REVIEW ARTICLE

Medycyna Środowiskowa – Environmental Medicine
www.environmed.pl

Environmental impact of anaesthetic gases – review of the most commonly discussed strategies

Wpływ gazów anestetycznych na środowisko: szybki przegląd najczęściej omawianych strategii

Alicja Obcowska[1,A-B,D,F], **Kinga Racisz**[2,A,E], **Joanna Duda**[3,B-C], **Aleksandra Walendzik**[4,D], **Jakub Kędzia**[3,D], **Łukasz Sencerek**[5,C,E], **Paweł Racisz**[6,C,F]

[1] *Clinic of Internal Medicine and Diabetology, Central Clinical Hospital, Medical University, Łódź, Poland*
[2] *Department of Nephrology, Hypertension and Kidney Transplantation, Central Clinical Hospital, Medical University, Łódź, Poland*
[3] *Department of Internal Medicine, Diabetology and Clinical Pharmacology, Central Clinical Hospital, Medical University of Łódź, Poland*
[4] *Faculty of Medicine, Medical University, Łódź, Poland*
[5] *Emergency Department, Primate Cardinal Stefan Wyszynski Regional Hospital, Sieradz, Poland*
[6] *Department of Dermatology, John Paul II Provincial Hospital, Bełchatów, Poland*
A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article

Obcowska A, Racisz K Duda J, Walendzik A, Kędzia J, Sencerek Ł, Racisz P. Environmental impact of anaesthetic gases – review of the most commonly discussed strategies. Med Srodow. doi: 10.26444/ms/203575

Abstract

Introduction and Objective. It is emphasized by the World Health Organization (WHO) that climate change poses a significant and increasing threat to human health. It is estimated that between 2030–2050, climate change could result in an additional 250,000 deaths annually due to factors such as flooding, droughts, air pollution, and infectious diseases. The healthcare system itself contributes to this crisis. Anaesthetic practices play a significant role in greenhouse gas (GHG) emissions. The aim of the review is to summarize current knowledge on the environmental impact of anaesthetic gases, while highlighting practical solutions that can be adopted in hospitals.

Brief description of the state of knowledge. Although the healthcare system improves lives, it also has an environmental cost, contributing to 1–5% of the total global environmental impact. Direct emissions from healthcare facilities constitute 17% of the sector's GHG emissions. Anaesthetic gases alone contribute 0.6% of healthcare emissions and 0.1% of the total global GHG emissions. Although the global share might seem small, the long-term accumulation of these gases in the atmosphere and their effects remain under-explored.

Summary. To mitigate the environmental impact of volatile anaesthetic agents, several strategies have been proposed. These include reducing the Fresh Gas Flow (FGF) during the maintenance phase of anaesthesia, minimizing or avoiding the use of more harmful volatile agents, and adopting Volatile Capture Technologies (VCT). Total intravenous anaesthesia, when clinically appropriate, is also highlighted as a viable alternative. Education and awareness among anaesthesiologists play a pivotal role in these efforts. Additionally, policy implementation by healthcare authorities is crucial to support long-term behavioural changes and promote sustainable practices in the medical field.

Key words

anaesthetic gases, environmental impact, global warming, volatile anaesthetic agents, sustainable anaesthesia

Streszczenie

Wprowadzenie i cel pracy. Światowa Organizacja Zdrowia (WHO) podkreśla, że zmiany klimatyczne stanowią poważne i narastające zagrożenie dla zdrowia ludzi. Szacuje się, że w latach 2030–2050 mogą one spowodować dodatkowo 250 tys. zgonów rocznie – e efekcie powodzi, susz, zanieczyszczenia powietrza czy chorób zakaźnych. Sam system opieki zdrowotnej przyczynia się do tego kryzysu, a praktyki anestezjologiczne odgrywają istotną rolę w emisji gazów cieplarnianych (GHG). Celem tego przeglądu jest podsumowanie obecnej wiedzy na temat wpływu gazów anestetycznych na środowisko, z jednoczesnym wskazaniem praktycznych rozwiązań, które mogą zostać wdrożone w szpitalach.

Opis stanu wiedzy. Choć system opieki zdrowotnej poprawia jakość życia, ma również koszt środowiskowy, odpowiadając za 1–5% globalnego wpływu na środowisko. Emisje bezpośrednie z placówek zdrowotnych stanowią 17% emisji GHG tego sektora. Gazy anestetyczne odpowiadają za 0,6% emisji sektora zdrowia i 0,1% globalnych emisji GHG. Ich udział co prawda wydaje się niewielki, jednak długotrwała akumulacja tych gazów w atmosferze i ich wpływ na środowisko są słabo zbadane.

