



Short title: Environmental sustainability BP

1. Introduction

The health of the environment is a public health issue. The Australian Medical Council's Code of Conduct for Doctors states that "good medical practice involves using your expertise and influence to protect and advance the health and wellbeing of individual patients, communities and populations".^{1(p17)} Anaesthetists and pain medicine physicians have a role to play in mitigating climate change and environmental degradation as daily work practices have the potential to influence environmental pollution and greenhouse gas emissions. On an average working day, an individual anaesthetist can contribute the CO₂ equivalent of more than 1000km of car driving by administering nitrous oxide or desflurane.^{2,3} Every day, operating room staff in the United States of America deposit into landfill more than 1000 tons of rubbish, of which anaesthesia practice is likely to contribute a quarter of the total, and of which up to 60% may be recyclable.⁴⁻⁷ Current data demonstrates that 7% of Australia's total carbon footprint can be attributed to the healthcare industry; 44% of emissions were from hospitals.⁸

2. Justification

Environmental degradation and pollution are major threats to our health. In 2012, the World Health Organisation (WHO) estimated that exposures to polluted soil, water, and air contributed to an estimated 8.9 million deaths worldwide⁹, with ambient air pollution alone causing 3.7 million deaths¹⁰. In Australia, over 3000 deaths per year are presently attributed to air pollution (double our national road toll)¹¹. Exposure to air pollution, toxic chemicals, and pesticides are the main forms of pollution today causing disease in high-income countries. WHO has published an Atlas on children's health and the environment, noting that "26% of the deaths of 5.9 million children who died before reaching their fifth birthday could have been prevented through addressing environmental risks".^{12,13} There is also increasing evidence that individuals can pass the risk of environmentally related non-communicable diseases to their children, for example via epigenetic mechanisms.¹²

Gases and volatile agents used in anaesthesia have environmental impact related to their physicochemical properties and waste associated with their manufacture, use and disposal. In addition, other elements of the life cycle of anaesthetic agents may also have a role in sustainable practice. A background understanding of sustainability issues related to agent choice provides the anaesthetist with obvious opportunities to reduce their impact on the environment. While the direct contribution of anaesthetic agents to issues such as climate change may be small compared to CO₂ released by fossil fuel combustion, it is a contribution over which anaesthetists exercise unique control.

For further information about climate change, we would refer readers to the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia (www.csiro.au/en/Showcase/state-of-the-climate), and in New Zealand, the National Institute of Water and Atmospheric Research (NIWA) (www.niwa.co.nz/natural-hazards/hazards/climate-change).

3. Review of issues

Anaesthetic agents

There are a few broad concepts that provide useful background when considering anaesthetic agents and their environmental impact. For volatile agents, concepts related to effects on radiation and what is meant by the term “greenhouse gas” are relevant. An understanding of the impact of nitrous oxide requires a consideration of potential impacts on the ozone layer. For these agents and intravenous anaesthetic agents such as propofol, life cycle assessment (LCA) is a particularly relevant methodology to grasp.

Ozone Layer Effects

The potential for compounds to be associated with ozone depletion is measured by the ozone depletion potential (ODP) of the agent in question. Nitrous oxide and halogenated agents that contain chlorine such as isoflurane can potentially be associated with catalytic destruction of ozone in the atmosphere.¹⁴ While halothane would also fall into this group it is now rarely used. Atmospheric oxidation of desflurane and sevoflurane seem not to result in ozone depletion in recent experimental studies. Isoflurane has a relatively short atmospheric lifetime therefore damage is minimal.

Concepts of Radiation and Greenhouse Gases

The key feature of gas agents that lends them potential as greenhouse agents is their behaviour as absorbers over the infrared spectrum. Each gaseous agent will absorb infrared radiation over a unique range of wavelengths and this can be assessed by the integrated absorption cross-section. This is a measure of how efficiently the gas in question may affect the balance of radiation entering and leaving the Earth's atmosphere.

Where a particular substance has the effect of pushing the balance between incoming and outgoing radiation energy to favour warming, this is referred to as positive radiative forcing. By combining the known lifetime of an agent in the atmosphere and radiative forcing over that time, it is possible to calculate the Global Warming Potential (GWP).³ GWP is a measure of how much heat a greenhouse gas traps in the atmosphere over a specific time compared to a similar mass of carbon dioxide.¹⁵

Inhalational Agents

Halogenated agents utilised in anaesthesia practice all absorb infrared radiation that would otherwise leave the Earth's lower atmosphere. It is these absorption characteristics that mean they are associated with a greenhouse gas effect.¹⁴ Isoflurane has additional ozone-depleting effects due to interactions with the chlorine groupings within the molecule. This effect is somewhat offset by the short life-span of isoflurane once in the atmosphere.

Accounting for the greenhouse impact of inhalational agents requires a consideration of both the time for which the relevant agents remain in the atmosphere and how efficient the agent is in absorbing radiation in the infrared spectrum. Nitrous oxide has an atmospheric lifetime of nearly 120 years, whereas isoflurane has an atmospheric lifetime of 3.2 years, desflurane 14 years and sevoflurane 1.1 years. This does not remove the potential for agents that exist in the environment for a relatively short period of time to be destructive to the ozone layer.

A further consideration with respect to inhalational agents is the amount of the agent required for clinical use. This can be calculated by multiplying the quantity of an agent used over a given period by the GWP over 20 years (GWP20) for that agent to produce the Carbon Dioxide Equivalent over 20 years (CDE20). Such calculations provide a demonstration of the significant differences between agents. By comparison to sevoflurane at 1 MAC with fresh gas flow (FGF) of 2 L/min, isoflurane at 1 MAC has an approximately equivalent global warming impact only if FGF is maintained at 1 L/min. For desflurane the comparison is even more stark. At 2.0, 1.0 and 0.5 L/min the CDE20 of desflurane is 39, 19.5 and 9.8 times higher than for sevoflurane at 2 L/min, respectively.^{3,14}

While most of the nitrous oxide emissions are related to non-medical sources, when used as an adjunctive agent in delivery of general anaesthesia, it can substantially increase the GWP20 for a given anaesthetic. Ryan and Nielsen demonstrated that addition of 60% nitrous oxide to an FGF of 2 L/min and over 1-MAC hour with sevoflurane or isoflurane increased the global warming impact by 590% and 290% respectively³.

