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Environmental sustainability in hospitals – a systematic review and research agenda

Forbes McGain[1] and Chris Naylor[2]

Abstract

Objectives: Hospitals are significant contributors to natural resource depletion and environmental change. Our objective was to establish the extent to which hospital environmental sustainability has been studied and the key issues that emerge for policy, practice and research.

Methods: The PubMed, Engineering Village, Cochrane and King's Fund databases were searched for articles relating to hospital environmental sustainability published in English between 1 January 1990 and 1 October 2013. Further studies were found by review of reference lists. One hundred ninety-three relevant articles were found and 76 were selected for inclusion in the review.

Results: Common research themes were identified: hospital design, direct energy consumption, water, procurement, waste, travel and psychology and behaviour. Some countries (particularly the United Kingdom) have begun to invest systematically in understanding the environmental effects of hospitals. We found large variability in the extent of the evidence base according to topic. Research regarding the architectural fabric of hospital buildings is at a relatively mature stage. Similarly, there is a developed research base regarding devices and technologies used within hospitals to reduce the environmental effects of direct hospital energy and water use. Less is known about the clinical, psychological and social factors that influence how health care professionals use resources, travel to/from hospital, and interact with the buildings and technologies available. A significant part of the environmental footprint of hospitals relates to clinical practice, e.g. decisions regarding the use of pharmaceuticals and medical devices. Medical 'cradle to grave' life cycle assessment studies have been published to understand the full financial and environmental costs of hospital activities. The effects of preventive or demand management measures which avoid unnecessary hospital procedures are likely to be much greater than incremental changes to how hospital procedures are performed.

Conclusions: There remain significant gaps in the evidence base on hospital sustainability. Assessments of environmental impacts and natural resource use are beginning to be produced, both at the level of individual hospitals and at the health system level. These are an important start, but in many areas do not yet provide sufficiently detailed information to guide decision-making. There are many areas where the interests of patients and the environment coincide, but others where tensions exist. Rising resource costs and climate change mitigation measures are likely to create an increasing stimulus for research on hospital sustainability. Such research will benefit from inter-disciplinary coordination across research funders and countries.

Keywords

environment, hospital, sustainability

Introduction

'Simply claiming that something is green, without demonstrating empirical benefits for human health and well-being, the environment, and economics, is not enough.'[1]

A process is sustainable if it can continue into the distant future without overwhelming finances,

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damaging ecosystems or exhausting natural resources.[2] The current financial and environmental sustainability of healthcare is uncertain. An ever-increasing proportion of national gross domestic product (GDP) is spent on healthcare in most developed countries and healthcare uses a significant (but unclear) proportion of the world's total natural resources – including oil, food, water and minerals. The delivery of healthcare contributes substantially to total CO_2 emissions,[3,4] adding to the serious health effects of climate change.[5] Further, healthcare systems are at risk of the effects of climate change on building infrastructure, human health, supply chains and resource security.[6]

We reviewed the evidence base concerning environmental sustainability in hospital settings and identified future research needs. Hospital-based activities account for the greatest share of financial, energy and resource consumption in healthcare.[3] We analysed the evidence base regarding the environmental effects of hospital activities, including: hospital buildings; energy and other resource use; transport; procurement; waste management and staff behaviour. The primary aim of this review was to examine environmental rather than financial sustainability, although the two subjects often are inter-related. A broader review of research needs for an environmentally sustainability approach to health has been undertaken by one of the authors.[7,8]

Many areas of research can contribute indirectly towards improving sustainability, but such fields are beyond the scope of this review. For example, demand for health services can be reduced through measures that confer health and environmental co-benefits (smoking cessation).[9] This review is primarily of hospitals in high income countries, but there is a large potential for research about hospital sustainability in other income settings, where the effects of climate change will be particularly great.

The focus of healthcare sustainability research is often on direct energy consumption (i.e. reducing CO_2 emissions). The National Health Service (NHS) in England accounts for 3% of the nation's CO_2 emissions,[3] while healthcare in the USA (with higher health expenditure per unit of GDP) is responsible for 8% of total CO_2 emissions.[4] In England, 19% of NHS CO_2 emissions in 2010 were related to direct energy use in healthcare facilities, with 16% related to staff and patient travel, and 65% resulting from the production of procured goods (e.g. pharmaceuticals, food and medical equipment).[3] In Australia, a national analysis of healthcare's 'carbon footprint' has not been performed, but the CO_2 emissions from metropolitan hospitals in Melbourne had similar results to those from England.[10]

Methods

The review was designed to identify all articles that added new findings to the evidence base on environmental sustainability within hospitals. The bibliographic databases PubMed and Engineering Village were searched for articles published in English between 1 January 1990 and 1 October 2013. The Cochrane library, the King's Fund library database and the websites of the Sustainable Development Unit (SDU) and the Sustainability for Health and Evidence Base for Action (SHEBA) were also examined.

