Catheter lock solutions are instilled into central venous access systems to have certain effects in this location. These access systems can be either dialysis catheters, Hickman-type lines or port-a-cath systems. The latter are used mainly in parenteral nutrition and for the administration of medication in oncology patients. These access systems are approved as medical devices and are CE marked. The central venous access is inserted in the subclavian, jugular or femoral veins.

The use of Antimicrobial Lock Solutions have been recommended in the "Hygiene Guideline complementing the German Dialysis Standard" and in the Position statement of European Renal Best Practice (ERBP)**. Pure heparin solutions containing no antimicrobial agent do not meet this criterion. Antibiotics are associated with the development of resistancy which is a major drawback. Highly concentrated citrate solutions and taurodilene-citrate solutions are therefore conceivably useful in this application.

Highly concentrated citrate solutions (30% and 46.7%) cause major adverse effects such as cardiac arrests and embolisms that are a significant risk for the patient. TauroLock™ as an antimicrobial lock solution has proven useful in dialysis, oncology and parenteral nutrition for many years and has meanwhile become established in the prevention of catheter-related infections.
The environmental impact of healthcare and haemodialysis: the Jekyll and Hyde dilemma

Kylie Dunbar-Reid & Elizabeth Buikstra

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Abstract
People with end-stage kidney disease require renal replacement therapy to sustain life. The delivery of haemodialysis (HD) as a renal replacement therapy option comes at a high financial and environmental cost. The current global HD patient population of over 2 million (Couser et al., 2011) is expected to double within the next decade (Tarrass et al., 2010), placing increasing demands on energy production, waste management and water sources and adversely affecting climate change. The environmental burden of providing HD is a high-stake contributor to the growing global concern with global warming and the resultant burden of increasing disease and mortality (World Health Organization, 2009). Green nephrology initiatives are important for supporting the sustainability of HD delivery and minimising environmental impact. Renal nurses need to be well informed of the health care impact on climate change to be strong advocates for climate-friendly health care and environmental protection that have no negative implications to patient safety or health care delivery but are imperative to meet social, economic and environmental objectives.

Keywords
Climate change, carbon footprint, haemodialysis, green nephrology.

Introduction
There are global health concerns related to climate change (World Health Organization [WHO], 2016). According to the Australian Academy of Science (2015), climate change is an alteration in the pattern of the climate, specifically referring to the statistical description of weather and of the related conditions of oceans, land surfaces and ice sheets and includes consideration of averages, variability and extremes. The human contribution to climate change is referred to as our carbon footprint, which looks “solely at the greenhouse gas emissions associated with the activities of an organisation, product or process and is measured in CO₂ equivalents” (Rasmussen, 2010, p.17). Globally, CO₂ emissions have increased by approximately 90% since 1970 (Intergovernmental Panel on Climate Change [IPCC], 2014). Whilst there are natural drivers of climate change, human-induced climate change, known as anthropogenic climate change has proven the greater and more rapid environmental threat with health care a substantive contributor (IPCC, 2007). Climate change has the potential to alter the social and environmental determinants of health, resulting in changes to the geographic range and seasonality of certain infectious diseases, the distortion of food-producing ecosystems, and increasing the frequency of extreme weather events (WHO, 2016). Using a base case socio-economic scenario, Hales et al. (2014) estimates the annual burden of mortality by 2030–2050 will increase by an additional 250,000 deaths. The quantitative risk assessment places malnutrition, malaria, diarrhoea and heat stress as the main future mortality predictors that are directly related to climate change and socio-economic vulnerability (Hales et al., 2014). Along with the significant loss of life, it is estimated the direct health care costs...
for managing climate change will be in the range of US$2–4 billion per year (WHO, 2016).

Health care services are a major contributor to anthropogenic climate change in Australia and comparable western countries. From health care alone, the National Health Service (NHS) England carbon footprint rose to 21 million tonnes of CO₂ emissions in 2007, 25% of the nation’s total (NHS Sustainable Development Unit, 2009) which is paled in contrast to health care buildings in the United States of America, being the second most energy-intensive of all commercial buildings (WHO, 2016), Lim et al. (2013) report that the carbon footprint of dialysis in Australia is 10.2 tonnes carbon dioxide equivalent (CO₂-e) per patient, and that estimated national emissions per person are 18.8 tonnes CO₂-e (in society generally) As such, it is imperative that health care providers take action to reduce the environmental impact of the services they provide (Connor et al., 2009; Tomson, 2015). The medical commitment of ‘to do no harm’ must now extend beyond being only committed to human health, but also carry the commitment to environmental health (WHO, 2009).