Intravenous agents

For intravenous agents, issues of direct contributions to climate change through their chemical properties are not the most significant issue. The more substantial issue with intravenous agents may relate to the entire procurement chain, which accounts for up to 60% of healthcare-related climate impact, of which at least half is derived from pharmaceuticals and medical equipment.¹⁶ In considering the impact of a drug over its entire life cycle, it is necessary to consider methods of manufacture, packaging, transport to the hospital, energy and materials required for drug delivery, whether it re-enters the environment in an unmetabolised form and waste production and management of unused drugs.

Propofol is the most commonly used intravenous agent reported on in the context of anaesthesia and sustainability. Sherman and colleagues have previously undertaken a life cycle assessment of propofol compared to sevoflurane, isoflurane and desflurane with or without the co-administration of nitrous oxide for each agent.¹⁷ For this work they assumed a 50% wastage rate of propofol and made calculations on a 1 MAC-hour equivalent. They also assumed disposable plastics for necessary equipment to deliver propofol and the energy consumption of the delivery pump. This LCA indicated that desflurane accounted for the largest life cycle greenhouse gas emissions both through release of waste anaesthetic gas and throughout other stages such as manufacturing. Life cycle greenhouse gas emissions were calculated as 15 and 20 times those of isoflurane and sevoflurane respectively when an oxygen/air mix was co-administered. Nitrous oxide again substantially increases life cycle greenhouse gas emissions.

The environmental impact of propofol was nearly four orders of magnitude lower than desflurane or nitrous oxide. The main related environmental impacts associated with propofol seem to result from energy requirements to operate syringe pumps, with minor contributions of manufacturing and waste.¹⁶

Infrastructure

In the USA, hospitals are the largest contributor of health sector carbon emissions, followed by the pharmaceutical industry. The entire sector contributes almost 10% of the country's greenhouse gas emissions.¹⁸ Reduction of resource intensity, different choices about infrastructure design, construction and utilisation, and extending financial horizons to include whole system costs can all lead to more environmentally sustainable healthcare. At the same time, aligning financial prudence and environmental priorities may improve healthcare in many different dimensions.

The Sustainable Development Unit (SDU) of the UK National Health System has worked with components of the health system at all scales to pursue a sustainable health system. Such a system is achieved "by delivering high quality care and improved public health without exhausting natural resources or causing severe ecological damage."¹⁹ The SDU has three main purposes:

- It rates the progress towards a healthier environment by the health and social care system.
- It prepares communities for resilience in changing times and climates.
- It has a "triple bottom line" approach where every decision should contribute to healthy lives, communities, and environments.

In 2016, compared with a baseline of 2009, the SDU has achieved a carbon reduction of 11% during a period of growth in activity of 18%. Ambitious targets are for a 25% reduction by 2020, and 50% by 2025.

²⁰

There are tools to assess the environmental impact of architecture and building. One such tool, Green Star, can be used at the design stage to show the potential environmental impact. Australia has the National Australian Built Environment Rating System (NABERS) and New Zealand has a similar scheme

(NABERSNZ). Assessment criteria for these tools include sustainability of site, energy efficiency, water efficiency, materials and resource in construction, indoor environmental quality, and waste and pollution.

The new South Wing of the Flinders Medical Centre in Adelaide, which opened in 2009, was the first healthcare facility in Australia to achieve Certification of Excellence under the Green Star rating tool.²¹ Compared with an equivalent benchmark building, it uses 42% less energy, 20% less water, and reduces CO₂ emissions by 4000 tonnes per year. The building incorporates solar hot water and high efficiency air conditioning under individual patient control. There is double glazing, natural light, and passive heating and cooling. Materials were chosen to reduce embodied carbon and minimise volatile chemicals in paints and adhesives. A sustainable supply chain was developed to make future purchasing decisions with regard to environmental priorities. The design incorporates architectural features proven to enhance health outcomes.

The Royal Children's Hospital in Melbourne has a high-performance envelope, harvests rainwater and has on-site wastewater treatment. It incorporates innovative energy generation including renewables, and has both natural ventilation and active chilled beam cooling. Natural light is used where possible, with energy efficient lighting used elsewhere. It is constructed from locally sourced materials, and has maximum recycled content in its precast concrete panels.²²

Beyond energy and resource efficient buildings, there is evidence-based architectural healthcare design that can improve patient well-being and staff satisfaction. Common findings are that quiet surroundings, natural lighting, and views or contact with nature improve patient recovery. Staff also benefit²³. The costs of constructing a quality indoor healthcare environment may be more than offset by increased productivity from happy and healthy staff.²⁴ In terms of the triple bottom line, efficient buildings: (1) reduce cost to the community, (2) are gentler on the environment and (3) may be designed for improved health of patients and productivity of staff.

Strategies and objectives for such healthcare design would include:

- Improving patient safety. Hospital design with respect to non-slip flooring, proximity between beds and bathrooms, airflow and ability to clean surfaces makes for lower patient injury and infection rates.
- Improving patient outcomes. Design should increase opportunities for staff to observe and interact with patients. Hospital construction that minimises movement of patients with changing acuity reduces handover, and reduces complications.²⁵ Workflow patterns should inform the design, not the other way around.
- Increasing the satisfaction of patient, family and staff. Sound attenuation and design that separates corridors and lifts for staff and visitors creates a healing environment. Rooms with space for family, and provision for individual patient control of temperature and lighting create patient satisfaction.
- Connection with nature. Unobstructed natural views and sunlight have positive effects on pain, mood, and hospital stay,²⁵ and natural scenery and vegetation have positive effects on staff and patients.
- Meeting expectations of staff and patients, and audit processes of preferences, expectations and satisfaction allows for continuous quality improvement.
- Improving effectiveness and efficiency of staff through standardisation, time in motion data, and design elements.
- Flexible elements of design may allow for future growth, or changes in configuration consistent with newer clinical requirements.
- Active design, a term derived from New York City's Active Design guidelines. Key features include: active transportation (walking, cycling, mass transit), active vertical circulation within buildings (encouraging stair climbing, discouraging lifts and escalators), and consumption of locally grown fruits and vegetables, and tap water. Active design methods promote environmental sustainability and universal accessibility, as well as increased activity.²⁶

The implementation of Lean theory in the management practices of clinicians may stimulate a rethinking of managing efficiency.^{27,28} Lean theory was first developed and described by Toyota in the production of their cars with the aim of improving efficiency and thereby minimising waste while maintaining safety in their manufacturing process. This methodology has been reviewed with respect to emergency department management but not to the provision of anaesthesia services. Its review and incorporation by individual institutions into perioperative and pain services may improve practice efficiency and waste minimisation.

