environmental compartments and raise concerns regarding potential effects on human health and ecosystems. Importantly, environmental risk assessment should not focus exclusively on active pharmaceutical ingredients (APIs), as pharmaceutical formulations are multicomponent mixtures that also contain excipients and other formulation constituents. These substances may undergo environmental transformation and, depending on their physicochemical properties, persistence, and biological activity, may contribute to the overall environmental impact of pharmaceutical products. In addition to their environmental relevance, excipients are not necessarily completely pharmacologically inert and some excipients used in medicines, including inhaled preparations, have been associated with adverse effects in humans. Therefore, assessment of the environmental impact of pharmacotherapy should consider the entire pharmaceutical formulation and its life cycle, rather than focusing solely on the active pharmaceutical ingredient. [4,5,6].

Environmental factors in the context of inhalation therapy encompases characteristics of drugs and inhalation devices that contribute to their overall impact on the environment throughout their life cycle, including the type and amount of propellant, greenhouse gas emissions, energy and resource consumption during production, transportation and disposal, as well as the potential release of pharmaceutical substances and device components into the environment. These factors can contribute to climate change, air, water and soil pollution, depletion of natural resources and waste generation [6].

The healthcare sector is also a significant contributor to GHG emissions, with a share of around 10% of total emissions in the US, 7% in Australia and 4.6% in Canada [7]. Increasing awareness of the environmental impact of health care resulted in the need for a more sustainable approach, including inhalation therapy [3]. Inhalation therapy is the basis of treatment for asthma and chronic obstructive pulmonary disease (COPD), and its impact on the environment depends on the type of inhaler. There are three basic types: Pressurized Metered Dose Inhalers (pMDIs), Dry Powder Inhalers (DPIs) and Soft Mist Inhalers (SMIs). pMDIs are among the largest single contributors to the pharmaceutical-related GHG emissions due to the use of hydrofluoroalkane (HFA) propellants. Although propellants used in pMDIs contribute less than 0.1% of global greenhouse gas emissions, reducing their carbon footprint has become a priority in respiratory care. Reliever inhalers such as short-acting β_2-agonist (SABA) inhalers account for a substantial proportion of pMDI-related emissions due to their widespread use, particularly in Europe and Canada [5]. Although inhaled corticosteroid (ICS)/long-acting β_2-agonist (LABA) combinations dominate the global respiratory market, short-acting β_2-agonists (SABAs) account for nearly half of all prescribed inhaler doses [8,9].

The healthcare sector has an important role in mitigating climate change by reducing greenhouse gas emissions. In respiratory care, this involves selecting inhaler devices that combine environmental sustainability with optimal clinical outcomes. Appropriate inhaler choice should consider treatment efficacy, patient capability and preference, cost, and clinical judgment, while patient education and improved awareness of the environmental consequences of different inhaler devices are essential for informed decision-making [10]. To reduce the environmental impact of respiratory care, global initiatives recommend the gradual transition from fluorinated pMDIs to lower-carbon alternatives such as DPIs, when clinically appropriate [11].

This review summarizes the evidence on inhaler choice across four domains - environmental performance, clinical efficacy, patient preferences, and cost-effectiveness - to support sustainable prescribing and optimal management of asthma and COPD.

METHODOLOGY

The literature search was conducted in the PubMed database, including works published from the beginning of the database through June 1, 2026. The search strategy included terms related to inhalation devices and their impact on the environment, with synonyms within each concept were combined with the OR operator, and main concepts with the AND operator: („inhalation device" OR „inhaler" OR „pMDI" OR „DPI" OR „SMI") AND („environmental impact" OR „carbon footprint" OR „greenhouse gas emissions" OR „sustainability"). Additional relevant studies were identified by reviewing the references of the retrieved articles. Given the broad aim and narrative nature of this review, no predefined inclusion or exclusion criteria were applied based on year of publication, study design, research setting, or research topic.

