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Green anaesthesia: a review of sustainable perioperative practices and the potential application in Malaysia

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Abstract

Global warming and worsening climate change threaten environmental sustainability and exacerbate disease burdens worldwide. Alarmingly, the healthcare sector emerged as a substantial contributor to this crisis. The operating theatre significantly contributes to hospital waste and greenhouse gas emissions. Anaesthesiologists are morally compelled to combat this crisis, aligning with our oath as physicians of "first, do no harm," ensuring patient safety extends beyond the operating room by advocating for sustainable practices that safeguard both health and the environment. Understanding the climate change indicators reveals the alarming impact of human actions on escalating greenhouse gas emissions and their dire repercussions, such as global temperature shifts, severe weather events, and heightened natural disasters.

Greener solutions and adaptive policymaking are essential to address procurement, greenhouse gas emissions, and waste management challenges in health care settings. Anaesthesiologists should collaborate with surgeons and hospital management to navigate patient-specific issues analysing the environmental impact of hospital visits, investigations, and comorbidities. Efforts toward sustainable healthcare practices in the preoperative setting, such as telemedicine

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adoption, promoting eco-friendly transportation, and optimising patient health before surgery should be encouraged.

Anaesthesiologists should focus on the environmental impact of anaesthesia drugs, medical equipment, and electricity usage on the environment. We should be more responsible and able to justify our practices concerning the ecological implications of inhaled anaesthetic gases, propofol disposal, plastic-based equipment, and energy demands in operating rooms. The emphasis lies on adopting the 6Rs—rethink, refuse, reduce, reuse, recycle, and research—within anaesthesia practices to minimise environmental footprints.

Keywords: anaesthesia, climate change, recycle, reduce, reuse,

Introduction

Climate change cannot be overlooked and ignored. Every year, the planet's temperature increases, and the rate of increase has doubled since 1981 at an average rate of 0.18 °C per decade.[1] Worldwide, there are more than 250 million general anaesthetic procedures performed for surgery annually.[2] It has been shown that anaesthesia contributes substantially to greenhouse gas (GHG) emissions, as it is an equipment- and waste-intensive specialty.[3] Thus, anaesthesiologists carry an ethical imperative beyond patient care of enhanced recovery after surgery and ensuring patient safety. We are entrusted as custodians of the environment; owing to the nature of our working environment, we profoundly impact patient health, community well-being, and societal equilibrium. This ethical responsibility extends beyond the operating room, intertwining patient care with environmental stewardship. Therefore, to proactively be involved in the sustainable practice of anaesthesia, we need to understand the science evolving on climate change globally. This review will contextualize the basic changes in climate change, evidence-based sustainable perioperative practices, and their potential application in Malaysia.

Basic changes in climate and the effect on future population health

The global climate is a complex system. Climate change refers to the long-term shifts in local, regional, or global temperature and weather patterns, which occur either naturally or due to anthropogenic factors.[4] In an attempt to provide a large-scale overview of the dynamic global climate system, the World Meteorological Organisation (WMO) has listed seven key indicators that include surface temperature, ocean heat content, ocean acidification, glacier mass balance, sea ice extent, sea level, and GHGs.[5] These climate indicators are used as the global framework to monitor the four domains that are most relevant to climate change (temperature and energy, atmospheric composition, ocean and water, as well as cryosphere).[6,7] Changes in atmospheric composition, *i.e.* increasing levels of GHGs, are of greatest concern due to the vulnerability to human influences and its widespread impact on the other three domains.[8]

Global GHG emissions have been increasing continuously since the 1900s.[7] Human activities have contributed greatly to the rising levels of GHGs in the atmosphere and have become the major driver of climate change. In 2021, the atmospheric concentration of carbon dioxide, the predominant GHG, increased by 149% compared to pre-industrial levels.[7] Other major GHGs such as methane and nitrous oxide have also increased by 262% and 124%, respectively, compared to pre-industrial levels.[7] The causes of increasing GHG emissions include power generation, manufacturing, deforestation, transportation, agriculture, and excessive power consumption.[4] GHG emissions are a major driver of global warming and climate change. The global surface temperature increases over time, resulting in extreme weather, rising sea levels, reduced biodiversity, food shortages, and heightened challenges such as health risks and poverty.[4]

