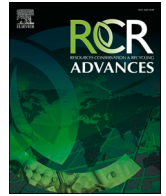


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## Barriers and facilitators to recycling waste in hospitals: A mixed methods systematic review

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### ABSTRACT

Hospitals generate large amounts of waste, part of which is recyclable. However, research shows that recycling opportunities in hospitals often get missed with human behaviour playing an important role. Following current behavioural science, better understanding the influences on hospital recycling behaviour can support the design of promising behaviour change interventions, which draw on identified facilitators and help overcome identified barriers, to maximise recycling potential. Therefore, this systematic review aimed to investigate the barriers and facilitators to hospital waste recycling.

Three databases were searched to identify studies in high-income countries, pertaining to barriers and facilitators to hospital waste recycling. Their findings were thematically analysed and narratively synthesised drawing on a combination of the Capability, Opportunity, Motivation – Behaviour (COM-B) model with a multi-level framework.

Twenty-four studies met pre-defined inclusion criteria. Reported influences on hospital waste recycling pertained to factors beyond the hospital environment (e.g. product design preventing recycling), the internal hospital environment (e.g. lack of access to recycling bins) and individuals working within hospitals (e.g. concerns about infection control). Most influences were located in the internal hospital environment. Many related to the physical opportunity of recycling behaviour, with the most dominant barriers being difficulties accessing appropriate recycling bins and lack of information or education on recycling.

This overview of barriers and facilitators to hospital waste recycling will aid researchers and practitioners in designing hospital waste recycling interventions addressing key identified influences. Combining the COM-B model with a multi-level framework allowed for identified influences to be organised in a nuanced manner.

### 1. Introduction

Healthcare creates considerable amounts of waste in its daily operations, particularly in high-income countries (Singh et al., 2022). The UK National Health Service in England produced 1230,100 tonnes of waste in the year 2020/2021 (NHS Digital, 2021). The sustainable healthcare organisation Practice Greenhealth (n.d.) estimated the annual hospital waste production in the US to exceed five million tons, with an annual median waste generation of 1002 tons per hospital (Practice Greenhealth, 2020). Healthcare footprint calculations by Malik et al. (2021) attribute 1,624,000 tonnes of waste in the year 2017 to the healthcare system of the Australian state New South Wales and its supply chain. This equates to 8 % of the state's total waste. Just under half of this waste (47 %) was attributable to hospitals (as opposed to

other healthcare locations) (Malik et al., 2021).

According to the World Health Organization (WHO), healthcare waste can be distinguished as hazardous or non-hazardous (Chartier et al., 2014). Hazardous waste includes, for example, infectious materials, sharps, pharmaceutical or cytotoxic waste and requires special treatment as part of its disposal process to reduce its risks to humans and the environment. Treatment options include incineration, autoclaving, chemical or microwave treatment (Chartier et al., 2014; EPA Victoria, 2009; Hossain et al., 2011). Depending on applicable local regulations, non-hazardous waste can be disposed of in the general waste or recycling waste stream without special treatment (Victorian Health and Human Services Building Authority, 2020). Recycling of healthcare waste has the potential to prolong the used materials' life cycles (van Straten et al., 2021) and can lead to financial savings (Riedel, 2011).

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Recyclable healthcare materials can be similar to household recycling materials, such as paper, plastic drink bottles or aluminium cans (Chartier et al., 2014), but there also exist healthcare-specific products with recycling potential. One study has, for example, shown that sterilisation wrap made from polypropylene (a type of plastic) can be recycled into new medical products (van Straten et al., 2021), while another study found that face masks have the potential to be recycled into material to build roads (Saberian et al., 2021). Polyvinyl chloride (PVC), another type of plastic found in oxygen tubes and masks and intravenous fluid bags, can be recycled into irrigation equipment (McGain, 2010; Vinyl Council Australia, n.d.).