TOPIC

Environmental performance

Originally, chlorofluorocarbons (CFCs), served as propellants in pMDIs, but they were banned under the Montreal Protocol in 1987 because of their ozone-depleting properties [12]. They were subsequently replaced by hydrofluoroalkane (HFA) propellants, such as HFA134a and HFA227ea, which are not ozone-depleting but have high global warming potential (GWP). The GWP of a gas is an indication of the amount of warming it causes over a specified period of time (typically 100 years) relative to CO_2. For instance, HFAs in pMDI (HFC-134a and HFC-227ea) are 1300-3350 times more potent than CO_2 and persist in the atmosphere for 14 years, causing climatic feedback. However, according to the Kigali Amendment to the Montreal Protocol, HFA-134a, HFA-227ea and the newest HFA-152a (with lower GWP potential) are expected to be phased down until 2050 [13]. In Serbia, HFA 134a is commonly used as the primary propellant in MDI inhalers [14,15]. The carbon footprint of an item is often expressed in „CO_2 equivalents", a unit that represents the potential global warming effect of all GHG emissions relative to CO^2. Hydrofluoroalkane propellants in pMDIs are responsible for roughly 0.03% of yearly global GHG emissions [12]. The carbon footprint of HFA-134a pMDI has been estimated to be comparable to that associated with driving approximately 2 km in a Seat Ibiza Ecomotive [16]. In contrast to pMDIs, SMIs and DPIs have a lower carbon footprint, as they do not use propellants, which is why they have a significantly lower impact on the environment [11].

The environmental impact of pMDIs is further increased by inappropriate disposal [17]. Unlike most DPIs, many pMDIs lack dose counters, leading to premature replacement and disposal of devices containing unused medication, which results in unnecessary greenhouse gas emissions and increased prescribing burden [18].

A survey of NHS patients also demonstrated that environmental impact is an important consideration for many patients when choosing an inhaler, highlighting increasing awareness of the carbon footprint associated with inhaler devices [19].

Evidence from Canada and the UK demonstrates the environmental benefits of switching from pMDIs to DPIs where clinically appropriate. The Canadian Thoracic Society has supported a target of replacing at least 20% of current pMDI prescriptions with DPIs, while a UK study estimated that substituting just 10% of prescribed pMDI with DPIs could reduce annual greenhouse gas emissions by approximately 58 $ktCO_2e$ [20,21].

Clinical efficacy

pMDI deliver medication as an aerosol using a propellant and are are designed to be used with coordinated actuation and inhalation. However, they require good coordination between actuation and inhalation, which can result in frequent errors in inhaler technique. Only approximately 10-20% of the emitted dose typically reaches the lungs, while a substantial proportion is depositedin the oropharynx [22]. The use of a spacer can improve lung deposition and overall effectiveness. Studies have consistently shown that correct inhaler technique is less common with pMDIs used without a spacer than with DPIs (23-43% vs. 53-59%) [23]. Another limitation is that many patients cannot tell when a pMDI is empty, potentially resulting in wasted medication or, more importantly, inadvertent use of an empty device during an exacerbation. Dry powder inhalers release powdered medication through the patient's inspiratory effort, thereby reducing coordination requirements and eliminating the need for propellants. Their advantage over the pMDIs is that their use does not require breath coordination. Most DPIs come equipped with a unit dose counter, which is not the case with most pMDIs. However, DPIs are ineffective for individuals who cannot generate sufficient peak inspiratory flow (PIF)- such as frail, elderly, very young patients, or those with muscle weakness - as suboptimal peak inspiratory flow can lead to inadequate drug delivery and reduced treatment effectiveness. [24,25,26]. For the Turbohaler®, a PIF>30 L/min is sufficient to ensure effective drug delivery in both adults and children [27,28]. To ensure rapid treatment of acute exacerbations, it has recently been proposed that patients keep a reliever pMDI and spacer in a separate emergency pack [29]. SMIs generate a fine mist through external pressure. Across devices, pMDIs and DPIs provide similar clinical efficacy in controlled settings when patients receive proper inhaler technique training [30,31].

Although DPIs have a substantially lower GWP than pMDIs, they are not suitable for all patients, and in some cases pMDIs provide superior clinical outcomes or remain the only available therapeutic option. To address the environmental impact of pMDIs, next-generation devices using low-GWP propellants, such as HFO-1234ze, are being developed to replace conventional hydrofluoroalkane propellants [32]. However, these newer formulations are not yet available in Serbia.