Podsumowanie Aby ograniczyć wpływ lotnych środków anestetycznych na środowisko, zaproponowano kilka działań: zmniejszenie przepływu świeżego gazu (FGF) podczas podtrzymywania znieczulenia, minimalizację lub eliminację bardziej szkodliwych gazów lotnych oraz wdrożenie technologii wychwytywania tych substancji. W sytuacjach uzasadnionych klinicznie zaleca się również całkowite znieczulenie

✉ Address for correspondence: Alicja Obcowska, Clinic of Internal Medicine and Diabetology, Central Clinical Hospital, Medical University, Łódź, Poland
E-mail: aobcowska@gmail.com

dożylne jako alternatywę. Kluczową rolę odgrywają edukacja i zwiększanie świadomości wśród anestezjologów. Niezbędne są także odpowiednie regulacje wspierające długoterminowe zmiany w praktykach medycznych oraz promujące zrównoważone rozwiązania w ochronie zdrowia.

Słowa kluczowe

gazy anestetyczne, wpływ na środowisko, globalne ocieplenie, środki wziewne

INTRODUCTION

It has been well-recognized that pollution, climate change and global warming are among the primary concerns of modern times [1]. This is especially true for medical fields, as these issues affect not only the environment but also the health of patients [2]. The World Health Organization (WHO) in their reports, estimates that between 2030–2050, climate change will be responsible for 250,000 additional deaths per year [1], due to flooding, droughts and fires, hunger, infectious or vector-borne diseases, air pollution, and others [1, 3, 4].

The health care system has a total environmental impact ranging from 1%-5%. Global greenhouse gas (GHG) emissions contribute to approximately 4.4% [5, 6], a percentage that varies between countries. Data from 2019 show that the United States healthcare system ranks first place in terms of GHG emissions, followed by China and the European Union [7].

The younger generations of health professionals should pay particular attention to the consequences of their actions in regard to environmental pollution, and actively seek various ways to reduce the harmful impact of healthcare on the planet.

OBJECTIVE

The aim of this review is to summarize current knowledge on the environmental impact of anaesthetic gases and their contribution to global warming, while highlighting practical solutions that could be adopted in hospitals. Emphasis is placed on strategies that balance sustainability with patient safety, ensuring that ecological responsibility does not come at the expense of effective medical care.

MATERIALS AND METHOD

For this review, articles from PubMed and Google Scholar were retrieved, excluding articles not written in English. For search purposes, such terms as 'anaesthesia', 'volatile anaesthetic gases', 'inhaled anaesthetics', 'environmental impact', 'climate change' and 'global warming' were used, either alone or in various configurations. The included articles were limited by publication date, with those issued before 2018 being excluded.

Contribution of healthcare to greenhouse gases emission. GHG release in health care originates from numerous sectors, such as the supply chain (71%), indirect emissions which include electricity, cooling, heating, etc. (12%), and finally, direct emissions from facilities (17%) [7].

Peri-operative care, which includes the emission of anaesthetic gases, is a particularly significant contributor to the carbon footprint of health care, specifically direct emissions from health care facilities [8]. Their contribution to the GHG emission is estimated at around 0.6% [7] and tends to increase [9]. Data from a recent document issued by the American Society of Anesthesiologists (ASA) [8] suggest that anaesthetic gases may account for 3% of GHG release from health care. From a wider perspective, anaesthetic gases contribute to global GHG emissions at 0.1% [10]. However, it is important to remember that the long-term consequences of substance accumulation are still unknown.

All of this data places anaesthesiologists in a unique position as individuals who can have a great impact on reducing the environmental footprint of hospitals and the health care sector.

Greenhouse gases. The term 'greenhouse gases' is widely used in the context of climate change. It refers to gases that can retain energy originating from solar radiation that is absorbed by the Earth's surface and then emitted back into the atmosphere as infrared radiation [11]. This ability is described by the Global Warming Potential (GWP) and depends on two variables – its ability to absorb infrared radiation and the duration for which a gas remains in the atmosphere without degradation [12]. GWP is referenced to CO2 and for this gas, it has a value of 1 [12]. Moreover, GWP can be analyzed in specific timeframes, which should be chosen based on the specification of the given gas and analytical needs. However, typically, basic GHG timeframes of 20, 100, and 500 years are used (GWP20, GWP 100, and GWP500) [13]. This should raise awareness about using these substances, which are considered to be GHG and, when feasible, increase efforts to limit their emission into the environment.