In 2022, a total of 272 recorded natural disasters were held accountable for 76,125 deaths, affected another 185 million people, and caused total (adjusted) damage that cost approximately USD 209 billion.[9] More than 90% of the documented natural disasters were potentially associated with global warming and climate change (drought, extreme temperature, flood, landslide, storm, and wildfires).[9] The impact of climate events on humanity depends on the vulnerability of the population and the preparedness of the community.[10] Extreme weather and natural disasters are known to adversely affect human health, both physically and mentally, as well as posing higher risks to health systems. The population, especially vulnerable ones such as older people or lower-income communities, faces greater risks of injuries and infections, exacerbated non-communicable diseases, as well as increased need for health care services post-disaster.[10,11] Based on the projected trend of GHG emissions, a predictable increase in the frequency and intensity of extreme climate events is foreseen in the coming decades.[7] Therefore, to minimise the negative impacts of climate hazards on population health, the building of climate-resilient health systems should be the main focus for policymakers and stakeholders. Climate adaptation and mitigation plans adequately supported by disaster risk management are essential to prepare health systems to manage health impacts associated with extreme climate events.[10,12]

Climate change presents contradictory challenges for the healthcare sector. Extreme climate events impact the population's health and increase the demand for health care services.[10,11] However, it is important to note that the health care sector is a large-scale and important socioeconomic sector and therefore is a significant contributor to GHG emissions itself, which eventually may lead to more climate hazards. On average, global health care is accountable for 5% of total GHG emissions (carbon dioxide equivalent).[11,13,14] This figure is equivalent to approximately one-fifth of the GHG emissions from the food and agricultural sectors.[11] Among the various GHGs, anaesthetic gases contribute from 0.01% to 0.1% of total emissions.[15] In addition to GHG emissions, increasing medical waste production is also one of the major sustainability shortfalls in health care. Operating rooms contribute to approximately 30% of daily medical waste, 25 % of which was attributable to anaesthesia practices.[16] A notable lack of awareness and commitment to "greener" solutions in health care, as well as anaesthesia practices, has warranted an increased effort to enhance research and policymaking to improve sustainability in the healthcare sector.

Preoperative environmental concerns

In the global pursuit of sustainable healthcare practices, the preoperative setting has emerged as a crucial arena for reducing the environmental footprint. The preoperative issues affecting global climate change can be discussed according to organizational and patient factors.

General and organisational issues

Shortcomings in the procurement process

Health care procurement typically revolves around seeking immediate financial advantages, often leaning heavily on cost-effectiveness. This prioritisation tends to overshadow the consideration of long-term environmental implications associated with purchasing pharmaceuticals and medical equipment. There is a prevalent misconception favouring disposable items due to their perceived lower initial costs and maintenance expenses compared to reusable alternatives. However, this perspective fails to account for the broader environmental impact and the extended costs over the life cycle of the products.[17]

Upstream greenhouse gas emissions

The majority of GHG emissions are prevalent upstream in the supply chains of health care services, particularly within hospitals where pharmaceuticals and medical equipment are procured. These emissions originate from various stages of the supply chain, spanning the production, transportation, and distribution of pharmaceuticals and medical supplies. The processes significantly contribute to the overall carbon footprint of health care institutions.[18] Gathering intricate environmental data on these products remains challenging. Companies often withhold critical manufacturing details necessary for exhaustive Life Cycle Assessments (LCAs), making it hard to gauge their true environmental impact. Conducting LCAs demands considerable expertise and financial investment, contributing to the complexity of integrating environmental considerations into procurement decisions.

Lack of institutional support and training

In a recent nationwide survey conducted among Canadian anaesthesiologists, several prominent barriers were identified that hindered effective sustainability practices. The survey highlighted key challenges, including limited support from hospital leadership (63.5%), insufficient knowledge levels (62.8%), indifferent staff attitudes (52.2%), and inadequate recycling facilities (51.5%).[19] Similar sentiments were echoed by anaesthesiologists in Malaysia during a recent nationwide survey, citing challenges such as lack of recycling facilities as the most significant obstacle, followed by the absence of support from hospital or operating theatre (OT) leadership, staff attitudes, and insufficient funding.