In an ideal waste management scenario, waste is avoided or reduced, where possible, or materials are reused, where appropriate (Chartier et al., 2014). However, infection control and legal requirements sometimes rule out these waste management approaches, leaving recycling as the most environmentally friendly option to address some healthcare waste (Hutchins and White, 2009).

Despite the important role of recycling, research shows that recycling opportunities in hospitals often get missed. A waste audit of an Australian operating suite, for example, found that around 41 % of waste was potentially recyclable, but only just over half (55 %) of these recyclable materials were placed in recycling bins (McGain et al., 2015). An audit of the same hospital's intensive care unit waste showed that 29 % of materials were potentially recyclable, while again only around half of them (49 %) were collected in recycling bins (Kubicki et al., 2015). Similarly, a waste audit of an emergency department in the US found that the recycling stream was underused for potentially recyclable items (Hsu et al., 2020). The findings of these studies suggest that human behaviour plays an important role in hospital waste recycling. Thus, models from behavioural science, which can guide the design of behaviour change interventions (Michie et al., 2014), have been drawn upon for suggestions how to improve hospital waste recycling (Barbariol and Baid, 2023).

According to Hagger et al. (2020), one well-established approach to designing behaviour change interventions is the Behaviour Change Wheel (Michie et al., 2011). The guidance around this approach stipulates that behaviour change interventions can be designed in three phases (Michie et al., 2014, p. 25): An initial phase to 1) "Understand the behaviour" lays the groundwork for the two subsequent phases to 2) "Identify intervention options" and 3) "Identify content and implementation options". One key step in the initial phase of understanding any behaviour in question is an investigation into barriers and facilitators to behavioural performance. Insights from such an investigation into behavioural influences are then used in the second phase of the Behaviour Change Wheel to guide the design of a targeted intervention drawing on the identified facilitators and help overcome identified barriers, thereby increasing the likelihood of intervention success (Michie et al., 2014). Therefore, following the logic of the Behaviour Change Wheel (Michie et al., 2014), better understanding barriers and facilitators to hospital waste recycling can enhance our understanding why recycling behaviour falls short of its potential, and support the design of targeted interventions to improve the situation.

There exist a number of primary studies on influences on hospital waste recycling (e.g. Azouz et al., 2019; McGain et al., 2012; Petre et al., 2019). A scoping review investigated barriers and facilitators to sustainability behaviours but had a wider focus on healthcare (not hospitals) and environmental sustainability (rather than recycling) (Aboueid et al., 2023). Other review-level studies in the field of healthcare sustainability also focus more widely on *environmental sustainability* in hospitals (e.g. McGain and Naylor, 2014) or *hospital waste management* (e.g. Lattanzio et al., 2022), rather than specifically on hospital waste recycling. Furthermore, some reviews only focus on sustainability-related research questions in specific hospital locations such as the operating theatre, as opposed to the whole hospital setting (e.g. Davies et al., 2023; Lam et al., 2023; Perry et al., 2023; Pradere et al., 2023). Given the potential of behavioural approaches in this area,

as well as the importance of understanding behavioural influences in order to design targeted behaviour change interventions as part of these approaches (Michie et al., 2014), lack of attention to review-level exploration of *barriers and facilitators* to hospital waste recycling is a gap in existing literature.

Therefore, this systematic review aimed to answer the research question "What are the barriers and facilitators to hospital waste recycling?".

## 2. Methods

Prior to commencing this review, the protocol was registered with the Open Science Framework (<https://doi.org/10.17605/OSF.IO/6C5GN>).

### 2.1. Search strategy

To identify eligible studies, in September 2021, three data bases (Web of Science Core Collection, Scopus and Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations, Daily and Versions(R)) were searched for studies published from 1999 onwards. The search strategy was developed in collaboration with a librarian and two literature review specialists. The Web of Science and Scopus databases were selected for their size and multidisciplinary coverage, while the MEDLINE database was added for its healthcare focus. The year 1999 was chosen as a cut-off date as it represents the publication year of the first edition of the WHO's influential guide on healthcare waste management titled "Safe management of wastes from health-care activities" (Chartier et al., 2014; Prüss et al., 1999).