A typical approach taken by hospitals and health services is to consider environmental issues on a macro-scale and this is evident in the abundance of guidelines and policies on waste management plans. This does not take into account how individual services, including renal services, can contribute in a meaningful way to environmental sustainability initiatives, such as water and waste management (James, 2007).

Global impact of chronic kidney disease

Chronic kidney disease (CKD) has now been described as a worldwide health crisis (Levey et al., 2007). It is estimated that currently over 2 million people worldwide require haemodialysis (HD) (Couser et al., 2011) with projections that this figure will rise to about 4 million dialysis patients worldwide by 2025 (Tarrass et al., 2010). Although there are huge disparities between what individual countries can either afford or actually budget for in managing CKD, the financial burden and strain on health care is alarming (Mushi et al., 2015).

The many advances in CKD, particularly the introduction of plastic into health care and single-use medical devices (North & Haldon, 2013), including the single-use HD dialyser and circuit means the environmental impact from renal replacement therapies is disproportionately high (Connor & Mortimer, 2010). Connor et al. (2011) have calculated that thrice-weekly in-centre HD has a carbon footprint of 3.8 tonne CO₂ equivalent per patient per year. On current global statistics, this equates to 7.6 million tonne CO₂ equivalent per year, with the projection to double to 15.2 million tonne CO₂ equivalent per year by 2025.

Along with the production of substantial clinical waste (Connor et al., 2010), HD generates large energy and electrical consumption (Connor et al., 2011) and requires exorbitant amounts of water as well as producing significant water wastage (Agar, 2015). This ironic situation of health care contributing detrimentally to the planet emphasises the responsibility that hospitals have to satisfy what is referred to as the ‘triple bottom line’ of people, planet and profits to aim for an environmentally preservative and sustainable health care culture (Hindle, 2009; Kagoma et al., 2012).

To add to the burden, Tomson and Connor (2015) warn of the changing spectrum of renal disease as a direct consequence of climate change. New presentations of climate change-induced conditions, such as heat stress nephropathy leading to CKD (Glasser et al., 2016), will, in itself, perpetuate the vicious cycle of increasingly large environmental damage from health care delivery, leading to further declines in climate changes.

Climate change contributors in HD

Clinical waste generation in HD

Outside the general waste generation in any HD unit, there is approximately 2.5 kg of clinical waste generated per patient per HD session (Connor et al., 2010), resulting in an estimated 390 kg of clinical waste per patient per year. This figure increases to an estimated 650 kg per person per year for patients receiving home HD (Connor et al., 2010). Globally, this figure sits at approximately 600,000 tonnes per annum (Piccoli et al., 2015).

Most dialysis waste is managed as landfill or incineration and both have reported adverse effects on health (Agar, 2015). Incineration, with temperatures below 800° Celsius (Kastl & Pancirova, 2011) may result in the production of hazardous air pollutants, such as dioxins and furans, along with significant amounts of steam, smoke, dust and ash (Lee et al., 2004). James (2010) purports that although incineration produces higher CO₂ emissions than landfill, the methane produced from landfill is approximately 23 times more potent than CO₂ as a greenhouse gas. This evidence is based on the calculations of the global warming potential (GWP) of gases, compared to carbon dioxide, and expressed as CO₂-e (Department of Environment and Energy, 2016). The GWP predicts the lifespan and environmental impact of direct, indirect or various gas emission factors over time. (Department of Environment and Energy, 2016). What is concerning with James’ (2010) statement, is that the United States Environmental Protection Agency (2016) reports that methane’s impact is shorter but harsher than carbon dioxide.