A research investigation discovered that nearly 92% of solid waste generated during surgeries was not properly sorted and ended up being treated as biohazardous material unnecessarily.[20] Another revealing survey conducted by the American Society of Anesthesiologists found that 56% of respondents incorrectly labelled items in contact with patients as biohazardous waste.[21] These findings underscore a significant lack of awareness among medical professionals regarding proper waste management protocols.

Patient-specific issues

Hospital visits and investigations

The journey patients undertake before surgery involves several hospital visits for assessments, clinic appointments, and numerous investigations. This not only strains their time and finances but also contributes to environmental impacts due to increased transportation. Patients traveling from distant locations encounter even more challenges due to the extended travel and additional logistical considerations. Many a time, when patients arrive from other health care facilities, inadequate or missing medical records often send health care providers on a scavenger hunt, wasting precious time in retrieving vital information. Moreover, this absence of comprehensive, centralised, and retrievable data often prompts health care professionals to reorder a battery of tests and examinations, from X-rays to blood work, adding unnecessary financial strain and environmental impact through duplicate procedures.

Comorbidities

Insufficient optimisation of a patient's health before surgery not only burdens the health care system but also amplifies its environmental impact.[22] Longer hospital stays and increased use of resources translate into higher energy consumption, greater waste generation, and elevated emissions. Additionally, postoperative complications often necessitate further interventions, leading to more medical procedures, which in turn contribute to additional environmental strain. This collective impact underscores the interconnectedness between health care practices, patient well-being, and environmental sustainability.

Sustainable preoperative practices and potential applications in Malaysia

Efforts toward sustainability in health care often encompass initiatives at two distinct but interrelated levels: institutional or organisational endeavours and patient-specific measures.

Institutional or organisational endeavours

Procurement and life cycle analysis

The foundation of understanding a product's environmental impact lies in the LCA methodology, crucial in gauging its effect on the environment from creation to disposal (cradle-to-grave impact). This detailed approach dives into the raw materials, energy use, emissions, and waste generated throughout a product's life stages, helping us evaluate its environmental effects comprehensively.[23] Applying LCA to procurement decisions in Malaysia's health care sector can be transformative. It allows for informed choices based not only on a product's efficacy and cost, but also on its environmental implications. For instance, in the acquisition of medical equipment or pharmaceuticals, LCA can provide insights into each item's environmental footprint, enabling hospitals and health care facilities to prioritise products with lower ecological impacts. Furthermore, leveraging LCA facilitates a deeper understanding of a product's overall cost to the healthcare system. This goes beyond the initial purchase expense, encompassing disposal, sterilisation, and potential repackaging costs for reusable items. By integrating life cycle costing into procurement strategies, institutions can identify environmentally sustainable alternatives that are also cost-effective in the long run. However, applying LCA in procurement in Malaysia comes with challenges. Access to comprehensive data and information on the environmental impacts of products, especially proprietary manufacturing details, might be limited. Additionally, conducting thorough LCAs requires specialised expertise and resources, which might not always be readily available.

Initiatives that exert pressure on sales representatives to supply LCA data can trigger a shift in the health care industry towards eco-conscious procurement. This encourages pharmaceutical and equipment companies to focus on evaluating and publishing the environmental assessments of their products. It may prompt them to optimise production processes, striving for more environmentally competitive options.[24]

Institutional support and education

Numerous sustainability initiatives transcend the confines of a singular department, posing a challenge for any individual service to claim ownership over such expansive projects. Collaborative 'green teams' composed of perioperative services and a diverse range of health care professionals and support staff play a pivotal role in addressing sustainability challenges.[25] We as anaesthesiologists should actively spearhead hospital green teams and leverage our clinical expertise to initiate recycling programs and implement sustainable waste management practices. Each hospital can form a dedicated sustainability committee that brings together influential decision-makers, including:

1) Senior leaders, who are empowered to approve capital investments and equipment purchases.

2) Representatives from crucial support services such as Facilities, Environmental Services, and Procurement, who are entrusted with managing the operational framework for sustainability practices.

3) A designated sustainability officer responsible for driving environmental initiatives and compiling pertinent statistics.

4) Multidisciplinary clinical champions encompassing frontline health care providers, surgeons, anaesthesiologists, and nurses. Their voluntary involvement facilitates communication between environmental services and various departments. They also coordinate staff education and action plans.