The search strategy included synonyms and terms related to "hospitals", "recycling" and "barriers" or "facilitators". In MEDLINE, applicable medical subject headings (MeSH) were used (see Appendix A for the full search strategy). While literature reviews were excluded from the review, reference lists of relevant self-identified systematic reviews were screened for additional primary studies.

### 2.2. Study selection and eligibility criteria

Search results were imported and de-duplicated in the software platform Covidence (Veritas Health Innovation, 2021). Study titles and abstracts were independently screened against pre-defined eligibility criteria (Table 1) by the first author (LJ) and two other members of the review team who shared the task of second reviewer (DG and FT). Disagreement between reviewers was resolved through discussion. If no consensus could be reached a third reviewer (PB) was consulted. Following this initial screening, full texts of studies selected for inclusion during the title and abstract screening were screened by the first author (LJ) with the three other team members sharing the role of second reviewer (DG, FT, PB).

The pre-defined eligibility criteria (Table 1) outlined participants, phenomena of interest and the context to be considered for inclusion (Stern et al., 2020). Study participants of interest were hospital staff and stakeholders, excluding visitors and patients. The phenomenon of interest were barriers and facilitators to hospital waste recycling, excluding studies with a sole focus on waste composition or intervention effectiveness. The study context was high-income countries as defined by the World Bank (The World Bank, n.d.). The limitation to high-income countries was deemed necessary because this systematic literature review forms part of an applied research project set in a high-income country and there exist contextual differences between high- and low- or middle-income countries with regards to healthcare waste management. High-income countries, compared with low- or middle-income countries, tend to have higher quality regulations and procedures in place, staff are better trained and more knowledgeable about the issue and waste separation occurs to a higher degree, while

**Table 1**  
Inclusion and exclusion criteria.

	Inclusion criteria	Exclusion criteria
<b>Population/ Participants</b>	Staff who work anywhere in a hospital setting Other stakeholders of hospital waste recycling (e.g. policy makers, NGOs)	Patients Visitors
<b>Phenomena of Interest</b>	Facilitators and barriers to hospital waste recycling (investigation of facilitators and barriers described either as the main focus of the study or as one of multiple foci of the study and addressed in a distinct piece of work) <b>Operationalisation of “hospital”</b> Hospitals (including studies which focus on a single ward within a hospital) <b>Operationalisation of “hospital waste”</b> Waste originating in clinical hospital wards (described as primary focus of the study) <b>Operationalisation of “recycling”</b> Recycling of hospital waste mentioned in study (either as main focus of the study or as part of a broader focus on hospital waste management or sustainability activities) Recycling described as benefitting the environment/ sustainability	Composition of hospital waste (e.g. waste audits) Effectiveness of recycling interventions Sole focus on waste not originating in clinical wards (e.g. waste occurring in administration or cafeteria) Food waste Wastewater Study only addressing reduction or reuse of materials Study about hospital waste management or sustainability without directly mentioning recycling Study about recycling in general without a main focus on hospitals Recycling described as benefitting other outcomes than pro-environmental/ sustainability ones
<b>Context</b>	High-income countries	Low- and middle-income countries
<b>Study types</b>	Peer reviewed primary research articles Qualitative, quantitative, mixed methods studies	Literature reviews (but their reference lists were screened for relevant primary studies) Theoretical papers Book chapters Editorials Commentaries PhD Theses Conference papers/ proceedings
<b>Language of publication</b>	Publications in English	Publications in languages other than English
<b>Date of publication</b>	From 01/01/1999	Prior to 01/01/1999

resource constraints limit low- and middle-income countries' choices in waste treatment technologies (Caniato et al., 2015). For inclusion, studies furthermore needed to be qualitative, quantitative or mixed methods peer reviewed primary research articles and be published in English since 1999. The choice to include qualitative, quantitative and mixed methods studies was based on the argument that reviews into barriers provide a more complete picture if they include quantitative and qualitative studies (Dixon-Woods et al., 2005).