Other challenges faced with landfill include the lack of infrastructure and financial backing to correctly manage the landfill, particularly in developing countries. This is evidenced by open dumping and simple pit systems for burial of waste, leading to waste picking (human and animal) and contamination into water sources and populated areas (Stringer, 2011). There is also international inconsistency in waste classifications and management, to further complicate effective waste management (Azmal et al., 2014). However, even landfill managed as per national legislation, results in significant amounts of greenhouse gases (WHO, 2009), as well as having other serious environmental effects such as water and waste management (James, 2007).
as surrounding soil and water contamination by leakage of metabolites and the off-gassing of methane (Kastl & Pancirova, 2011). The breakdown of PVC, which is abundant in HD, produces toxic substances, such as dioxins which has been reported to result in skin lesions, altered liver function and impairment of the immune system and be detrimental to the developing systems of the growing foetus (Kastl & Pancirova, 2011) as well as opportunistically entering the human food chain from food and dairy sources (James, 2010). Over time, methane and carbon dioxide account for 50–60% and 40–45% of greenhouse gas production (James, 2010). James (2010) reports the carcinogenic and/or toxic trace components as a direct result of landfill breakdown may link to long-term adverse health, for not only this generation, but generations to come.

**Energy production and consumption**

The production and use of energy, which is mostly from fossil fuels, contributes to climate change (Environmental Protection Agency [EPA], 2015). The phenomenal amounts of energy required for the delivery of health care have made WHO (2009) concerned that the resulting toxic emissions from this energy production is responsible for the deterioration in health of the societies it is meant to serve. The EPA (2015) cites that energy accounts for more than 84% of US greenhouse gas emissions. Electricity generation is the main cause of carbon pollution in Australia, with 73% of electricity coming from burning coal and 13% from burning gas. The remaining 14% comes from renewable energy sources, which do not emit carbon pollution. Australia's level of CO₂ pollution per person is more than four times the world average (WWF Australia, 2016). Dell et al. (2014) also warn of the probable shift in energy usage, specifically in addressing the predicted global temperature increase (for example, increased air conditioner usage) which will also likely affect greenhouse gas emissions and climate change further.

Transportation is one energy source that is relied on heavily in health care (WHO, 2009), from transportation of structural equipment and all elements involved in health delivery, such as food, pharmaceutical supplies, office supplies and waste removal, to the specific delivery of HD essentials, including patient transfers. Transportation alone is responsible for up to an astounding 18% of the United Kingdom’s total carbon footprint (NHS Sustainable Development Unit, 2009). Specifically to health care, approximately 60% of the total carbon footprint of the NHS is related to procurement (NHS Sustainable Development Unit, 2009).

**Water consumption in HD**

HD is a water-hungry therapy option (Agar, 2015). To facilitate HD, up to 500 litres of total feed water per treatment is required (Connor et al., 2010). The process to generate water for HD equates to 60–70% of the presented mains, tank, bore, or well water at the reverse osmosis (RO) system membrane being rejected as part of the purification processes to enable the incoming water source to be treated to meet international water standards for safe use in HD (Connor et al., 2010). On a global scale, per year, the dialysis population creates approximately 3,675 million litres of wasted water (Perkins & Agar, 2013).

The water usage in HD is a real dilemma as water scarcity is one of the main global problems in the 21st century (United Nations Department of Economic and Social Affairs [UNDESA], 2007). The UNDESA (2007) projects that there will be 1.8 billion people living in countries or regions with absolute water scarcity, and two-thirds of the world’s population living under water-stressed conditions by the year 2025. This number is projected to increase to almost half the world’s population living in areas of high water stress by 2030 (UNDESA, 2007).

**Global initiatives**

The first international agreement on climate change, The Kyoto Protocol, adapted in Japan in the 1990s has paved the way for the current climate change commitments (United Nations, 1998). In December 2015, at the 21st session of the Conference of the Parties (COP21) at the United Nations Framework Convention on Climate Change held in Paris, 195 countries adopted the first universal climate change agreement. Known as ‘The Paris Agreement’, this internationally and legally binding global action plan has been developed to foster climate resiliency and mitigate the adverse effects of climate change, aiming for global carbon neutrality by 2050 (United Nations, 2015). The 22nd session of the Conference of the Parties (COP 22) held in Marrakech in November 2016 further explored the urgency of combating climate change and also investigated how to keep the commitment and momentum of bringing together the whole international community to tackle “one of the greatest challenges of our time” (United Nations, 2016a).