A search of PubMed for 'sustainability' alone revealed more than 8500 references. Assessing the title and/or abstract of the first 200 of these, the majority were found not to pertain to environmental sustainability. To improve the specificity of the search we developed a search algorithm based on: (1) the main themes related to environmental sustainability found in the first 200 references and (2) an existing conceptual framework developed by the SDU.[3]

We used this algorithm to search specifically for evidence relating to the following themes:

- Hospital design;
- Energy;
- Water;
- Travel;
- Procured goods;
- Waste;
- Staff behaviour

The search algorithm required that articles include the term 'sustainability' AND at least ONE of the following: 'hospital, green, environment, architecture, energy, water, travel, life cycle assessment, waste, recycling, reusing, reprocessing, psychology and behaviour'. Further studies were found by review of other publications' references, in particular recent related reviews[7,8] and books.[1,2,11] To avoid missing important studies in this review we rechecked the first 200 (of >8500) references found using 'sustainability' alone as a search term. Our more focussed search algorithm included the same studies as those found in the broader search.

The inclusion criteria were that studies had to be relevant to environmental sustainability within hospitals (as defined by the previous search algorithm) and either introduce new data or provide the latest review of a topic. Novel approaches/trends to the study of sustainability within hospitals (such as life cycle assessment (LCA), reprocessing and behaviour change) were included.

We excluded comment/advocacy pieces unless they introduced new themes or topics. Studies that were older or very specific and covered by more general or

newer reviews were also excluded. A formal quality appraisal tool was not used as our objective was to assess the breadth of the evidence base, including all methodologies and study designs. Web searching and review of reference lists did not identify significant numbers of additional articles, indicating that the database search had been sufficiently comprehensive.

The articles were analysed using the same thematic framework that formed the basis of the search algorithm (see above). For each article, we summarized (1) research findings which provided an assessment of the scale of the environmental impacts of hospital care and (2) findings which provided an evaluation of the effectiveness of interventions to mitigate these impacts. The results section is structured along the same lines.

Results

We found a total of 1209 references using the search algorithm in the 'Methods' section. Of these 1209 references, we excluded 1016 (title and abstract not relevant), leaving 193 studies that were retrieved for evaluation. Of the 193 articles reviewed in full, we excluded a further 117 because they did not introduce new data, were advocacy pieces rather than empirical research or repeated other studies/reviews. The remaining 76 references were used as the basis of our analysis (see Supplementary Material available online). In this article, we excluded articles limited in their scope that were covered by more general reviews, or for which there were references on similar topics, leaving those citations that we considered to be the most significant and helpful for the reader. Table 1 provides a summary of the number of articles included on each research theme.

The first 10 references have appeared in the 'Introduction' section and elsewhere; these are general in their content, and each covers several of the themes that were identified in Table 1, including several books that themselves have many references. There is a large evidence base regarding sustainable architecture and technologies used to reduce energy and water use; we did not provide a detailed re-examination of these endeavours unless they were specific to hospitals, e.g. operating room (OR) ventilators and reuse of dialysis water.

Table 1. Final 49 references.

Theme	No. articles
General/several themes	10
Hospital design	10
Energy	6
Water	3
Travel	4
Procurement	8
Waste	4
Staff behaviour	4

Hospital design

Sustainable architecture has an extensive research base, including textbooks with hundreds of references and standards focussed specifically on healthcare.[11] For example, the Green Guide for Health Care details methods to improve hospital design, construction, operation and maintenance and provides a toolkit for self-assessment towards best environmental practice.[12]

The initial capital costs of a hospital building represent less than 10% of full lifetime costs.[1] This indicates the importance of incorporating energy efficiency at the planning and design stage for securing longer-term efficiencies.[13] Energy usage per unit area (m^2) for hospitals is the second highest for all building types,[14] but varies considerably between hospitals depending on design.[15] Most modern hospitals are built on a deep-plan design (with a large distance from the centre to the periphery), requiring high electricity consumption for ventilation of the building's core.[15]

There have been some encouraging research findings regarding the benefits of sustainable buildings to staff and patients, but more will be needed.[16,17] Absenteeism appears to be less in sustainable work environments, though this has been rarely studied in healthcare environments.[17] There are potential areas of conflict between greater upfront costs and reduced recurrent costs. Single patient rooms may be associated with reduced infection rates, but have greater initial costs and energy requirements compared with multiuse patient rooms.[11,17] Two reviews[18,19] suggested that the benefits of single patient rooms are not yet proven and that further research is needed to investigate the balance of costs and benefits.