Securing support from senior leadership is crucial in the Malaysian context for the success of organisational-wide sustainability initiatives. When top level executives genuinely endorse and prioritise sustainability within the organisation, these values permeate the organisational culture, fostering a collective embrace of pro-environmental behaviours among all staff members.

Increasing awareness and offering comprehensive education and training are vital components for successful environmental sustainability in health care. Implementing structured training sessions for waste management, sustainable procurement, and energy efficiency is crucial. Regular audits and adopting sustainability efforts as part of hospital or departmental quality improvement projects reinforce these practices, fostering a culture of environmental responsibility among health care professionals.

Patient-specific measures

Technological innovations for preoperative visits

Tackling patient travel is crucial in reducing health care institutions' carbon emissions. In Malaysia, innovative strategies can be applied to address this issue and create a positive impact. The COVID-19 pandemic acted as a catalyst for the adoption and acceleration of telemedicine practices worldwide, including in Malaysia. Embracing telemedicine practices can significantly reduce the need for patients to physically travel to health care facilities for preoperative consultations, routine check-ups, and follow-up appointments. This technology allows health care providers to offer remote consultations, minimising travel-related emissions and reducing the burden on patients, especially those residing in rural areas.[26] However, the major challenge in fully implementing telemedicine lies in infrastructure limitations. In remote or underserved areas, inadequate internet connectivity or technology access can hinder effective telemedicine adoption. Also, the diversity of platforms and technologies used for telemedicine creates interoperability challenges and could lead to data privacy and security concerns. These are things we need to investigate to ensure the success of telemedicine.

The Malaysian health care system should investigate adopting electronic medical records EMRs across states or nationwide to enhance efficiency and accessibility while reducing the necessity for patients to carry physical records. It streamlines the health care process, curbing unnecessary trips for medical data retrieval as well as redundant investigations and testing.[27] Implementing EMRs faces various challenges, including initial costs for system setup, data migration from existing records, and staff training for seamless integration. Security concerns regarding patient data privacy and interoperability issues between different EMR systems also hinder their smooth adoption.

Investing in and promoting eco-friendly modes of transportation, such as improving public transit networks and establishing bicycle facilities, can significantly reduce carbon emissions. Hospitals can encourage staff and patients to use public transportation or cycling by providing adequate facilities, such as bike racks and designated lanes, or promoting public transit incentives.[17]

Premorbid optimisation

The proactive involvement of primary care teams and general practitioners in identifying and addressing patients' pre-existing health concerns is crucial. Initiating measures such as early blood pressure and sugar control, supporting smoking and drinking cessation, and beginning rehabilitation can significantly enhance a patient's condition before surgery, leading to better outcomes. This not only reduces hospital resource usage and length of stay but also contributes to environmental sustainability by cutting down on overall healthcare impact.

Intraoperative sustainability practices and potential applications in Malaysia

The environmental impact of intraoperative services managed by anaesthesiologists is substantial, primarily due to the frequent utilization of drugs, medical equipment, and electricity. The global climate changes contributed by intraoperative anaesthesia will be discussed along these lines.

Anaesthesia drugs

Inhaled anaesthetic gases

General anaesthesia comprises a delicate equilibrium between narcosis, analgesia, and muscle paralysis. Inhaled anaesthetic gases (IAGs) such as sevoflurane and desflurane are usually primarily employed to induce narcosis. However, the implications of utilising IAGs extend beyond the operating room. These IAGs have a discernible impact on our climate through multiple pathways. They play a role in exacerbating global warming and contribute to ozone layer depletion.[28] The measurement of their influence is often quantified using the concept of Global Warming Potential (GWP). GWP evaluates the comparative warming effect of a gas over a specified duration, typically 100 years, in contrast to carbon dioxide, the benchmark unit for global warming. The potency of inhaled anaesthetics as GHGs is striking. Desflurane, for instance, exhibits a staggering GWP100 of 2540, denoting its 2540-fold contribution to global warming compared to carbon dioxide. Similarly, isoflurane and sevoflurane register GWP100 of 510 and 130, respectively.[29] To illustrate, in the United States, emissions from inhalational anaesthetic agents measured with a GWP100 comparison equate to the annual output of a coal-fired plant or the collective emissions of nearly 1 million automobiles annually.[30]