In keeping with Lean theory, rethinking building and workplace design and how these spaces are utilised can help to improve efficiency both in energy consumption and in minimising excessive movement of personnel. For example, reducing electricity use for heating and lighting by improving insulation and allowing windows for natural light, designing buildings to allow for better patient flow (having emergency departments, intensive care units, operating theatres and radiology units on the same level where possible), and designing the workspace so that excessive movements are minimised (e.g. from having intravenous access in the patient on the same side as the anaesthetic drug trolley to locating recycling bins next to set-up trolleys to encourage and ensure recycling occurs). Having single stream recycling with segregation at the recycling facilities is another way of rethinking and encouraging recycling practices through increasing ease for staff and reducing the number of recycling bins required in these small spaces.^{29,30}

Equipment and Consumables

Operating theatres use large amounts of energy, procure many consumables and produce excessive waste, often contributing to a quarter of all hospital waste.⁷ Factors guiding the purchasing of anaesthesia equipment have traditionally been: safety, efficacy, functionality, financial cost, and infection control. A relatively novel approach to medical purchasing is also to consider environmental sustainability.^{4,7,31} Often there has been a 'trade off' between a device's financial cost and functionality or infection prevention. Similarly, there may be a tension between the environmental effects of producing a reusable product and the financial costs or infection prevention.³¹ The functionality of robust, reusable anaesthesia equipment may align with lower environmental effects compared with less robust and more environmentally problematic single-use equipment. Beyond the direct purchasing of anaesthesia equipment and consumables, anaesthetists on hospital committees are strongly advised to consider the implications of purchasing of other (i.e. surgical) operating equipment.

Infection control concerns vary between countries, leading to differences in anaesthesia equipment use. For example, due particularly to the concerns about variant Creutzfeldt-Jakob Disease, the Association of Anaesthetists of Great Britain and Ireland states that 'The use of such (single-use) anaesthesia equipment is to be encouraged. However, there are problems of cost, storage and disposal of single patient use devices'.³² There is the added problem of environmental costs, recognising that effective CSSD (Central Sterile Services Department) quality assurance is an integral part of hospital infection control and can be environmentally sustainable.

Life Cycle Assessments

Life cycle assessment (LCA) is the 'cradle to grave' analysis of the environmental 'footprints' arising from the extraction, manufacture, transport, use, recycling/waste disposal/reuse of equipment or processes.³³ Environmental footprints can be found for energy, carbon (climate change), water, pollutants (aquatic and terrestrial), and ozone depletion amongst others. A general introduction to LCA for the anaesthetist is available in the medical literature.⁷ Large, established databases and software^{34,35} assist researchers to find the relative environmental costs associated with products/procedures. Rigorous LCA is time consuming and can be financially expensive, thus historically there have been few studies in any medical domain.

However, there have now been LCAs of multiple anaesthesia items, comparing reusable versus single-use variants. A review of five prior studies comparing reusable versus single-use surgical gowns concluded that using reusable gowns had at least a 50% lower environmental footprint than using single-use gowns.³⁶

A study based in Germany (a country with high renewable electricity generation) showed that the use of reusable linens for drapes instead of disposable drapes was shown to have a lower carbon footprint.³⁷ In a study of anaesthetic drug trays, it was found that using reusable drug trays had significant financial advantages over the single-use trays (\$A5000 for a six-theatre hospital in 2009), but that the environmental effects were similar when the hospital location was Victoria, Australia.³⁸ In 2012, Eckelman and colleagues found that the environmental footprint of using reusable laryngeal mask airways (LMAs) was less than half that of using single-use LMAs for most parameters and the carbon footprint for the reusable LMAs was two-thirds that of the single-use LMAs.³⁹ On the contrary, in a study comparing reusable and single-use central venous catheter (CVC) insertion kits in Australia the reusable versions of the CVC insertion kits had a carbon footprint more than twice that of the single-use CVC insertion kits, due to coal being the source of electricity in Australia.⁴⁰ If the same study had been performed in New Zealand or Europe, the carbon footprint would have found in favour of the reusable CVC insertion kits.

The environmental footprint of all commonly used anaesthesia equipment (face masks, direct and video-laryngoscope handles and blades, breathing circuits, and LMAs) has been studied.⁴⁰ In this comparison between two Australian hospitals, one hospital used reusables, the other used mainly disposables. For the six-theatre operating suite it was found that using reusable equipment saved \$A30,000 per annum (inclusive of all labour/non-labour costs).

Anaesthesia breathing circuits can be used for variable periods of time in different countries. In the USA, it is recommended by the Center for Disease Control that all anaesthesia breathing circuits be disinfected or discarded for each patient even in the presence of single-use bacterial/viral filters.⁴¹ On the contrary, the German Society of Hospital Hygiene (DGKH) and the German Society for Anaesthesiology and Intensive Care (CGAI) jointly recommend that anaesthesia breathing circuits can be used continuously for one week so long as single-use filters are changed for each patient.⁴² Several studies have indicated that it is as safe from a microbiological standpoint to change/wash anaesthesia circuits weekly versus daily.^{43,44} Using reusable circuits versus single use circuits saves money, although this is minor when washed weekly, and once again the environmental footprint will depend upon the source of electricity,⁴⁰ being strongly in favour of reusable circuits in New Zealand. *PG28(A) Guideline on infection control in anaesthesia* does not comment upon the duration of use of anaesthesia breathing circuits, provided that each patient receives a separate single-use filter.

These life cycle studies indicate that using reusable anaesthesia items appears to consistently save money when compared to single-use equipment, but the environmental effects depend very much upon the source of electricity. Furthermore, efforts to improve the efficiency of hospital equipment (washers and sterilisers) used for cleaning reusable items can have considerable beneficial effects, both financially and environmentally. For example, improving hospital steam steriliser load efficiency and a 'switch off the steriliser' policy when not in use can save large amounts of money, electricity and water^{45,46}.