Patient preferences

When making treatment choices, patients with asthma and COPD prioritize ease of use and symptom control. Ramadan et al. (2017) reported that DPI users were significantly more likely than pMDI users to find their inhaler easy to use (73.3% vs. 46.3%, $p < 0.05$) and expressed greater satisfaction with their therapy [33]. Most patients successfully remain on a DPI after switching from a pMDI with appropriate education, while changing inhalers without patient consent and training can lead to worse clinical outcomes. A pilot study conducted at the Dispensary for Pulmonary Diseases in Novi Sad, Serbia included 104 patients with asthma or COPD receiving inhalation therapy. When evaluating the factors that would influence acceptance of switching inhalers, 90.40% of patients cited better symptom relief as the most important reason [34]. The results obtained are similar to research from New Zealand and within the NHS in England. In a study from New Zealand, the most important reasons for switching inhalers were better symptom relief (89%), ease of use (70%) [35]. In the NHS study, 80% of patients cited ease of use as an important or very important factor when choosing an inhaler [36]. These results indicate that clinical effectiveness and ease of use remain the most important criteria when choosing an inhaler. The authors conclude that the choice of inhaler should be based on a patient-centered approach, with shared decision-making and appropriate education on proper inhalation technique.

A 2011 study evaluated the feasibility of switching patients with COPD from pMDIs to DPIs during hospitalization for an acute exacerbation [37]. Patients received inhaler training at the time of the switch, and most continued using the DPI three months later, suggesting that a structured, supported transition is both feasible and acceptable. In contrast, switching inhalers without patient agreement or adequate education on inhaler technique may negatively affect asthma and COPD outcomes [38].

Price et al. demonstrated that switching inhalers through a shared decision-making approach, supported by patient consultations, did not compromise clinical effectiveness [39]. A patient-centered approach should guide inhaler prescribing, integrating patient preferences with clinical considerations. While pMDIs remain the preferred option for some individuals, DPIs may be more appropriate for others. Shared decision-making, supported by patient education and regular assessment of inhaler technique, is essential to ensure both effective treatment and successful implementation of clinically appropriate inhaler switching.

Finally, the greatest variable is the patient, who will ultimately decide whether their treatment is acceptable for their needs. In a study from New Zealand, willingness to switch inhalers due to lower environmental impact was 43% before additional information about the carboon footprint of the inhaler and 42% after reading the information, which is similar to the results of our study (45.20% before and 47.12% after education) [35]. In the NHS study, 44% highlighted the importance of the inhaler's carbon footprint [36]. These results indicate that clinical effectiveness and ease of use remain the most important criteria when choosing an inhaler, while the importance of environmental aspects is growing, but is still not decisive.

To increase awareness of the environmental impact , health professionals need to pay greater attention to the environmental condition. It is clear that as some civilization global developing and at the same time eco-destructive processes are not possible to terminate, it is necessary to increase the level of knowledge that would enable us to survive and make conditions for strong respect of environmental regulations [40].

Cost effectiveness

Maintaining current patterns of inhaler prescribing is projected to increase GHG emissions over the coming decades, further contributing to climate change and its associated health consequences. These include an increased burden of respiratory and cardiovascular diseases, climate-related injuries, mental health disorders, and premature mortality resulting from extreme weather events and changes in the distribution of infectious diseases [41]. As the prevalence of asthma and COPD continues to rise and access to guideline-recommended treatment improves, continued reliance on pMDIs may further increase the environmental burden of respiratory care. Consequently, transitioning clinically eligible patients to DPIs or other low-emission alternatives has emerged as an important strategy to reduce healthcare-related GHG emissions while maintaining effective disease management [35].

Evidence from several countries suggests that such a transition can provide both environmental and economic benefits. In England, replacing 10% of pMDIs with the least expensive DPI alternatives was estimated to reduce annual emissions by approximately 58 kt CO_2e while saving around £8.2 million in medication costs [35]. Similarly, in the Netherlands, substituting pMDIs with propellant-free inhalers was projected to reduce emissions by 63 kt CO_2e and generate annual savings of approximately €49 million [42]. However, the economic impact of inhaler switching depends largely on the replacement strategy and the cost of the selected alternatives. Supporting this observation, studies from South Korea and India found no significant differences in total treatment costs between pMDIs and DPIs [43,44]. These findings suggest that the long-held assumption that DPIs are invariably more expensive than pMDIs is no longer justified. Instead, inhaler selection should be guided primarily by clinical appropriateness, while also considering environmental impact, patient preferences, device usability, and cost-effectiveness.