The addition of nitrous oxide to volatile agents will reduce the amount of other volatile agents needed to deliver one minimum alveolar concentration hour of anaesthetic. However, nitrous oxide has an ozone depletion property, a GWP100 of 248, and an atmospheric life span of atmospheric life of 114 years. In comparison, the atmospheric lifetimes of isoflurane, sevoflurane, and desflurane are, respectively, 3.2, 1.1, and 14 years.[31,32]

Propofol

Intravenous anaesthetic drugs significantly contribute to global waste and subsequent pollution through various avenues. The disposal of unused drugs, along with the vehicles for drug administration, *e.g.*, plastic syringes, needles, and tubing, contributes to medical waste. Packaging materials comprising plastic, paper, and glass further compound the environmental impact. The environmental toxicity of drugs can be evaluated using the Swedish Chemicals Agency classification system for aquatic pollutants. This system, known as PBT, evaluates a drug's persistence (P), potential for bioaccumulation (B), and toxicity (T) upon release into the environment.[33] Unfortunately, conventional wastewater treatment plants are ill-equipped to eliminate pharmaceuticals, leading to their discharge into surface water bodies and subsequent contamination.

Among the most utilized and wasted drugs in anaesthesia is propofol.[34] It consistently ranks among the highest in the PBT index for drugs used in anaesthesia with a PBT of 9, as compared to atracurium with a PBT of 3.[35] It often finds its way into sewage systems via disposal practices. Propofol's resistance to biodegradation in water and its toxicity to aquatic organisms lead to inhibition of algae growth and acute harm to small crustaceans and freshwater fish.[36]

Equipment
Medical waste constitutes 4% of the total plastic waste globally.[16] In the landscape of anaesthesia practice, the importance of infection control since the COVID-19 era has further increased reliance on disposable single-use equipment, significantly made from various plastic materials. However, this trend comes with ecological repercussions as plastics, a main component of essential tools like supraglottic airway (SGA) devices, laryngoscope blades, facemasks, circuits, oxygen tubing, and personal protective equipment, resist decomposition and biodegradation. The life cycle of these plastics inflicts considerable harm on our environment and human health, perpetuating GHG emissions and polluting air, water, and soil.

Electricity
Sustainability in anaesthesia encompasses not only equipment and waste management but also addressing the substantial energy demands within operating rooms. These spaces are significantly more energy-intensive per square foot than the rest of the hospital due to stringent heating, ventilation, and air conditioning (HVAC) needs, extended hours of lighting, patient monitoring devices, and specialized air handling units (AHUs). AHUs play a vital role in maintaining sterile environments to reduce the risk of wound contamination and infections.

The source of obtaining the energy to generate electricity is also paramount. Hydropower is the most efficient way to generate electricity. Modern hydroturbines can convert as much as 90% of the available energy into electricity as compared to fossil fuel plants, which are only approximately 50% efficient.[37] Obtaining a source of energy from hydroelectric is cleaner than obtaining the energy required from coal.

Sustainable perioperative practices and their potential application in Malaysia

In practicing sustainable perioperative practices, the use of the 6Rs (rethink, refuse, reduce, reuse, recycle, and research) in our daily work is imperative.

Rethink
Given the substantial greenhouse effects associated with volatile agents in general anaesthesia, reconsideration of these agents is imperative. Opting for volatile agents with lower GWP100, where viable and safe for patients, becomes a responsibility. Prioritizing the use of such agents in the absence of contraindications aligns

with our ethical duty to mitigate environmental impact while ensuring optimal patient care during anaesthesia. This shift in selection criteria for volatile agents underscores our commitment to eco-conscious anaesthesia practices.

Whether regional anaesthesia should be the primary anaesthesia technique when possible is still uncertain. A LCA on administering general anaesthesia using sevoflurane or total intravenous anaesthesia (TIVA), or administering spinal anaesthesia with intravenous sedation had similar carbon footprint production.[38] However, the same study suggested a lower carbon footprint is emitted when low-flow gases are used for general anaesthesia, either with sevoflurane or TIVA. Thus, we should consciously practice low-flow anaesthesia with the appropriate equipment and monitoring. In addition, this study also found that reducing single-use plastics and collaborating with engineers to augment energy efficiency are more beneficial in reducing the carbon footprint than choosing between regional anaesthesia or TIVA over general anaesthesia with sevoflurane.