Rational Use of Diagnostic Tests and Prescribing

Environmental sustainability is also related to clinical inefficiencies in the provision of health care, such as interventions that do not meet patient expectations or provide the desired outcomes.^{27,47} These include unnecessary activity by both patient and staff movement, maintenance of stock levels, excessive waiting times, and the over-ordering of investigations and interventions.^{28,47} If waste and value are linked, minimisation of inefficiencies increases the value of the services we provide. Programs such as Choosing Wisely have been introduced in Australia and New Zealand to improve clinical care while promoting a rational use of resources. The UK's Academy of Medical Royal Colleges published a report "Protecting resources, promoting value – A doctor's guide to cutting waste in clinical care"²⁷ that demonstrated how appropriate use and resources can not only achieve better value in care but also reduce the carbon footprint of a health service.^{28,48}

The environmental impact of diagnostic tests and prescriptions is primarily generated from the production of (often single-use) medical items and medications, transport and procurement, and waste disposal.

Reducing the number of unnecessary diagnostic tests and prescription of drugs can result in significant reductions to the overall environmental footprint.

Pharmaceutical preparation and manufacturing (along with surgical and medical equipment manufacturing) have been reported to have the greatest ozone depletion effect of all health sector activities in the USA, (almost 25% each of total).¹⁸ In regard to morphine it appears that the packaging and sterilisation contribute to the greatest greenhouse gas contribution of its life cycle assessment.⁴⁹

Waste management

Waste can be defined as a substance that is discarded, emitted or deposited in the environment so as to cause an alteration in that environment; any discarded, rejected, unwanted, surplus or abandoned substance; any discarded, rejected, unwanted surplus or abandoned substance that is intended for recycling, reprocessing, recovery or purification.⁵⁰ This waste may be general waste, recyclable waste or clinical waste.⁵¹ Clinical waste is waste that has the potential to cause disease, sharps injury or public offence, including but not limited to cytotoxic waste, pharmaceutical waste, chemical waste, radioactive waste and laboratory waste. The type of waste determines how it is treated and its final destination: landfill, recycling, treatment, biodegradation, incineration, storage or transfer.⁵²

Reducing waste is an important and key component in improving environmental sustainability in anaesthetic practice and mitigating climate change.^{27,47,53} The Australian Government has a National Waste Policy with the aims of improving efficient resource use and reducing the environmental impact of waste management in order to assist with and provide strategies in reducing waste generation.⁵⁴ Operating rooms generate 20-30% of total hospital waste and of this, 20-25% comes from anaesthetic services specifically.^{4,53,55} Unfortunately, waste production, including the production of hazardous waste, is increasing and our current efforts are not keeping up.^{52,54, 56,57}

There are many different ways in which waste production can be reduced: taking responsibility for waste, reduce, reuse, recycle, rethinking and researching.^{4,5,7,29,58,59} An alternative approach which addresses reducing clinical inefficiencies utilises the Lean theory.²⁸

Responsibility and Stewardship

Taking responsibility is the first step in reducing waste production.^{5,23,54} Responsibility does not just fall to the individual or organisation. It comes down to all parties, from individuals, to hospitals/businesses and governments, to ensure that all steps are taken to manage and reduce waste in a safe manner throughout products' and services' entire lifecycle.

Barriers to waste management are many and varied. Reasons postulated include lack of knowledge and facilities, convenience and logistics and a lack of leadership.^{5,55} Clinical and pharmaceutical waste contributes 1.4% to Australia's hazardous waste production, according to the Hazardous Waste in Australia Report 2015.⁵² The fate of this waste includes incineration (35%), chemical and physical treatment (28%), storage (18%) and landfill (18%).

Reducing Waste Production

Anaesthetists generate a large proportion of operating theatre waste.^{4,53} Reducing waste production is "grass roots" waste management and the first step in reducing our environmental impact.

Having fewer consumables to discard is one means of reducing waste production including the ordering of less stock to ensure stores remain within expiry dates and are not being discarded unnecessarily.^{58,60}

Opening consumables only when they are needed also reduces the amount of waste produced, in addition to reducing wastefulness.^{4,55,58,61} This can apply to both drugs and equipment. Drug waste can have a significant impact on the environment as it has been shown that the procurement of pharmaceuticals and

medical supplies contributes more to carbon emissions than total building energy use or travel due to the financial and environmental costs of manufacturing, packaging, transport and disposal.⁵⁸

Unnecessary drug preparation contributes to environmental pollution and waste from both a manufacturing and disposal point of view, not to mention the financial costs of unused medications.^{60,61} The use of prefilled pharmaceutical syringes reduces the amount of pharmaceutical waste produced as drugs are not opened and drawn up unnecessarily, rather they are opened only when required.⁴ Reducing wasted drugs can significantly reduce our environmental impact. Propofol is arguably the most commonly used drug in anaesthesia practice and Mankes has previously reported a wastage rate of 32% in a hospital operating suite, accounting for 45% of all drugs wasted.⁶⁰ Simply reducing the size of drug vials available can impact on drug wastage, as shown in an audit of propofol use.⁶⁰ This audit showed that limiting the availability of propofol vials to the smallest available size (20mL) reduced the amount of propofol wasted from 29.2mL/day/bin wasted to 2.8mL/day/bin, thereby reducing financial waste and potential environmental contamination.

Preparing endotracheal tubes and LMAs “just in case” is another example of waste which can be avoided in the same way as pre-drawing up medications. Avoiding over-frequent changing of anaesthetic machine tubing can also reduce the amount of waste produced and still provide safe anaesthetic.^{43,44}

Reformulating pre-fabricated kits (for example cannulation kits or dressing packs) so that they only contain the products required can reduce the wastage of unnecessary items. Reducing the amount of packaging material is the responsibility of manufacturers, however we have the ability to choose materials with minimum packaging which may force the hand of manufacturers in order to maintain competitiveness.⁴

Reducing paper use reduces the environmental impact of anaesthetic services and paper products should be avoided where possible.⁵⁸ Methods for achieving this are through the use of electronic records (being mindful that there is an environmental impact to this alternative), avoiding printing or printing double-sided where needed and re-using paper that has been printed on one side only (caution: confidentiality). The use of recycled paper diverts paper waste from landfill which is a significant contributor of greenhouse gases.⁵⁸

Anaesthetists use large amounts of plastics for service provision – from airways, tubing and lines, to syringes, vials, fluids. When not recycled or reused, these contribute a high volume to landfill. They may leech harmful chemicals into the environment when disposed of in this manner and are a source of dioxin when incinerated.³⁰ Any reduction in the use of plastics will mitigate these effects and reduce the environmental impact of anaesthetic services.