Energy

Direct energy use by healthcare accounts for approximately 20% of all public sector energy consumption in Victoria, Australia[20] and is likely to be similar in other developed countries. Heating, ventilation and air conditioning typically account for at least half of direct hospital energy usage, with lighting and equipment accounting for most of the remainder.[21] How much energy use arises from individual hospital areas such as the operating suite is not well established. Further, there is incomplete information on the energy consumption of many common machines as they are actually used within hospitals (e.g. washers, sterilizers).[22]

A large body of architectural and engineering research focuses on reducing direct energy consumption in buildings of all types. There are several instances in which the large and continuous energy requirements of hospitals have stimulated research into specific technologies and energy sources, such as gas-fired co-generation, solar thermal cooling and ground-sourced heat pumps.[21] Co-generation (combined heat and power) is ideal for hospitals which require continuous electricity and heat, provides added energy security and can have reasonable payback times.[14]

There has been a limited amount of hospital-specific research examining energy usage for heating, ventilation and air conditioning. Tensions can exist between protecting the patient and the environment, often due to infection control concerns.[23] A 1°C rise in room temperature in summer or reduction in winter can reduce annual cooling/heating costs by 5%.[2] Methods to reduce hospital energy consumption by widening the permitted temperature range, particularly during extreme weather events, without compromising safety or alienating patients or staff are largely unexplored.

Ventilation within most buildings is routinely mixed ventilation (supply air mixes with room air) or, less commonly, displacement ventilation (supply air spreads from the floor and rises as it warms).[24] Displacement ventilation can produce equivalent air quality with lower energy consumption, but quantification of savings is unclear within hospitals.[24] Hospital ventilation is routinely left running continuously, including within ORs that are unoccupied overnight. There is, however, evidence of no difference in the microbiological load of air samples from ORs where the ventilators are turned off in idle ORs overnight compared with ORs with continuous ventilator usage.[25]

Water

Hospitals use considerable amounts of water – e.g. 1% of a city's total water consumption.[26] Within a hospital the majority of water use occurs in four areas: wash basins, sinks and showers (20–40% of total), toilets (15–30%), laboratories, cooling towers, macerators and sterilizers (15–40%) and food preparation (5–25%).[26]

Water savings of 10–25% can be achieved through simple means which do not require further innovations or research: auditing usage including installing data-logging metres and sub-metering, checking for leaks, applying flow restrictors on hand basins and showers, installing dual-flush toilets and reclaiming water from dialysis units and sterilizers.[26] Areas of ongoing research have focussed upon the operating suite and the dialysis unit. Significant water savings are possible (hundreds of litres/tap/day) from altering the surgical hand scrub whether through water-saving devices such as automatic tap timers or replacing water use with other disinfectants.[27] Water savings of several thousand litres/day are also possible from dialysis units.[28]

Travel

Hospital travel incorporates ambulance, private and public transport. Car travel in particular is a major contributor to CO_2 emissions as well as being an inactive, unhealthy form of transport. The SDU estimate that 16% of carbon emissions related to healthcare are attributable to staff/patient travel.

The research agenda for improving the sustainability of hospital travel can be subdivided into: technical, financial and social:

- Technical changes include any incremental improvements to vehicle technologies and service transformation to reduce travel.
- Financial interventions include incentives to increase active and public transport or increasing car parking fees to reduce car travel.
- Social and cultural factors shape the forms of transport used by hospital patients and staff.

Technical changes may lead a transformation of hospital travel. Improved teleconferencing/telemedicine can reduce travel demand for business, patient and staff leading to financial, environmental and time savings.[29] Other clinical innovations, however, may increase patient travel. Replacing thrombolysis in local hospitals with interventional cardiological procedures in more distant, larger hospitals will increase ambulance CO_2 emissions,[30] highlighting conflicts that can arise between protecting the patient and the environment.[23]

Whether altered financial or tax incentives can change travel pathways to hospitals is an important topic for future research. Perverse incentives may mean that the pecuniary interests of hospitals are at odds with sustainability; e.g. rent from car parking versus lower fees for pooled cars, or tax reimbursements for inter-hospital travel.[31]

Social factors are also likely to be important in altering hospital transport. Large reductions in car transport to hospitals are possible with improved public transport services, car-pooling and encouraging cycling. For example, at Addenbrooke's hospital, Cambridge, UK, by doubling the number of bus services and greatly improving hospital bicycle facilities the proportion of journeys made by car was reduced from 60% in 1999 to 38% in 2006.[32] Social norms and peer influence within the hospital workforce may shape staff decisions regarding how to travel to work.