Responsively, there are many countries pledging to actively engage in mitigating climate change, including China, Canada, France, Germany and New Zealand (United Nations, 2016b). Of the 132 parties who have ratified the Paris Agreement (United Nations, 2016b), Australia provides a framework for businesses to achieve carbon reductions and carbon neutrality through a National Carbon Offset Standard and a Carbon Neutral Program for businesses and organisations to voluntarily reduce and offset their emissions (Department of Environment, 2015).

Examples of exemplary carbon neutral commitments continue to emerge, such as Copenhagen’s Climate plan to be the first carbon-neutral capital in the world by 2025 (The Technical and Environmental Administration, 2009). Putting words into action has this city already citing over 20% CO₂ emission reductions over the last decade (The Technical and Environmental Administration, 2009). The Carbon Neutral Adelaide Action Plan (2016–2021) has Adelaide aiming to be the world’s first carbon neutral city (Department of Environment, Water and Natural Resources, 2016). Similarly, Canberra’s target of 100% renewable energy by 2020 is said to be secured as a result of diligent focus to implement strategically placed wind and
solar farms throughout the country’s capital (ACT Government, 2016). These carbon-neutral commitments, and the next frontier of prospective large-scale negative emission technology (NET) (Quader & Ahmed, 2017; Moreira & Pires, 2016) will directly impact on the infrastructure and delivery of future health care, further aspiring to balance the international community’s health care needs with environmental sustainability.

Health care and renal health care initiatives

In 2009, WHO published the Healthy hospitals, healthy planet, healthy people: Addressing climate change in healthcare settings report, identifying health system programs that contribute to the reduction of health care-induced greenhouse gas emissions. Included in the report are seven elements of a climate-friendly hospital. These elements come under the headings of energy efficiency, green building design, alternative energy generation, transportation, food, waste, and water (WHO, 2009). This report is now supported by the WHO Operational Framework for building climate-resilient health systems (WHO, 2015).

Since the first green nephrology summit in the United Kingdom in 2009 (Campaign for Greener Healthcare, 2009) and the 2011 climate and health summit (The Climate & Health Council et al., 2011) there continues to be positive environmental initiatives and involvement in the renal community, both nationally and internationally (Connor et al., 2009; Connor et al., 2010; James, 2010; Perkins & Simmonds, 2011; Kastl & Pancirova, 2011; Agar, 2012, 2015). Specific to nephrology, in 2010, The Green Nephrology Programme implemented the Campaign for Greener Healthcare 10:10 Renal Checklist, which includes promoting simple measures to aim for a 10% carbon emission reduction (Centre for Sustainable Healthcare, 2017). Also, the newly-formed ANZSN Environmental Working Group is aiming to raise the profile of environmental issues within the Australasian nephrology community and beyond (Mortimer, 2009).

Renal health care: HD-specific initiatives

Health care professionals need to address the main environmental contributors related to HD to limit anthropogenic climate changes and pursue carbon neutrality. Three of the main contributors are waste production, water wastage and energy usage.

Waste minimisation and management

There are new waste minimisation and management initiatives such as the Queensland Waste Avoidance and Resource Productivity Strategy (2014–2024) (Department of Environment and Heritage Protection, 2014) and Green procurement initiatives available to further aim for the provision of a more sustainable and ecologically safe health service (Department of Sustainability, Environment, Water, Population and Communities, 2013). In Australia, clinical waste management and clinical waste reduction initiatives align with Standard 15 of the EQuiPNational Standards: Corporate Systems Waste and environmental management, which supports safe practice and a safe sustainable environment (The Australian Council on Healthcare Standards, 2017). Specifically relating to the renal profession, there are the EDTNA/ERCA Environmental Guidelines for Dialysis (Kastl & Pancirova, 2011).

Incineration, sterilisation, microwave treatment and plasma gasification are all viable waste management options to explore. Recently changed specifications for incinerators has resulted in higher incineration temperatures and, according to James (2010), include energy-recovery processes and the possibility to use the remaining solid processed residue in construction.