Volatile anaesthetic gases – potent greenhouse gases. Volatile anaesthetic gases – sevoflurane (fluoromethyl hexafluoroisopropyl ether), desflurane (difluoromethyl 1,2,2,2-tetrafluoroethyl ether), isoflurane (1-chloro-2,2,2-trifluoroethyl difluoromethyl ether), and N2O, can absorb infrared radiation due to their chemical structure and, therefore, are considered potent greenhouse gases [8]. Additionally, N2O and isoflurane (the latter contains the chlorine atom in its structure) also contribute to ozone layer depletion [8–10], thereby reducing its protective abilities against UV radiation [10]. Therefore, anaesthetic gases have a significant impact on the environment, but they also vary from one another on this issue (Tab. 1).

A comparison of these gases based on their GWP100 reveals considerable differences. Desflurane has the highest GWP100 among the analyzed agents, ranging from 2300–2540, depending on the source [13, 14]. Sevoflurane has a GWP100 ranging between 130–185 [9, 13, 14] while isoflurane ranges from 490–510 [13, 14].

Volatile anaesthetics also differ among themselves according to how long they stay in the atmosphere in their original form. Once again, desflurane ranks first with a duration of 14 years in the atmosphere, with isoflurane ranking second with 3.2–3.6 years, and last – sevoflurane with 1.1–1.9 years [8, 9, 15]. Nitrous oxide (N_2O) should also be acknowledged in this context. Due to its properties (it requires very high concentrations to achieve adequate anesthesia) N_2O is rarely used alone, but rather with other volatile agents as a carrier gas [16]. GWP of N_2O is 265 and its atmospheric lifetime is approximately 123 years [14].

However, it is important to take into account a broader perspective of the situation. The environmental impact ofthe mentioned substances also depends on how much of these agents are used in a specific timeframe, which is influenced by how high the concentration in the breathing mixture of volatile anaesthetic should be accomplished for adequate anaesthesia [9, 15]. When considering this aspect as well, desflurane once again performs unfavourably as it requires a higher concentration to achieve adequate anaesthesia [9]. In summary, desflurane has the highest climate impact among the volatile agents [17].

To better illustrate the scale of the greenhouse potential of anaesthetic gases, their impact is often compared to CO_2 emissions from car travel. According to data from Özelsel TJ-P. et al. [15], using sevoflurane at 1L/min Fresh-Gas Flow (FGF) for 7 hours has the same environmental impact as driving 1,566 kilometres. On the contrary, using desflurane, under the same condition (FGF = 1L/min for 7 hours) is equivalent to driving 7,849 km.

Table 1. Environmental characteristics of commonly used volatile anaesthetic agents [14]

Volatile anaesthetic	SEVOFLURANE	DESFLURANE	ISOFLURANE	N2O
Ozone depleting potential	(-)	(-)	(+)	(+)
Lifetime in atmosphere (years)	1.9	14.1	3.5	123
GWP100	185	2300	490	265

POSSIBLE SOLUTIONS

Based on the analysis of the above data, the appropriate reaction seems to be striving to minimize as much as possible the emission of harmful anaesthetic agents into the environment. However, it should also be remembered to prioritize the well-being of the patients and act with caution [18, 19].

One of the major challenges in reducing the environmental impact of anaesthesia is the lack of awareness on this topic [18]. Gonzalez-Pizarro P. et al. [20], in their recommendations agree with this statement, and emphasize that the environmental impact of healthcare and anaesthesia is not covered during medical training at university before physicians begin their practice. This issue needs to be addressed. White SM. et al. [17] recommend that education about the harmful effects of anaesthesiologists' actions on the environment should be incorporated and discussed during specialisation training. This education should be multifaceted and utilize various teaching methods. When conducted effectively, it can lead to highly desirable positive behavioural changes [18]. However, education and proper training alone are not sufficient. Authorities should implement changes regarding such significant and important issues top-down, starting from the highest levels, through clear and specific strategies [21]. Additional motivation may come from the fact that reducing the harmful environmental impact of anaesthetic gases often aligns with reducing the overall cost [18].