Refuse

Although nitrous oxide remains prevalent in Malaysian practice due to its efficacy in reducing volatile agent usage for anaesthesia, its climate impact prompts refusals. Embracing alternatives becomes imperative, *e.g.*, leveraging patient electroencephalogram readings to monitor the state of narcosis such as utilising the bispectral index (BIS) during anaesthesia. Research highlights BIS-guided anaesthesia's efficacy in curbing unnecessary anaesthetic exposure by adjusting drug consumption based on BIS values.[39] Implementing strategies such as BIS monitoring enables precise dosing, presenting a tangible step towards environmentally conscious anaesthesia practices. This tailored approach enhances patient safety and minimizes volatile agent administration.

Reduce and recycle

As plastics are non-recyclable and non-biodegradable, a heightened consciousness is warranted when accessing plastic-made equipment. It is crucial to minimize routine drug preparation and syringe usage. Prioritizing the minimum essential syringes and refraining from opening emergency drugs unless necessary while ensuring immediate accessibility proves prudent. A recent quality improvement initiative in our centre showcased significant cost savings by abstaining from opening and diluting emergency drugs over two months.[40] This approach not only preserves resources but also aligns with sustainability objectives. Such findings underscore the financial benefits and ecological responsibility gained by judiciously managing plastic-based equipment and drug utilisation in anaesthesia practices.

Mitigating electricity consumption in the OT involves proactive measures, *e.g.*, powering down OT lights, air-conditioning units, and idle equipment and monitors. Concurrently, minimizing avoidable waste production within the OT is essential. Collaborative initiatives between the OT team, hospital management, and Biomedical Engineering units can facilitate the reprocessing of devices, ensuring their safety and, when feasible, recycling the waste. This collaborative approach aligns with sustainability objectives, fostering responsible resource management and waste reduction within anaesthesia practices. By embracing these strategies, anaesthesia teams contribute to a more eco-conscious healthcare environment while optimizing operational efficiency and resource utilization in the OT.

Reuse

Achieving sustainable anaesthesia practices entails a delicate balance between infection control and reducing the carbon footprint, often necessitating a choice between single-use and reusable equipment. Collaborating closely with hospital infectious disease units becomes paramount to align practices with local guidelines for optimal outcomes. LCA on certain equipment such as SGA devices and anaesthetic drug trays showed that reusing them leads to lower carbon footprints.[41]

However, the assumption that reusing equipment always reduces the carbon footprint is not universal. For instance, in Australia, the carbon footprint of reusable equipment can slightly surpass that of single-use counterparts due to greater water consumption in the cleaning process.[42] This challenges the conventional belief, highlighting the intricate considerations for sustainable choices. We should encourage our government to use cleaner energy sources such as hydroelectric and wind turbines. In addition, cost-efficient use of water supply to clean our OR equipment should be emphasized among our health professionals.

Unused equipment holds the potential for donation to suitable areas, aiding education and skill development. Expired equipment, for instance, can enrich medical school clinical skills labs, offering students valuable practice opportunities. Such donations foster learning environments and repurpose unused resources for educational advancement, benefiting aspiring health care professionals in their training and skill development.

Research

A significant portion of anaesthetic gases administered during surgery is exhaled by patients, escaping into the atmosphere via scavenging systems. This release contributes to greenhouse effects and ozone depletion. Current research focuses on recycling these exhaled anaesthetic gases to mitigate environmental impact.

Innovations like CONTRAfluran (ZEOZYS, Luckenwalde, Germany) aim to capture 99% of waste anaesthetic gases, intending to recycle them after treatment at dedicated facilities.[43] However, extensive evaluation is necessary before widespread implementation. Addressing propofol disposal is also crucial. Research must determine effective methods to degrade propofol, rendering it environmentally safe before discarding.

Conclusion

In conclusion, anaesthesiologists have the ethical obligation to practice sustainable anaesthesia. Integrating evidence-based sustainability practices within the Malaysian health care system presents an opportunity to reduce the environmental footprint without compromising health care quality or financial stability. Supporting informed procurement, energy efficiency, appropriate waste management, multi-disciplinary collaborative initiatives, and embracing the 6Rs in our daily practice can pave the way for a more sustainable future.

Declarations

Ethics approval and consent to participate:
Not applicable, as this is a review article.

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