An additional decision rule was added during the screening process to clarify eligibility of a number of studies which reported on broad healthcare settings, that is, beyond hospitals. These studies were included if they included hospital settings (i.e. hospital being one of the case study sites, hospital staff being among study participants, or studies referring to “hospital waste”).

### 2.3. Data extraction and quality appraisal

The following data was extracted by the first author (LJ): study reference information, study aim, country and setting, waste management focus, study design, data collection methods, participant details, and identified barriers and facilitators. Data extraction focused only on content pertaining to the aim of the review – barriers and facilitators to hospital waste recycling. For this reason, authors' descriptions of overall study design sometimes varied from the design of the section on influences on hospital waste recycling of a study.

References to recycling varied in context across included studies. Specifically, some studies explored barriers and facilitators in the wider context of waste management or sustainability. To account for this variability, during data extraction barriers and facilitators were categorised “recycling”, “waste management” or “sustainability” according to their context. To stay true to the scope of the review aim, only recycling-specific data on barriers and facilitators was subsequently included in data synthesis.

The quality of included studies was assessed by the first author (LJ) using the Mixed Methods Appraisal Tool (MMAT), version 2018, which was developed to assess the methodological quality of empirical studies included in mixed methods systematic reviews (Hong et al., 2018). Quality appraisal of included studies is based on defined sets of criteria for different types of quantitative as well as qualitative and mixed methods studies (Hong et al., 2018) (see Appendix B). A second member of the review team (DG) performed an independent quality appraisal for 10 % of included studies. Discrepancies were resolved through discussion and final decision rules were reflected in the appraisal of all studies.<sup>1</sup>

As with data extraction, for studies with multiple aims or research questions and discrete data collection methods for each component, only the methods relevant to the research question of this systematic review were assessed for quality.

### 2.4. Synthesis

As a theoretical underpinning for data synthesis, this systematic review drew on a combination of the Capability, Opportunity, Motivation – Behaviour (COM-B) model (Michie et al., 2014, 2011) and a multi-level framework (Boulet et al., 2021; Macklin et al., 2023). Both, as well as the rationale for combining them, are outlined below followed by the applied synthesis approach.

#### 2.4.1. The COM-B model

Behaviour is influenced by various factors. To guide an investigation into barriers and facilitators to behavioural performance, the Behaviour Change Wheel approach (Michie et al., 2014), which is referred to in the introduction section of this paper, draws on the COM-B model (Michie et al., 2014, 2011). The COM-B model stipulates that human behaviour is influenced by our capability (C), our opportunity (O) and our motivation (M) to perform the behaviour (B) (Michie et al., 2014, 2011). Capability and motivation describe our internal dispositions to perform the behaviour. For capability this means whether we possess the necessary intrapersonal ability (i.e. capability) to perform the behaviour. For motivation this means whether we feel inclined (i.e. sufficiently motivated) to perform the behaviour. Opportunity, on the contrary, relates to whether the external environment in which a behaviour is meant to be performed allows us to do so. The three determinants of behaviour can be further broken down in two sub-categories each. Capability can be divided in our physical capability (e.g. possessing necessary strength or physical skills) and our

<sup>1</sup> This is in deviation to the registered review protocol, which outlined that all studies would be independently appraised by a second review team member. This change became necessary due to reviewer availability.

psychological capability (e.g. holding necessary knowledge). Motivation includes reflective motivation (e.g. conscious evaluations and beliefs as to whether performing a behaviour is desirable) and automatic motivation (e.g. habits or emotions). Opportunity includes the physical opportunity (e.g. financial, time or other environmental resources enabling behaviour performance) and the social opportunity (i.e. a social environment facilitating the behaviour like having supportive peers or social norms) (Michie et al., 2014, 2011).