Water is a resource which needs to be managed in order to reduce waste.³⁰ In many areas, water availability is becoming scarcer and it frequently has a monetary value attached to it as desalination is more frequently being utilised to source this natural resource.⁶² More emphasis must therefore be placed on its conservation. This includes the use of water aerators to reduce the amount of water used for the same apparent volume, fixing leaking plumbing, motion-sensitive automatic surgical taps, and ensuring maximum capacity of washers (both in equipment and laundry cleaning).⁵⁸ With respect to consumables, water usage can also be reduced by either choosing products whose manufacturing or reprocessing utilises minimum water requirements.⁶²

Reducing energy consumption can have positive impacts on the anaesthetic carbon footprint, regardless of the energy source.⁶³ This can be achieved again through mindful choosing of consumables whose manufacturing or processing is energy efficient.^{7,39,62} Turning off equipment and lights when not in use provides a self-explanatory means of reducing energy consumption. Ensuring medical facilities are energy efficient through improved design reduces both energy consumption for heating and cooling and assists with both mitigation and adaptation to climate change via less production-related pollution and greenhouse gas emissions.^{63,64}

Reuse

There is a trend to an increase in use of disposable equipment used in anaesthesia.⁴ This may be due to many factors including convenience, marketing and perceived financial savings and sterility and cleanliness issues. In general, having reusable or reprocessed equipment and consumables reduces the environmental impact of anaesthesia and should be an attractive option for health care facilities as reusing and reprocessing often saves money.^{5,7,55} In order to specifically assess this, full LCAs of disposable items and their re-usable counterparts need to be performed.^{5,7,58,65} The use of re-usable operating room textiles, LMAs, and central venous line insertion kits have been assessed and it has been found that the use of reusable textiles and LMAs is preferred from both a financial and environmental standpoint, though this is not the case for CVC insertion kits.^{36,39,62}

Recycle

Recycling has many benefits both economically and in mitigating the effects of climate change on the environment, though it should be noted that compared to reducing waste production and reusing items, it is less energy efficient.^{5,57-59} Recycling allows the diversion of waste from landfill to other products whether it be reprocessing into the same product (e.g. paper recycling), or reproduction into new products through the waste product being used as raw materials. From an environmental standpoint, manufacturing goods using recycled products as raw materials uses less fossil fuels and so has a smaller contribution to the production of greenhouse gases and climate change. It also means less deforestation for the production of paper production, less mining for metals and reduced need for oil for plastics production.⁵ The biodegradation of landfill generates methane which is a greenhouse gas.^{56,57,59} For products which would otherwise be incinerated, recycling releases less carbon dioxide into the environment.^{57,59} Diverting recyclables away from landfill reduces leachate and potential groundwater contamination which can occur at landfill sites.⁵⁷

From a financial point of view, recycling also saves money.^{4,58,59} An audit conducted in a US hospital revealed savings of \$4672.88 over their six-month audit period from the addition of single-stream recycling (recyclables segregated at the recovery facility).⁵⁹ The recycle bins were purchased on a grant, however payback on these was completed in under a year. The audit was also able to show energy conservation in this period. Compared to landfill disposal, recycling has an economic advantage of job creation through its labour intensive processing through the transport of recyclable waste, sorting and transformation of materials.⁶⁶ Any potential costs of transporting and disposal of recyclable waste may be mitigated (depending on the area) by on-selling these potential raw materials to recycling facilities.⁴

Although recycling reduces the carbon footprint of anaesthesia, consideration should also be made for preferentially purchasing products that are made from recycled materials and whose environmental impacts have been calculated as being low.⁵⁹

Up to 25% of operating theatre waste is produced by anaesthesia and up to 60% of this is recyclable.^{4,5} When surveying anaesthetists there is a strong desire for recycling to occur however it is felt that multiple barriers to recycling exist.^{4,5,55} These barriers include a lack of knowledge, convenience, absence of recycling facilities, lack of management support, leadership or encouragement in this area and concerns regarding infectious contamination.

- Most waste can be recycled if not contaminated by body fluids. Items which can be recycled include:^{4,58}
- Paper and cardboard.
- Blue surgical/equipment wrap.
- Plastics.
- Glass, including drug vials as drugs remain present in only small amounts and the incineration temperatures are sufficient to render drugs inert.
- Batteries.
- Fluorescent light bulbs.

- Electronics under e-Recycling programs.

It is important to ensure that waste which is destined for recycling is not contaminated as it will not be accepted by the recycling facilities and that entire waste haul is then treated according to the highest level of risk.⁵¹ This then becomes a costly exercise both environmentally and financially and may hinder recycling facility relationships.

Rethinking Waste Management

Rethinking how clinicians produce waste and ways in which waste minimisation can occur will help to make changes that are sustainable in the long term. Given the amount of change required to reduce and reverse current environmental sustainability trends, the development of policies on a national and institutional level that encourage rather than hinder waste management processes is important.^{5,54}

In contrast to single stream recycling, it is important for other waste, specifically contaminated waste and sharps, to be separated and discarded appropriately. To reinforce the above, waste is managed according to the highest level of risk. There are higher costs associated with the disposal of medical waste both financially and also ecologically due to the processing needed (incineration or treatment) prior to final disposal.^{4,50,51} Princess Alexandra Hospital in Brisbane has demonstrated that appropriate segregation of clinical waste from general waste can result in a 60% reduction of waste disposal costs.⁶⁷ Another example of judicious segregation producing savings, both financially and environmentally, is the disposal of sharps. The management of sharps waste is financially and environmentally costly due to the processing required (maceration/autoclaving). The reduction in the volume of sharps waste produced by ensuring only sharps are located in sharps bins (needles and easily broken glass medication vials) reduces the speed in which these receptacles are filled and require energy-intensive processing.