Avoiding specific substances. One of the primary strategies to reduce the environmental impact of anaesthesia is to limit or eliminate the use of certain substances. As mentioned above, the most harmful anaesthetic agents are desflurane and N_2O, and most articles and recommendations focus on these substances [8, 10, 18, 22–24]. Gonzalez-Pizarro P, et al. [20] with 94% consensus recommend the superiority of sevoflurane over isoflurane and desflurane. Wyssusek K, et al. [25] even suggest that despite the fact that desflurane may have some advantages over sevoflurane in specific clinical situations, these differences are so minimal that, when considering the significant harmful effect of desflurane on the environment, the benefits of its elimination from clinical practice become predominant. White SM, et al. [17], however, propose defining strict and clear guidelines on when the usage of desflurane should be allowed, rather than completely discontinuing its use.

Fresh Gas Flow (FGF). Defined by the amount of uninhaled gases delivered to the breathing circuit during anaesthesia, with the flow rate typically measured in litres per minute (L/min). Proper FGF is crucial for maintaining the correct concentration of anaesthetic agents in the breathing circuit.

The discussion about Fresh Gas Flow (FGF) during general anaesthesia in the context of reducing the emission of anaesthetic agents into the environment is quite dynamic. However, it is generally accepted that the use of Low-Flow FGF (0,5–2L/min) is widely recommended [19, 20, 23]. Gordon D. [22] in his study emphasizes that this action is the second most critical factor in reducing the carbon footprint of volatile agents.

The recommended FGF for sevoflurane is 2L/min, and 0.5–1L/min for desflurane and isoflurane [10]. Previously, there were some concerns about FGF below 2L/min for sevoflurane, due to rising concerns about the possible nephrotoxicity of Compound A, which forms when sevoflurane reacts with CO_2-absorbers during Low-Flow anaesthesia [22]. Recent findings, however, report that FGF at 1L/min for sevoflurane is safe [26]. Some studies recommend even lower values (0.5L/min) of FGF for sevoflurane during the maintenance phase of anaesthesia [20, 24]. Additionally, because Low-Flow reduces the overall consumption of anaesthetic gases, it may also contribute to cost reduction [25]. However, it is important to note that this technique may lead to faster degradation of CO_2-absorbers during the anaesthesia, therefore careful monitoring of their lifespan is recommended [22, 26, 27].

Volatile Capture Technologies (VCT). In the human body, anaesthetic gases undergo minimal metabolism [10, 25] – for sevoflurane, only 4% and for other agents it is less than 1% [28]. This means that the majority of used anaesthetic gases enter the atmosphere in their unchanged form. Some systems and technologies are emerging which allow capturing these agents [8, 20, 29]. They are generally referred to as Volatile Capture Technologies (VCT). Captured anaesthetics gases could be further extracted and undergo some reprocessing (to less harmful substances) [8, 20, 29]. Additionally, in some countries, such as Canada, Austria, and Germany, some regulations are being introduced that enable the reuse of captured volatile anaesthetics (after purification), which may significantly contribute to reducing their harmful impact on the environmental [29].

Hu X et al. [28], their study estimated the effectiveness of VCT technologies at around 70%; however, Gandhi, J., et al. [29] highlight that this value may be overestimated additional ESAIC and ASA, indicating that some anaesthetic gases can still escape into the environment due to deep extubations when released during the waking up process in post-operative care units [8, 20, 30].

Another limitation of VCT technology is the presence of leaks in anaesthesia circuits, which may result from suboptimal airway management techniques [29]. Proper sealing of the cuffs on airway devices is also critical to minimizing leakage from the circuit [31]. Induction with volatile agents, commonly used in paediatric anaesthesia, can significantly increase the emissions of anaesthetic gases into the atmosphere [22, 30]. To reduce this outcome, turning off the FGF during intubation until the circuit is closed again, is recommended [22, 31]. As a result, the anaesthetic gases do not escape from the system into the surroundings. However, these actions are recommended only for experienced professionals [22].

Alternatives – Total Intravenous Anaesthesia (TIVA). Propofol – used in total intravenous anaesthesia – has a significantly lower carbon footprint than volatile agents [28], although it still has some negative impact on the environment [10, 17]. This should be taken into consideration, especially because propofol is a significant contributor to drug wastage in medical facilities (up to 50% of drowned-up propofol is being thrown out without usage [32]) and when unmetabolized, it is environmentally persistent and toxic to the aquatic ecosystem [27, 31, 32]. Van Norman GA, et al. [31], however, highlights that adequate planning of anaesthesia and choosing the smallest possible ampoules of propofol can significantly reduce its environmental impact. In this anaesthesia technique, concerns may arise regarding the amount of single-use syringes, ampoules, and tubing utilized, as well as their impact on the environment [33].