Research regarding the most important determinants of travel behaviours is limited.

Procurement

Several studies have found that procured goods represent by far the largest contributor to healthcare's carbon footprint.[3] Research on haemodialysis, for example, has shown that dialysis consumables are responsible for similar CO_2 emissions to total dialysis transport and dialyser energy use combined.[33] Over the past 30 years many reusable products have been replaced by disposable ones across most specialties, such that 'hospitals are now awash in throwaway supplies.'[34] The research base examining the environmental effects of hospital procurement is far less developed than for hospital architecture and engineering.

Efforts to understand the entire 'cradle to grave' environmental and financial costs of items or processes are based upon the method of LCA. Such costs include: the energy, water, petrochemical costs and pollution produced in obtaining raw materials, manufacturing, transportation, use, reuse, maintenance, recycling and waste disposal. Despite being common in other fields, LCAs are relatively novel to healthcare.[22] Most medical LCAs have occurred in the fields of anaesthesia, surgery and dialysis units.

Operating theatre LCAs have primarily been comparisons between reusable and single use variants of medical devices: surgical drapes, suction canisters, gowns, laparoscopic ports, drug trays, laryngeal masks, central venous catheter (CVC) insertion kits and sharps containers have been examined.[22] Reusable versions were found to be less expensive and had lower environmental effects (CO_2 emissions, water use, land and water pollution) than the single use variants for all but the CVC insertion kits. LCAs have been performed of cataract surgery and caesareans/vaginal deliveries. Such LCAs of whole procedures complement studies of individual devices.

There is a natural tension between the potential environmental and financial benefits of reusable medical devices and their possible infection control concerns.[23] The move to single use items has not been well studied and appears to be driven by other factors beyond infection control practices, such as cost, ease of use, difficulty making some reusable items patient ready again, individual (doctor) preferences and marketing.[22,34]

Openly available LCAs of pharmaceuticals will become increasingly important due to their high costs and large carbon footprint.[35] Pharmaceutical companies have rarely engaged with LCA researchers and published in peer-reviewed journals, perhaps due to concerns regarding commercial confidentiality.[22] In December 2012 however, a UK guideline on 'Carbon footprinting pharmaceuticals and medical devices' was promulgated by a collaboration of pharmaceutical representatives, health services employees, clinicians and LCA experts.[36] Chemists and chemical engineers have established a scientific foundation to 'green chemistry' which could be emulated in medicine.[37] There has been some engagement of manufacturers of healthcare products and organisations such as Healthcare Without Harm (HCWH) to reduce the effects of packaging and waste.[38] There is also renewed interest in return of unused medicines, one study finding that one-fourth of all returned medicines were suitable for reuse.[39]

Interest in the environmental effects of treating dialysis patients has been stimulated by funding from the UK Green Nephrology Scholarship.[40] The frequency of dialysis has a greater effect upon CO_2 emissions than dialysis duration.[33] With the rise of home dialysis delivered more frequently, innovative approaches will be required to prevent the predicted doubling of CO_2 emissions per dialysis patient, including methods to reduce consumables and waste disposal.[33] Embedding sustainability into overall hospital procurement is still in its infancy and faces financial (real or perceived) and attitudinal barriers.[41]

Waste

Hospitals in the USA alone generate an average of 5500 tons of waste each and every day.[42] There is thus much opportunity to reduce hospital waste leading to financial and environmental improvements. The environmental and financial benefits of improving waste management processes are generally greater when moving progressively through the 'waste hierarchy' from discarding, through recycling, reuse, reduction and finally to avoidance of creating waste materials in the first place.[43] Avoidance of unnecessary or unproven hospital procedures is likely to have a greater effect than all current hospital recycling initiatives. Hospital recycling does, however, have an established research base. Examination of waste disposal shows financial and environmental benefits stemming from treating infectious waste by microwaving rather than autoclaving, lime or incineration.[44] Approximately 30% of all hospital waste is paper/cardboard and a similar proportion is plastic, indicating high recycling potentials.[45]

Infection control concerns regarding hospital waste recycling can be managed provided there is appropriate education.[46] Approximately 20% of all hospital waste stems from the OR.[45] The associations of anaesthetists and surgeons in the UK and Ireland have separately issued policy documents to promote consideration of,

and research about, the sustainability of anaesthesia and cost-effective and sustainable surgery.