Drug disposal is another important means of reducing environmental impact as they may contribute to water table contamination and toxicity if incorrectly disposed.^{29,60,68} This is a particular problem with propofol for example, as it is poorly biodegradable, accumulates in fat and is toxic to aquatic life if leaching into water occurs. It can only be destroyed by high temperature incineration – squirting left over propofol into sharps bins which are incinerated is one method of ensuring it is adequately destroyed without contaminating landfill and water tables. This method of drug destruction is also recommended for local anaesthetic agents.⁶⁰ Ephedrine is also toxic to fish and aquatic invertebrates though no recommendations have been made for its disposal.

Away from the clinical environment, other methods that can be considered in waste production and management include having composting facilities available in hospital lunch rooms.⁵⁸ Though this does not necessarily reduce the amount of waste produced, it does change the way in which it is disposed and can be reused in hospital gardens as fertiliser, thereby reducing the cost to the hospital of transport as well as potentially reducing the gardening and maintenance costs by reducing the need to purchase processed fertilisers. Lunch rooms can also do away with recycling costs by eliminating the use of single-use kitchenware (cups, crockery, cutlery) in favour of staff providing their own reusable items.

Finally, encouraging audit and research in the area of waste management will continue to assist in improving and rethinking methods of waste reduction and environmental sustainability.^{5,7,51,58,65} This may include researching technological advances for ways in which waste generation can be reduced, or re-usable products can be used in a sustainable way to increase both product manufacturing and recycling efficiencies.

References

1. Australian Medical Council. Good Medical Practice: A Code of Conduct for Doctors in Australia. Australian Medical Council; 2009 Jul.
2. McGain F. Why anaesthetists should no longer use nitrous oxide. *Anaesth Intensive Care*. 2007 Oct;35(5):808-9.
3. Ryan SM, Nielsen CJ. Global warming potential of inhaled anesthetics: application to clinical use. *Anesth Analg*. 2010 Jul;111(1):92-8.
4. Axelrod D, Bell C, Feldman J, Hopf H, Huncke TK, Paulsen W, et al. Greening the Operating Room and Perioperative Arena: Environmental Sustainability for Anesthesia Practice. [Internet]. American Society of Anesthesiologists; [Updated 2017 Jan; cited 2019 Mar 4]. Available from: <https://www.asahq.org/about-asa/governance-and-committees/asa-committees/committee-on-equipment-and-facilities/environmental-sustainability>.
5. Hutchins DCJ, SM W. Coming round to recycling Waste management in the NHS. *BMJ* 2009 Mar 11;338:b609.
6. McGain E, Hendel SA, Story DA. An audit of potentially recyclable waste from anaesthetic practice. *Anaesth Intensive Care*. 2009 Sep;37(5):820-3.
7. McGain F, Story D, Kayak E, Kashima Y, McAlister S. Workplace sustainability: the "cradle to grave" view of what we do. *Anesth Analg*. 2012 May;114(5):1134-9.
8. Malik A, Lenzen M, McAlister S, McGain F. The carbon footprint of Australian health care. *The Lancet Planet Health*. 2018 Jan;2(1):e27-e35.
9. The Lancet Planetary Health. Our polluted world: the need for a global pollution strategy. [Editorial] *The Lancet Planet Health*. 2017 Sep 1; 1(6):e209.
10. World Health Organization. Burden of disease from Ambient Air Pollution for 2012. Summary of results. [Internet]. Geneva, Switzerland: World Health Organization; 2014. Available from: http://www.who.int/phe/health_topics/outdoorair/databases/AAP_BoD_results_March2014.pdf?ua=1
11. Begg S, Vos T, Barker B, Stevenson C, Stanley L, Lopez AD. The burden of disease and injury in Australia 2003. Canberra: Australian Institute of Health and Welfare; 2007.
12. Poore KR, Hanson MA, Faustman EM, Neira M. Avoidable early life environmental exposures. *Lancet Planet Health*. 2017 Aug 1;1(5):e172-e173.
13. World Health Organization. Inheriting a sustainable world? Atlas on children's health and the environment. Geneva: World Health Organization; 2017.
14. Andersen MPS, Nielsen OJ, Wallington TJ, Karpichev B, Sander SP. Medical intelligence article: assessing the impact on global climate from general anesthetic gases. *Anesth Analg*. 2012 May;114(5):1081-5.
15. Australian Government Department of the Environment and Energy. Synthetic greenhouse gases [Internet]. [Accessed 2019 Jun 5]/ Available from: <https://www.environment.gov.au/protection/ozone/ozone-science/synthetic-greenhouse-gases>
16. Sustainable Development Commission. NHS England Carbon Emissions Carbon Footprinting Report - September 2008 (Updated August 2009). London: Sustainable Development Commission; 2009.
17. Sherman J, Le C, Lamers V, Eckelman M. Life cycle greenhouse gas emissions of anesthetic drugs. *Anesth Analg*. 2012 May;114(5):1086-90.
18. Eckelman MH, Sherman J. Environmental Impacts of the US Health Care System and Effects on Public Health. *PLoS One*. 2016 Jun 9;11(6):e0157014.