There are autoclave steam sterilisation devices that can sterilise and shred nearly all dialysis waste, which can be used as landfill (Perkins & Agar, 2013). One product promotes the process of sterilising and shredding clinical waste, with the potential for reuse of the sterile “shredate” in the production of bricks and bitumen, which is a proactive, environmentally friendly solution (Perkins & Agar, 2013). Microwave treatment and chemical processing of medical waste are also showing promising waste management options (Zafar, 2015). Plasma gasification is also an emerging option for hospital waste that uses an oxygen-starved reactor with extreme temperature to break down the waste, producing synthesis gas, known as Syngas, as well as producing a glassy aggregate (Waste Management Association of Australia, 2016.; Zafar, 2015).

Energy production and expenditure

The WHO (2009) recommends initiatives that range from using combined heat and power technology and alternative forms of clean and renewable energy — such as solar and wind energy and some biofuels, through to the small but significant measures such as switching to compact fluorescent and light-emitting diode light bulbs, and appropriate settings of thermostat temperatures. One stellar example of environmental stewardship is the Geelong Home Dialysis Unit in Victoria which is using solar power (Agar, 2011). Another benefit from this project has been the ability to claim government subsidies (Agar, 2011).

Purchasing of energy-efficient products and also designing energy-efficient buildings or retrofitting current buildings to cut energy waste can all have major environmental impacts (WHO, 2009). Along with turning off unnecessary lights, the renal 10:10 checklist (Centre for Sustainable Healthcare (2017) advocates the use of motion-sensor light switches for cupboards and toilets. There are environmental strategy papers, such as the NHS Saving Carbon, Improving Health (NHS Sustainable Development Unit, 2009) to provide health care facilities with strategies to reduce its carbon emissions and become more sustainable. Also, environmental campaigns such as the WWF Australia are committed to environmental sustainability by having targets such as the aim to achieving 100% renewable energy in Australia before 2050, including 100% renewable electricity before 2035 (WWF Australia, 2016).
The WHO (2009) also suggests that transportation emissions can be reduced by using high-efficiency or alternative-fuel vehicles, minimising waste transportation, staff carpooling, and by purchasing from local suppliers or/and suppliers who use fuel-efficient transportation. Future possibilities such as transitioning to electric vehicles are starting to take traction (Climate Works Australia, 2016; Kangaroo Island Council, 2015) and implementation into health services may prove environmentally and financially beneficial. The renal 10:10 checklist (Centre for Sustainable Healthcare, 2017) promotes purchasing the minimal amount of volumes and looking at suppliers’ environmental policies; this includes also promoting reduce, re-use, recycle principles wherever possible. The renal 10:10 checklist also discusses how to decarbonise care, which looks at reviewing all clinical care and health care advice and ascertaining if it aligns with environmental sustainability (Centre for Sustainable Healthcare, 2017).

Water conservation and reject water recycling
More than 70% of the total mains water drawn from most dialysis services is salvageable and re-usable (Green dialysis, n.d). Even though modern ROs are more efficient and reject less water (Tarrass et al., 2010), there is consensus that the wise use of water in dialysis, as well as further exploration into recycling water in HD merits national and international attention (Agar, 2015; Tarrass et al., 2010). Projects, such as systems that focus on Sorbent regeneration of used dialysate, are still in the research and development phase (Agar, 2015). Renal health professionals and hospital executives must place their focus on water conservation and recycling of rejected RO water. Agar (2015) and Connor (2009) hold strong to the fact that RO systems’ reject water should be a valid option for almost any water source purpose, from re-looping water back to the RO to the successful use of reject water in crop irrigation. Connor et al. (2010) cited one project that used 14,400 litres of reject HD water per day in place of tap water, which resulted in 1,239.88 kg of CO₂ equivalents per year savings.

Future directions: meeting the challenge of renal health provision and environmental stewardship
While there is promising pre-clinical work in stem cell-based treatment for chronic renal failure, there is no specified timeline or guarantee of when the development of cell-based therapeutic interventions in a clinical setting will come to fruition (Papazova et al., 2015). Also, whilst there is acknowledgement that the exorbitantly high amount of plastic used in dialysis requires greater attention (Piccoli et al., 2015), it would be unlikely that the dialyser and line reuse debate or change in legislation would resurface in Australia in the near future (Agar, 2015). Rather, the ecological potential of manufacturing recyclable dialysis products merits further exploration (Piccoli et al., 2015). The practice of health care companies successfully manufacturing ‘green products’ that have less plastic packaging and have been made using recycled materials (Philips, 2010) is promising and will hopefully pave the way for future renal resources. Interestingly, Tomson and Connor (2015) also note that the supply chains for pharmaceuticals and medical equipment are major carbon emission contributors and there is a large body of work required to address this, including shared decision-making strategies and renal industries collaborating more efficiently.