The COM-B model is a prominent and well-established model to investigate barriers and facilitators to behavioural performance. It has been used extensively in applied behavioural science across multiple topic areas in systematic reviews (e.g. Graça et al., 2019; Redvers et al., 2023) and primary studies (e.g. Manika et al., 2022; Roy et al., 2022). However, it has been noted that the category “opportunity” does not allow for a nuanced differentiation of environmental influences (Caperon et al., 2019).

#### 2.4.2. Multi-level frameworks

Multi-level frameworks, also known as ecological models (Boulet et al., 2021; Richard et al., 2011), structure influences on behaviour based on intrapersonal factors and various layers of environmental factors (Sallis and Owen, 2015). While different models or frameworks use different terminology and distinctions for different levels (Sallis and Owen, 2015), their commonality lies in including refined categories of environmental influences of increasing broadness (Richard et al., 2011). Two recent applications of multi-level frameworks for systematic reviews in the waste management space distinguish between the categories of micro-, meso- and macro-level (Boulet et al., 2021; Macklin et al., 2023). Both of these studies investigate influences on household waste management behaviour, specifically on household recycling (Macklin et al., 2023) and on household food waste (Boulet et al., 2021). They consider the micro-level to reflect individual-level factors, such as attitudes or knowledge. Macklin et al. (2023) additionally define the micro-level to include certain characteristics of the waste item itself. Both studies describe the meso-level to reflect the household environment in which waste management behaviours are performed, while Macklin et al. (2023) also explicitly include the subcategory “physical setting” of recycling behaviours in this level. Finally, both studies group influences beyond the household under the macro-level, which they divide into various subcategories (Boulet et al., 2021; Macklin et al., 2023). In adaptation of the approaches in both of these waste-related multi-level framework studies, the following levels of a multi-level framework are defined for data synthesis in this systematic review:

- Micro-level: Influences on hospital recycling behaviour directly linked to individual hospital staff
- Meso-level: Influences on recycling behaviour which are rooted in the internal physical or social hospital environment
- Macro-level: Influences on recycling behaviour which are based on the context or environment external to the hospital.

#### 2.4.3. Combining the COM-B model with a multi-level framework

Combining the COM-B model with a multi-level framework for coding purposes, allows the most fit-for-purpose distinction between influences on hospital waste recycling for this systematic review. This combination has been recognised as beneficial by other literature reviews (e.g. Nguyen et al., 2022; van Kasteren et al., 2020; Yin et al., 2022) and primary studies (e.g. Caperon et al., 2019; Hunter et al., 2020). The application of a multi-level framework adds nuance to the COM-B category “opportunity” by dividing it into different levels of environmental influences (Caperon et al., 2019; Yin et al., 2022), such as meso- and macro-level influences, while application of the COM-B model provides nuance to the “individual” level in multi-level frameworks by explicitly distinguishing between capability and motivation (Yin et al., 2022).

#### 2.4.4. Data synthesis approach for this systematic review

The extracted data was synthesised in four steps (Fig. 1). Initially, barrier, facilitator, and bi-directional influence<sup>2</sup> statements were inductively coded to identify influences on hospital waste recycling in the data (Braun and Clarke, 2006). In a second step, identified influences were mapped to the components of the COM-B model (Michie et al., 2014, 2011). In a third step, the combination of influences and COM-B components was inductively grouped to broader themes of influences on hospital waste recycling. In a final fourth step, these themes were mapped to the multi-level framework categories outlined above. Results are narratively synthesised in the results section of this paper.

### 3. Results

#### 3.1. Search results and included studies

The search strategy outlined above identified 12,512 papers (see Fig. 2 for the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) diagram (adapted from Page et al., 2021)). After removing duplicates, a total of 9188 papers were title and abstract-screened, leading to the subsequent screening of 187 full-text papers. This resulted in the inclusion of 28 papers for data extraction. Of these 28 papers, four papers drew on the same study (Tudor et al., 2007a, 2007b, 2007c; Tudor et al., 2008b), while another two papers reported data from a second identical study (Grose et al., 2012; Nichols et al., 2013). These six papers were combined as appropriate to represent two (instead of six) studies resulting in the final inclusion of 24 studies (Li et al., 2022), consisting of 28 papers, for data extraction and quality appraisal. Given the unit of analysis for this review being individual studies (Li et al., 2022), not papers, the cited papers in the remainder of this review can exceed the reported study numbers.