19. Sustainable Development Unit. What is Sustainable Health? [Internet]. Cambridge, UK: Sustainable Development Unit; [cited 2019 Mar 4]. Available from: www.sduhealth.org.uk/policy-strategy/what-is-sustainable-health.aspx 2018.
20. Sustainable Development Unit. Sustainable Development in the Health and Care System: Health Check 2017. Cambridge, UK: Sustainable Development Unit; 2017 Jan.
21. Green Building Council Australia. Flinders Medical Centre - New South Wing. [Internet]. Green Building Council Australia; Available from: www.gbca.org.au/uploads/32/34336/Flinders_Medical_CentreNew_South_Wing.pdf
22. Robin G, Gail V. Sustainable Healthcare Architecture. 2nd ed. New Jersey: John Wiley & Sons, Inc.; 2013.
23. Phiri M, Chen B. Sustainability and Evidence-Based Design in the Healthcare Estate. New York Dordrecht Heidelberg London: Springer; 2014.
24. Department of Health & Human Services. Alexandra District Hospital longitudinal study - The impact of hospital design on health and wellbeing. [Internet] Melbourne: Victoria State Government; 2015 Oct. Available from: <https://www2.health.vic.gov.au/Api/downloadmedia/%7B0F6077DD-DC43-4B6F-8017-3304F1B745BF%7D>
25. Hendrich AL, Fay J, Sorrells AK. Effects of acuity-adaptable rooms on flow of patients and delivery of care. *Am J Crit Care*. 2004 Jan;13(1):35-45.
26. Center for Active Design. Active Design Guidelines [Internet]. Center for Active Design; 2010. Available from: <https://centerforactivedesign.org/guidelines/>.
27. Maughan D, Ansell J. Protecting resources, promoting value – A doctor’s guide to cutting waste in clinical care. London, UK: Academy of Medical Royal Colleges; 2014 Nov 6.
28. Pinkney J, Rance S, Bengner J, Brant H, Joel-Edgar S, Swancutt D, et al. How can frontline expertise and new models of care best contribute to safely reducing avoidable acute admissions? A mixed-methods study of four acute hospitals. 2016 Jan. *Health Serv Deliv Res*;4(3).
29. Blau E, Asrar FM, Arya N, Schabort I, Abelsohn A, Price D. Greener medical homes: Environmental responsibility in family medicine. *Can Fam Physician*. 2016 May;62(5):381-4.
30. Sneyd JR, Montgomery H, Pencheon D. The anaesthetist and the environment. *Anaesthesia*. 2010 May;65(5):435-7.
31. Daschner FD, Dettenkofer M. Protecting the patient and the environment-new aspects and challenges in hospital infection control. *J Hosp Infect*. 1997 May;36(1):7-15.
32. The Association of Anaesthetists of Great Britain and Ireland. Safety Guideline. *Infection Control in Anaesthesia*. [Internet] 2008 Sep; 63(9): 1027–36. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2773534/>.
33. Rebitzer G, Hunkeler D. Life cycle costing in LCM: Ambitions, opportunities, and limitations - Discussing a framework. *Int J LCA* 2003. 8(5):253-6
34. Frischknecht R, Jungbluth N, Althaus H-J, Doka G, Dones R, Heck T, et al. The ecoinvent Database: Overview and Methodological Framework. *Int J Life Cycle Assessment*. 2005;10(1):3- 9.
35. Weidema B P, Bauer C, Hischer R, Mutel C, Nemecek T, Reinhard J et al. Overview and methodology. Data quality guideline for the ecoinvent database version 3. *Ecoinvent Report 1(v3)*. St. Gallen: The ecoinvent Centre; 2013.
36. Overcash M. A comparison of reusable and disposable perioperative textiles: sustainability state-of-the-art 2012. *Anesth Analg*. 2012 May;114(5):1055-66.
37. Dettenkofer M, Griesshammer R, Scherrer M, Daschner F. [Life-cycle assessment of single-use versus reusable surgical drapes (cellulose/polyethylene-mixed cotton system)]. *Chirurg*; . 1999 Apr;70(4):485-91; discussion 491-2.

38. McGain F, McAlister S, McGavin A, Story D. The financial and environmental costs of reusable and single-use plastic anaesthetic drug trays. *Anaesth Intensive Care*. 2010 May;38(3):538-44.
39. Eckelman M, Mosher M, Gonzalez A, Sherman J. Comparative life cycle assessment of disposable and reusable laryngeal mask airways. *Anesth Analg*. 2012 May ;114(5):1067-72.
40. McGain F, Story D, Lim T, McAlister S. Financial and environmental costs of reusable and single-use anaesthetic equipment. *Br J Anaesth*. 2017 Jun 1;118(6):862-9.
41. Centers for Disease Control and Prevention (CDC). Guidelines for Preventing Health-Care-- Associated Pneumonia, 2003 - Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee. [Internet]. CDC; 2003. Available from: <https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5303a1.htm>.
42. Kramer A, Kranabetter R, Rathgeber J, Züchner K, Assadian O, Daeschlein G, et al. Infection prevention during anaesthesia ventilation by the use of breathing system filters (BSF): Joint recommendation by German Society of Hospital Hygiene (DGKH) and German Society for Anaesthesiology and Intensive Care (DGAI). *GMS Krankenhhyg Interdiszip*. 2010 Sep 21;5(2).
43. Dubler S, Zimmermann S, Fischer M, Schnitzler P, Bruckner T, Weigand MA, et al. Bacterial and viral contamination of breathing circuits after extended use - an aspect of patient safety? *Acta Anaesthesiol Scand*. 2016 Oct;60(9):1251-60.
44. McGain F, Algie CM, O'Toole J, Lim TF, Mohebbi M, Story DA, et al. The microbiological and sustainability effects of washing anaesthesia breathing circuits less frequently. *Anaesthesia*. 2014;69(4):337-42.
45. McGain F, Moore G, Black J. Hospital steam sterilizer usage: could we switch off to save electricity and water? *J Health Serv Res Policy*. 2016 Jul;21(3):166-71.
46. McGain F, Moore G, Black J. Steam sterilisation's energy and water footprint. *Aust Health Rev*. 2017 Mar;41(1):26-32.
47. The Royal Australasian College of Physicians (RACP). Environmentally Sustainable Healthcare Position Statement, November 2016. Sydney, NSW: RACP; 2016 Nov.
48. Intergovernmental Panel on Climate Change (IPCC). Summary for Policymakers. In: Masson- Delmotte, VP, Zhai, H-O, Pörtner, D, Roberts, J, Skea, PR, Shukla, A, et al., editors. *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Geneva, Switzerland World Meteorological Organization, 2018.
49. McAlister S, Ou Y, Neff E, Hapgood K, Story D, Mealey P, et al. The Environmental footprint of morphine: a life cycle assessment from opium poppy farming to the packaged drug. *BMJ Open*. 2016 Oct 21;6(10):e013302.
50. Sustainable Resource Use Pty Ltd. *Australian Waste Definitions - Defining waste related terms by jurisdiction in Australia*. North Melbourne: Department of Sustainability, Environment, Water, Population and Communities; 2012 May 28. Report No.: R01-02-A11306
51. Government of Western Australia, Department of Health. *Clinical and Related Waste Management Policy*, 2016. Government of Western Australia; 2016 Jan.
52. Latimer G. *Hazardous Waste in Australia 2017*. [Internet]. Victoria: Department of Environment and Energy, and Blue Environment Pty Ltd; 2017 May 30. Available from: <https://www.environment.gov.au/system/files/resources/291b8289-29d8-4fc1-90ce-1f44e09913f7/files/hazardous-waste-australia-2017.pdf>
53. Pungsornruk K, Forbes MP, Hellier C, Bryant M. A renewed call for environmentally responsible anaesthesia. *Anaesth Intensive Care*. 2015 Nov;43(6):800-1.