Tomson and Connor (2015) explain how remote care initiatives, such as telephone clinics are also examples of low-carbon kidney care initiatives. Many health services are now strong advocates for videoconferencing to be used for direct patient contact as well as to link with remote health professionals to co-ordinate patient care and services (Oliveira et al., 2013). Along with the health and quality of life benefits of empowering patients, Connor et al. (2010) also discuss how patient empowerment and self-care facilitates low-carbon health care. In alignment with a cradle-to-grave life cycle assessment that projects the environmental impact of a business (Khasreen et al., 2009), any advances in medicine and technology that can prevent CKD and improve transplantation rates merits continued focus in this plight to mitigate anthropogenic climate change (Tomson & Connor, 2015).

Implications for clinical practice
By renal nurses having an understanding of the environmental impact of health care and HD and the resources available to guide changes in practice, individual units can explore quality improvement initiative options that can assist in the provision of sustainable health care for people with CKD requiring renal replacement therapy as well as for providing health care that is also environmentally sustainable. Implementing positive environmental projects can raise staff awareness of the importance of being more conscientious about adopting carbon-friendly initiatives into their health service. Having open dialogue about environmental issues and the concept of green dialysis initiatives provides staff with a feeling of pride in their accomplishments and fosters a culture that supports staff and patients being able to discuss and trial other possible climate-friendly strategies that contribute to positive health, economic and social outcomes. Renal health professionals can become familiar with the many web-based resources, such as Green dialysis and Global dialysis that are globally respected and are easily accessible for guidance with implementing climate-friendly health care initiatives.

The reshaping of health care through the reduction of greenhouse gases and the implementation of low-carbon health care initiatives provides an excellent opportunity for patient involvement in renal units (Mortimer, 2009) and at all levels of health care (ACHS, 2017). Along with the positive environmental impact of climate-friendly QI activities, any monetary savings from such projects can contribute to other much-needed health care services whilst having no
negative impact on patient care or staff safety. Successful implementation of such QI activities can be a benchmark for other renal units in the attempt of the renal society collectively addressing this health care and climate change crisis. By sharing positive environmental initiatives in the renal department to the multidisciplinary team and interdepartmentally, there may be a heightened awareness of the environmental and health care issues and this could be incentive for other departments to research and implement department-specific waste minimisation and/or environmentally sustainable practices.

In alignment with the recommendation by the WHO (2009), renal nurses are well positioned to educate hospital staff about climate change issues, as well as being part of the change agents to ensure environmental health, climate change and the health sector’s role in climate change are part of the required curriculum in teaching institutions. On a larger scale, McCoy and Hoskins (2014) suggest that as health professionals, we have the professional mandate and scientific training to potentially place ourselves in important roles that enables policy makers and the general public to be well informed on climate change issues.

Conclusion

As stated by WHO Director-General Dr Margaret Chan during the United Nations Human Rights Council, “A ruined planet cannot sustain human lives in good health” (WHO, 2015). The exorbitant generation of waste, water and the energy-intensive requirements to deliver health care, in particular HD, may pose challenges to the ethical principles of to do no harm (non-maleficence) and to do the most good for most people (justice and beneficence) (Summers, 2014). By renal nurses holding fast to their code of ethics of “valuing and promoting best practice patient care in a socially, economically and ecologically sustainable environment” (Nursing and Midwifery Board of Australia, 2008), renal nurses are excellently positioned in the health care system to be able to identify potential areas of improvement and support other health professionals, executive and policy makers to strive to find, implement and respect all possible low-carbon dialysis care options to be able to continue to provide essential, life-sustaining health care to their patients whilst minimising the carbon footprint. Whilst renal nurses are mindful of the pressures of the health organisations that they are currently working within, patient safety is imperative. Providing the highest quality of care and working in collaboration with patients to support them having optimal quality of life is the cornerstone of the renal nurses’ workload. In the plight for climate-friendly health care, renal nurses must now also appreciate that their duty of care extends to also being highly diligent with environmental considerations that stretch far beyond the HD unit.

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