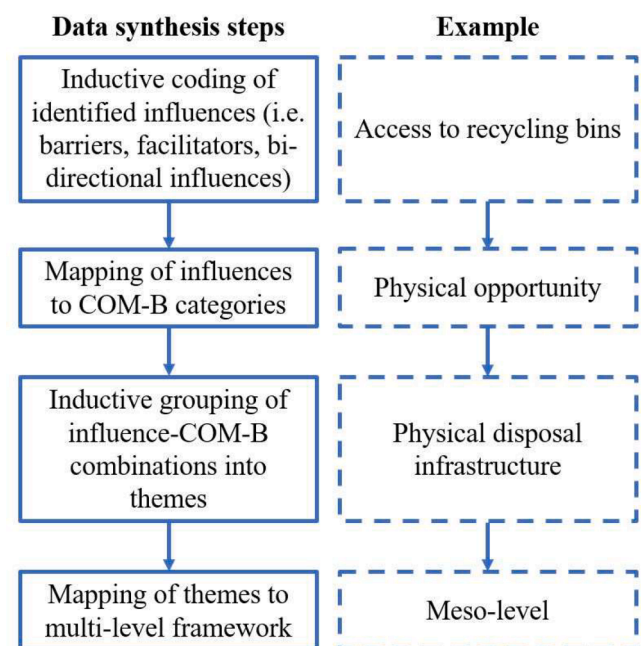


Fig. 1. Data synthesis approach.

<sup>2</sup> The category “bi-directional influences” was only used when no clear positive or negative direction could be identified for a data point (e.g. for statistical associations).



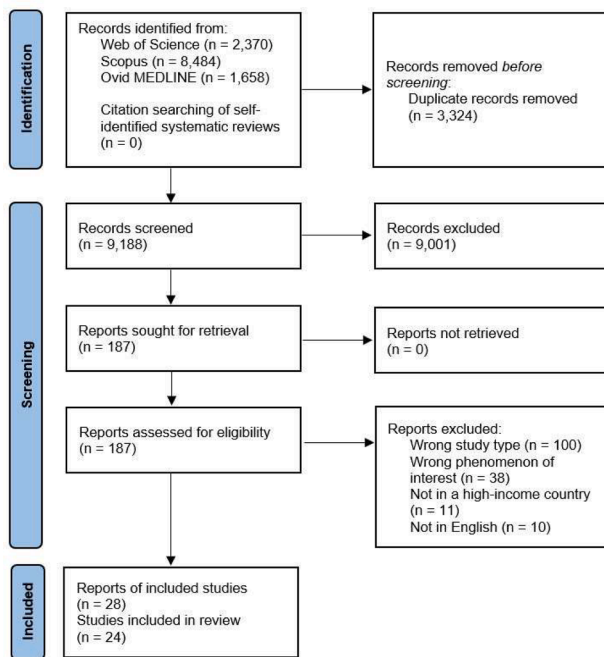


Fig. 2. PRISMA diagram.

### 3.2. Quality appraisal of included studies

The overall quality of the included studies can be described as low to medium. Only one third (8 studies) met all five assessment criteria in the respective MMAT section(s), with the remaining two thirds displaying issues in one MMAT criteria in the respective sections(s) (2 studies) or in two or more MMAT criteria in at least one of the respective sections(s) (14 studies). See Appendix B for more details. The overall quality of the included studies should be taken into account when interpreting the results of this review.

### 3.3. Details of included studies

The included studies were published between 2000 and 2022 and show an increasing trend in publications over time, with over half of the included studies published since 2016 and a quarter published since 2020. For details on characteristics of individual studies, see Appendix C.