Reducing the impact of inhalation therapy on the environment can be reduced not only by switching to DPIs, but also by developing new pMDI inhalers with propellants with a low global warming potential, such as HFA-152a and HFO-1234ze [44,45]. In addition, proper disposal of used inhalers and education of patients on the correct inhaler use can contribute to the reduction of unnecessary emissions and more rational use of inhaled drugs.

CONCLUSION

Climate change represents one of the most significant public health challenges, which is why the health sector has an important role in reducing its environmental impact. Although inhalation therapy makes up only a part of the overall carbon footprint of the healthcare sector, appropriate selection of inhalation devices can contribute to reducing emissions, while preserving the effectiveness and safety of treatment. The finding of this research indicates that the decision to switch from pMDI to DPI inhalers should not be made solely on the basis of environmental or economic criteria. For certain therapeutic groups, the transition can simultaneously reduce the carbon footprint and treatment costs, while for others it leads to an increase in healthcare expenditure. Therefore, an individualized approach is necessary, taking into account the clinical needs of the patient, the economic justification and the impact on the environment. Such an approach can contribute to more sustainable health care, while preserving the quality of inhalation therapy.

CONFLICT OF INTEREST

All authors declare no conflict of interest.

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Ekološka održivost inhalacione terapije kod respiratornih bolesti: smanjenje ugljeničnog otiska uz očuvanje individualizovanog pristupa lečenju pacijenata

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KRATAK SADRŽAJ

Uvod: Klimatske promene su se pojavile kao jedna od najvećih pretnji po globalno zdravlje, a zdravstveni sektor značajno doprinosi emisiji gasova staklene bašte. U lečenju respiratornih bolesti, inhaleri pod pritiskom sa doziranim dozama (pMDI) su važan izvor emisija jer sadrže hidrofluoroalkanske pogonske gasove sa visokim potencijalom globalnog zagrevanja.
Metodologija: Ovaj edukativni rad sumira trenutne dokaze o uticaju inhalera na životnu sredinu i procenjuje ekološka, klinička, pacijent-vezana i ekonomska razmatranja koja bi trebalo da vode održivo propisivanje inhalatora za astmu i hroničnu opstruktivnu bolest pluća (HOBP). Pretraga literature je sprovedena u bazi podataka PubMed od početka do 1. juna 2026. godine koristeći termine za pretragu „inhalacioni uređaj" ILI „ekološki". Sedamdeset devet članaka je identifikovano i dopunjeno relevantnim publikacijama sa referentnih lista.
Tema: Trenutni dokazi pokazuju da inhaleri sa suvim prahom (DPI) i inhaleri sa finom maglom (SMI) imaju znatno manji ugljenični otisak od pMDI, a istovremeno pružaju uporedive kliničke ishode za pacijente kada se pravilno odaberu. Međutim, izbor inhalera ne bi trebalo da se zasniva isključivo na ekološkim razmatranjima, jer klinička efikasnost, karakteristike pacijenta, tehnika inhalacije, preferencije i dostupnost uređaja ostaju bitne determinante uspešnog lečenja. Ekonomske procene sugerišu da prelazak klinički podobnih pacijenata sa pMDI na alternative sa nižim sadržajem ugljenika može smanjiti i emisiju gasova staklene bašte i troškove zdravstvene zaštite u odabranim uslovima, iako finansijski uticaj zavisi od strategije zamene i lokalnih cena.
Zaključak: Generalno, održivo propisivanje inhalera trebalo bi da integriše ekološku održivost sa kliničkom praksom zasnovanom na dokazima i zajedničkim donošenjem odluka kako bi se optimizovali ishodi pacijenata, a istovremeno smanjio uticaj respiratorne nege na životnu sredinu.

Ključne reči: klimatske promene, emisija gasova, staklene bašte, ugljenični otisak, inhaleri, održiva zdravstvena zaštita

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