Despite some doubts, total intravenous anaesthesia is still recommended (when clinically acceptable) as an alternative for volatile anaesthetics for reducing the general anaesthesia impact on the environment [8, 20, 22].

CONCLUSIONS

Minimizing the environmental impact on healthcare involves addressing the ecological footprint of substances used in daily medical practice. Anaesthesiologists often use agents that have significant environmental impacts, which has made reducing their footprint a key priority. Education and awareness within the anaesthesiology community play a key role in these efforts.

Practical strategies can also be valuable in reinforcing core principles. Van Norman GA, et al. [31] suggest adopting the '5R' strategy – reduce, reuse, recycle, rethink, research. White, SM, et al. [17] strongly advocate for adherence to this approach. For anaesthetic gases, the focus should particularly be on '**reduce**' – minimizing overall use and lowering FGF during inhalational anesthesia; **'rethink'** – considering alternatives for a given gas or anaesthesia method; and **'research'** – continuously educating oneself on the environmental impact of clinical practices and exploring innovative solutions.

REFERENCES

1. World Health Organization. Climate change and health. WHO. https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health (access: 2024.12.15).
2. Fuller R, Landrigan PJ, Balakrishnan K, et al. Pollution and health: a progress update. Lancet Planet Health. 2022;6(6):e535-e547. https://doi.org/10.1016/S2542-5196(22)00090-0
3. Pichler P-P, Jaccard IS, Weisz U, Weisz H. International comparison of health care carbon footprints. Environ Res Lett. 2019;14(6):064004. https://doi.org/10.1088/1748-9326/ab19e1
4. Romanello M, McGushin A, Napoli CD, et al. The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. Lancet. 2021;398(10311):1619–1662. https://doi.org/10.1016/S0140-6736(21)01787-6
5. Lenzen M, Malik A, Li M, et al. The environmental footprint of health care: a global assessment. Lancet Planet Health. 2020;4(7):e271-e279. https://doi.org/10.1016/S2542-5196(20)30121-2
6. Tennison I, Roschnik S, Ashby B, et al. Health care's response to climate change: a carbon footprint assessment of the NHS in England. Lancet Planet Health. 2021;5(2):e84-e92. https://doi.org/10.1016/S2542-5196(20)30271-0
7. Health Care Without Harm. Health care's climate footprint: How the health sector contributes to the global climate crisis and opportunities for action. 2019. https://noharm-global.org/sites/default/files/documents-files/5961/HealthCaresClimateFootprint_092319.pdf (access: 2024.12.15).
8. ASA Committee on Environmental Sustainability. Greening the OR. 2023. https://www.asahq.org/about-asa/governance-and-committees/asa-committees/environmental-sustainability/greening-the-operating-room (access: 2024.12.15).
9. Gaya da Costa M, Kalmar AF, Struys MMRF. Inhaled anaesthetics: environmental role, occupational risk, and clinical use. J Clin Med. 2021;10(6):1306. https://doi.org/10.3390/jcm10061306
10. Varughese S, Ahmed R. Environmental and occupational considerations of anesthesia: a narrative review and update. Anesth Analg. 2021;133(4):826–835. https://doi.org/10.1213/ANE.0000000000005615
11. Kweku DW, Bismark O-A, Maxwell A, et al. Greenhouse effect: greenhouse gases and their impact on global warming. J Sci Res Rep. 2018;17(6):1–9. https://doi.org/10.9734/JSRR/2017/39630
12. McGain F, Muret J, Lawson C, Sherman JD. Environmental sustainability in anaesthesia and critical care. Br J Anaesth. 2020;125(5):680–692. https://doi.org/10.1016/j.bja.2020.06.055
13. Andersen MPS, Nielsen OJ, Sherman JD. Assessing the potential climate impact of anaesthetic gases. Lancet Planet Health. 2023;7(7):e622–e629. https://doi.org/10.1016/S2542-5196(23)00139-1
14. World Meteorological Organization. Scientific assessment of ozone depletion: 2018. Geneva: World Meteorological Organization; 2018.
15. Özelsel TJ-P, Sondekoppam RV, Buro K. The future is now—it's time to rethink the application of the Global Warming Potential to anesthesia. Can J Anaesth. 2019;66:1291–1295. https://doi.org/10.1007/s12630-019-01478-6
16. Hudson AE, Herold KF, Hemmings Jr HC. Pharmacology of inhaled anaesthetics. In: Sullivan JB Jr, Krieger GR, editors. Pharmacology and physiology for anesthesia. Elsevier; 2019. p. 217–240. https://doi.org/10.1016/B978-0-12-813213-3.00014-7
17. White SM, Shelton CL, Sutherland A, et al. Principles of environmentally-sustainable anaesthesia: a global consensus statement from the World Federation of Societies of Anaesthesiologists. Anaesthesia. 2022;77(2):201–212. https://doi.org/10.1111/anae.15670
18. Nolan BC, Cashman J, Campbell M, et al. Promoting behavioural change by educating anaesthetists about the environmental impact of inhalational anaesthetic agents: A systematic review. Anaesth Intensive Care. 2024;0310057X241263113. https://doi.org/10.1177/0310057X241263113
19. Buhre W, De Robertis E, Gonzalez-Pizarro P. The Glasgow declaration on sustainability in Anaesthesiology and Intensive Care. Eur J Anaesthesiol. 2023;40(7):461–464. https://doi.org/10.1097/EJA.0000000000001846