Just over half of the included studies (13) used qualitative study designs, which always included participant interviews sometimes in combination with observations and focus groups. Eight studies used quantitative study designs, which all took the form of a survey. Two studies applied a mixed methods design, with one combining interviews with procurement data (Hu et al., 2022), while the other combined a survey, interviews, observations and a waste audit (Tudor et al., 2007c, 2008b). Finally, one study described part of its data collection as “market research”, which did not allow for an assessment of the chosen study design (Tudor et al., 2005, p. 610).

The included studies were conducted in ten countries, with three studies including data from multiple countries (McGain et al., 2012; Singleton et al., 2021; Viani et al., 2016). Half of the studies (12) were set in the UK followed by five studies conducted in the US, three studies included data from Canada and two from Australia. The remaining countries of studies were Saudi Arabia, Belgium, Germany, Greece, Italy and New Zealand.<sup>3</sup>

<sup>3</sup> The sum of countries adds up to 28 not 24 (i.e. number of included studies) because of three studies being set in multiple countries.

Most studies (15) were undertaken exclusively in a hospital setting, while seven studies were conducted in wider healthcare settings. Finally, one study each included data about a hospital-and-home or a healthcare-and-home setting respectively. However, in both instances data referring to a home setting could be clearly distinguished from data referring to a hospital or healthcare setting. Of the 16 studies in a hospital or hospital-and-home setting, the most prominent hospital setting was the operating theatre (6 studies), followed by the neonatal intensive care unit (2 studies), the hospital pharmacy department (1 study) as well as a combination of internal medicine units and the emergency room (1 study). Four studies provided no specific hospital location, while two studies focussed on specific hospital items (laryngoscopes and CO<sub>2</sub> absorbers). Study participants were a combination of hospital and healthcare staff and stakeholders. Depending on the study, the latter included representatives from government (e.g. Alharbi et al., 2021), NGOs (e.g. Nichols et al., 2013), consultancies (e.g. Bailey et al., 2004), the waste management industry (e.g. Harding et al., 2021) or device manufacturers (e.g. Burbridge et al., 2019). Four studies specifically focussed on anaesthetists (Ard et al., 2016; McGain et al., 2012; Petre et al., 2019, 2020).

The majority of studies (21) reported some recycling-specific data on barriers and facilitators. However, three studies, while meeting the inclusion criteria for this review, reported influences on general waste management so that no recycling-specific data could be extracted (Dilly and Shanklin, 2000; Nichols and Manzi, 2014; Theofanidis et al., 2008). Of the 21 studies with recycling-specific data, most (17) did not define any specific recycling stream of interest a priori. One study each specifically focussed on single-use plastics (Hu et al., 2022) and recyclable waste from pharmaceuticals (Singleton et al., 2021) respectively, while two studies set out to investigate recycling and broader waste management aspects of specific instruments, laryngoscopes and CO<sub>2</sub> absorbers (Burbridge et al., 2019; Viani et al., 2016).

### 3.4. Barriers and facilitators to hospital waste recycling identified in included studies

This systematic review identified 27 influences (i.e. barriers, facilitators and bi-directional influences) on hospital waste recycling. Barriers were reported in 20 studies, while only eight studies included facilitators and two studies included bi-directional influences.

The following section, including Table 2, describes these influences in detail according to their level in the multi-level framework and relevant theme.

#### 3.4.1. Macro-level – influences in the environment external to the hospital

**3.4.1.1. Procurement context (COM-B category “physical opportunity”).** Influences in the procurement context related to **product design** acting as a barrier to recycling (Burbridge et al., 2019; Viani et al., 2016). Using the examples of laryngoscopes and carbon dioxide absorbers, two studies described how these products contain recyclable components but their design does not allow for these products to be taken apart and segregated into recyclable and non-recyclable materials (Burbridge et al., 2019; Viani et al., 2016).