Behaviour

The psychological and social factors that shape hospital staff and patient behaviours is an important research topic.[47] While an interest in the environment in their personal lives has been found to increase the likelihood that individuals would recycle at the hospital, often environmentally sustainable personal behaviours are not carried into the workplace.[46]

Topf examined staff indifference to unsustainable hospital practices such as excessive lighting, consumption and waste.[48] This research suggested that hospital environments encourage environmental 'numbness', and elicit a range of coping mechanisms including denial that unsustainable behaviour is occurring; overly critical thinking that may prevent change; myths that green practices and buildings are prohibitively expensive; temporal justification (i.e. staff being too busy dealing with short term goals to become involved in enduring concerns); and the so-called 'moral offset' – 'I'm doing enough good just being a doctor/nurse'.[48]

Group coping mechanisms include diffusion of responsibility (someone else will solve the problem) and 'groupthink' (the illusion of unanimity due to the leader's influence).[48] By supporting employees to make ethical decisions that align with their own values, they are more likely to take action to address these concerns.[49] There has been minimal research within healthcare about which of these psychological factors are the most important to address in order to encourage sustainable practices and minimal understanding of patients' views of healthcare sustainability.

Discussion

Limitations

This systematic review of hospital environmental sustainability was focused on particular themes, thus potentially overlooking other relevant literature. Studies that were very specific and covered more broadly elsewhere were also excluded. Nevertheless, the themes were based on existing frameworks as well as our initial examination of the literature, and we believe they capture the most important ways in which hospital activities affect the natural environment. Our search was limited to two major databases (plus additional sources) and articles written in English. Further, hospital architecture and engineering had been reviewed previously,[11] as has LCA in medicine,[22] thus we did not include all of the associated references contained within these works.

Sustainable hospitals: building the evidence base

We found many relevant research findings from a variety of academic disciplines, yet there remain substantial knowledge gaps. Engineering and architectural research concerning hospital buildings and the technologies used within them is at a relatively mature stage, but less is known about the clinical, psychological and social factors which influence how healthcare professionals use these buildings and technologies. Further research is also needed to understand how the environmental effects of procured goods can be reduced, and how potential trade-offs between sustainability and service quality/cost can be minimized.

The need for research extends well beyond hospital settings to include public health research aiming to understand how best to reduce demand for hospital care and its associated environmental effects. Further research is needed in the following areas:

- Measurement of the 'footprints' of hospitals-buildings, energy and water, transport and the life cycles of procured items and processes/patient care.
- Innovations (technological, clinical, organizational, etc.) that will improve the sustainability of healthcare.
- Social and psychological research to understand the behaviours, attitudes and cultures that will be needed within hospitals and our wider society to improve sustainability.
- Policy research to clarify how the overall design of health systems influences the uptake of sustainable behaviours and innovations.
- Assessing the anticipated effects of environmental and climate change on health and hospitals.

The impetus to conduct research across these areas will come both from 'push' factors such as compliance with environmental legislation, and 'pull' factors centred on the potential patient benefits of sustainable healthcare. The UK's 2008 Climate Change Act mandates the entire UK to reduce CO_2 emissions by 34% by 2020, and by 80% by 2050. Even in countries without similarly ambitious policies, other legislative requirements may provide further impetus for research.

Most research on hospital sustainability (e.g. architecture) has been performed by specialists in isolation, with minimal clinician participation. Due to the broad nature of hospital sustainability, collaboration will be needed to improve research outcomes. This collaboration includes: clinicians, engineers, architects, chemists/pharmacists, life cycle assessors and social scientists. Joint work between different specialties is now occurring, e.g. LCAs of medical devices. Collaboration between engineers and clinicians to achieve energy and water efficiencies while also improving or at least not

adversely affecting patient outcomes would be valuable. Clarifying barriers to change, particularly behavioural, will be the domain of social scientists working with clinicians. A significant barrier to research is the difficulty building collaborative funding arrangements.

The global nature of the 'sustainability challenge' indicates that collaboration will also be needed across national frontiers, with international bodies such as the World Health Organisation and health and environmental NGOs playing an important coordinating role. Developing the evidence to support a sustainable approach to healthcare represents a challenge to the international health research community, but one that it cannot afford to ignore.

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Supplementary Material

The online appendix is available at http://hsr.sagepub.com/supplemental-data.

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