20. Gonzalez-Pizarro P, Hendrickx JF, Feldman JM, et al. European Society of Anaesthesiology and Intensive Care consensus document on sustainability: 4 scopes to achieve a more sustainable practice. Eur J Anaesthesiol. 2024;41(4):260–277. https://doi.org/10.1097/EJA.0000000000001942
21. Braithwaite J, Churruca K, Long JC, et al. Strategies and tactics to reduce the impact of healthcare on climate change: systematic review. BMJ. 2024;387:e075616. https://doi.org/10.1136/bmj-2023-075616
22. Gordon D. Sustainability in the operating room: reducing our impact on the planet. Anesthesiol Clin. 2020;38(3):679–692. https://doi.org/10.1016/j.anclin.2020.05.008
23. Devlin-Hegedus JA, Rix E, Wilkinson S, et al. Action guidance for addressing pollution from inhalational anaesthetics. Anaesthesia. 2022;77(9):1023–1029. https://doi.org/10.1111/anae.15825
24. Rübsam M-L, Weiss A, Berger-Estilita J, et al. A call for immediate climate action in anesthesiology. Can J Anaesth. 2023;70(3):301–312. https://doi.org/10.1007/s12630-022-02329-0
25. Wyssusek K, Nickel TJ, Riedel BJ. Greenhouse gas reduction in anaesthesia practice: a departmental environmental strategy. BMJ Open Qual. 2022;11(3):e001867. https://doi.org/10.1136/bmjoq-2022-001867
26. Kennedy RR, Hendrickx JFA, Feldman JM. There are no dragons: low-flow anaesthesia with sevoflurane is safe. Anaesth Intensive Care. 2019;47(3):223–225. https://doi.org/10.1177/0310057X19843119
27. Maria-Alexandra P, Malherbe S. Environmentally sustainable perioperative medicine: simple strategies for anaesthetic practice. Can J Anaesth. 2020;67(8):1044–1063. https://doi.org/10.1007/s12630-020-01715-7
28. Hu X, McNeill J, Tucker A, et al. The carbon footprint of general anaesthetics: a case study in the UK. Resour Conserv Recycl. 2021;167:105411. https://doi.org/10.1016/j.resconrec.2021.105411
29. Gandhi J, Khan FA, Franklin K, et al. Volatile capture technology in sustainable anaesthetic practice: a narrative review. Anaesthesia. 2024;79(3):261–269. https://doi.org/10.1111/anae.16163
30. Sherman JD, Chesebro BB. Inhaled anaesthesia and analgesia contribute to climate change. BMJ. 2022;377:e068045. https://doi.org/10.1136/bmj-2021-068045
31. Van Norman GA, Jackson S. The anesthesiologist and global climate change: an ethical obligation to act. Curr Opin Anaesthesiol. 2020;33(4):577–583. https://doi.org/10.1097/ACO.0000000000000893
32. Fang L, Hixson R, Shelton C. Sustainability in anaesthesia and critical care: beyond carbon. BJA Educ. 2022;22(12):456–465. https://doi.org/10.1016/j.bjae.2022.07.008
33. Jabaudon M, Huette P, Bourgoin A, et al. Balancing patient needs with environmental impacts for best practices in general anesthesia: Narrative review and clinical perspective. Anaesth Crit Care Pain Med. 2024;43(1):101389. https://doi.org/10.1016/j.accpm.2023.101389