54. Commonwealth of Australia. National Waste Policy: less waste more resources.[Internet]. Canberra: Commonwealth of Australia; 2018. Available from: <http://www.environment.gov.au/system/files/resources/d523f4e9-d958-466b-9fd1-3b7d6283f006/files/national-waste-policy-2018.pdf>
55. Ard JL, Jr., Tobin K, Huncke T, Kline R, Ryan SM, Bell C. A Survey of the American Society of Anesthesiologists Regarding Environmental Attitudes, Knowledge, and Organization. *A A Case Rep.* 2016 Apr;6(7):208-16.
56. NHS Sustainable Development Unit. Saving Carbon, Improving Health - NHS Carbon Reduction Strategy for England, January 2009. Cambridge, UK: NHS Sustainable Development Unit; 2009 Jan.
57. Denne T, Irvine R, Atreya N and Robinson M. Recycling: Cost Benefit Analysis Prepared for Ministry for the Environment, April 2007. [Internet]. Auckland, NZ: Ministry for the Environment; 2007 Apr. Available from: <https://www.mfe.govt.nz/sites/default/files/recycling-cost-benefit-analysis-apr07.pdf>
58. RNZCGP, Randerson R, Phipps R. Greening General Practice. A toolkit for sustainable practice. Wellington: The Royal New Zealand College of General Practitioners; 2016.
59. Riedel LM. Environmental and financial impact of a hospital recycling program. *AANA J.* 2011 Aug;79(4 Suppl):S8-14.
60. Mankes RF. Propofol wastage in anesthesia. *Anesth Analg.* 2012 May;114(5):1091-2.
61. Weinger MB. Drug wastage contributes significantly to the cost of routine anesthesia care. *J Clin Anesth.* 2001 Nov;13(7):491-7.
62. McGain F, McAlister S, McGavin A, Story D. A life cycle assessment of reusable and single-use central venous catheter insertion kits. *Anesth Analg.* 2012 May;114(5):1073-80.
63. The Royal Australasian College of Physicians (RACP). The Health Benefits of Mitigating Climate Change Position Statement,. November 2016. Sydney, NSW: RACP; 2016 Nov
64. The Royal Australasian College of Physicians (RACP). Climate Change and Health Position Statement, November 2016. Sydney, NSW: RACP; 2016 Nov.
65. Ryan S, Sherman J. Sustainable anesthesia. *Anesth Analg.* 2012 May;114(5):921-3.
66. Access Economics Pty Ltd. Employment in waste management and recycling. Canberra: The Department of the Environment Water, Heritage and the Arts; d2009.
67. Wysusek KH, Foong WM, Steel C, Gillespie BM. The Gold in Garbage: Implementing a Waste Segregation and Recycling Initiative. *AORN J.* 2016 Mar;103(3):316.e1-8.
68. Gilbert N. Drug waste harms fish. *Nature.* 2011 Aug 15;476(7360):265.

Process of review

ANZCA Council approved the drafting of this professional document in November 2016 and the membership of the document development group, comprising:

- Dr Scott C Y Ma FANZCA (lead, SA)
- Dr Rob Burrell FANZCA (NZ)
- Dr Eugenie Kayak FANZCA (Vic)
- Dr Forbes McGain FANZCA (Vic)
- Dr Vanessa Percival FANZCA (WA)
- Dr Andrew Weatherall FANZCA (NSW)
- Dr Ingo Weber FANZCA (SA)
- Dr Peter Roessler FANZCA (DPA Professional Documents, Vic)

Related ANZCA documents

PG07(A) Guideline on pre-anaesthesia consultation and patient preparation

PG28(A) Guideline on infection control in anaesthesia

PG51(A) Guideline for the safe management and use of medications in anaesthesia

Further reading

Maughan D, Ansell J. Protecting resources, promoting value: a doctor's guide to cutting waste in clinical care [Internet]. Academy of Medical Royal Colleges, 2014 Nov. Available from: http://www.aomrc.org.uk/wp-content/uploads/2016/05/Protecting_Resources_Promoting_Value_1114.pdf

Choosing Wisely Australia <http://www.choosingwisely.org.au/home>

Choosing Wisely New Zealand <http://choosingwisely.org.nz/>

Professional documents of the Australian and New Zealand College of Anaesthetists (ANZCA) are intended to apply wherever anaesthesia is administered and perioperative medicine practised within Australia and New Zealand. It is the responsibility of each practitioner to have express regard to the particular circumstances of each case, and the application of these ANZCA documents in each case. It is recognised that there may be exceptional situations (for example, some emergencies) in which the interests of patients override the requirement for compliance with some or all of these ANZCA documents. Each document is prepared in the context of the entire body of the college's professional documents, and should be interpreted in this way.

ANZCA professional documents are reviewed from time to time, and it is the responsibility of each practitioner to ensure that he or she has obtained the current version which is available from the college website (www.anzca.edu.au). The professional documents have been prepared having regard to the information available at the time of their preparation, and practitioners should therefore take into account any information that may have been published or has become available subsequently.

Whilst ANZCA endeavours to ensure that its professional documents are as current as possible at the time of their preparation, it takes no responsibility for matters arising from changed circumstances or information or material which may have become available subsequently.

Promulgated: 2018
Reviewed: July 2019
Current document: July 2019

© Copyright 2020 – Australian and New Zealand College of Anaesthetists. All rights reserved.

This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without prior written permission from ANZCA. Requests and inquiries concerning reproduction and rights should be addressed to the Chief Executive Officer, Australian and New Zealand College of Anaesthetists, 630 St Kilda Road, Melbourne, Victoria 3004, Australia. Email: ceo@anzca.edu.au

ANZCA website: www.anzca.edu.au