**3.4.1.2. Disposal context (COM-B category “physical opportunity”).** Influences in the disposal context included **systems outside the hospital which are dealing with recycling** (Bailey et al., 2004; Hu et al., 2022; Tudor et al., 2008a, 2005; Viani et al., 2016). This influence was most frequently reported as a barrier where the external recycling system for example lacked end-markets for recycled products (Bailey et al., 2004; Tudor et al., 2005; Viani et al., 2016) or recyclers altogether (Hu et al., 2022). Other comments referred to recycling only being viable if sufficiently large quantities of recyclables can be collected (Bailey et al., 2004; Viani et al., 2016). However, working with social enterprises

**Table 2**  
Barriers, facilitators and bi-directional influences on hospital waste recycling.

Multi-level	Theme	COM-B category	Influence on hospital waste recycling	Number of studies reporting influence	Number of studies reporting influence as barrier	Number of studies reporting influence as facilitator	Number of studies reporting influence as bi-directional	
Macro	Procurement context	Opportunity (physical)	Product design preventing recycling	2	2			
	Disposal context	Opportunity (physical)	Systems to deal with recycling outside hospital	5 <sup>1</sup>	4	2	1	
		Opportunity (physical)	Legislation/regulation outside hospital		4	3	1	
Meso	Physical disposal infrastructure	Opportunity (physical)	Cost of waste treatment if not recycled	2		2		
		Opportunity (physical)	Access to recycling bins	8	7	1		
		Opportunity (physical)	Lack of space	5	5			
		Opportunity (physical)	Lack of facilities (not specific to bins)	3	3			
	Organisational resources beyond the disposal infrastructure	Opportunity (physical)	Challenges with removal of recycling from initial sorting area	1	1			
		Opportunity (physical)	Challenges related to specific bin characteristics (e.g. tearing bin liners)	1	1			
		Opportunity (physical)	Lack of information/education on recycling	7	7			
		Opportunity (physical)	Lack of time	5	5			
		Opportunity (physical)	Lack of policy to support recycling within organisation	3	3			
		Opportunity (physical)	Lack of incentives/presence of disincentives	2	2			
		Opportunity (physical)	Financial constraints/cost	1	1			
		Opportunity (physical)	Lack of available staff to dismantle potentially recyclable items	1	1			
		Social infrastructure within the organisation	Opportunity (social)	Unsupportive staff	5	5		
			Opportunity (social)	Lack of leadership or hospital administration support	3	3		
	Opportunity (social)		Supportive champion	2		2		
	Micro	Individual reflective motivation	Opportunity (social)	Difficulties making bottom-up improvement suggestions heard at higher levels	1	1		
			Motivation (reflective)	Concerns about infection control	4	4		
Motivation (reflective)			Pro-environmental considerations	2		1	1	
Motivation (reflective)			Existing evidence base on effectiveness of recycling	2	1	1		
Individual psychological capability		Motivation (reflective)	Individuals' interest in recycling	1			1	
		Capability (psychological)	Lack of knowledge	3	3			
		Opportunity (physical)	Recycling item contaminated (with non-infectious substance)	1	1			
Individual physical opportunity		Opportunity (physical)	Recycling at home	1			1	
		Behaviour	Sorting mistakes of others	1	1			

<sup>1</sup> Number of studies reporting this influence as barrier, facilitator and bi-directional does not add up to 5 because one study contained data presenting hindering, facilitating and bi-directional aspects of this influence.

could provide solutions for recycling as well as benefits for the community (Tudor et al., 2008a).

A second influence in the disposal context referred to the mostly facilitating effect of **legislation or regulations** (Bailey et al., 2004; Nichols et al., 2013; Petre et al., 2020; Singleton et al., 2021), for example for mandatory recycling (Petre et al., 2020) or producer

responsibility (Nichols et al., 2013) or which legislate market mechanisms to increase the cost of disposal of waste (Singleton et al., 2021).

Related to the latter point, studies described as a third influence **higher disposal costs of non-recycled waste** through rising landfill or incineration costs as a facilitator to recycling (Grose et al., 2012; Singleton et al., 2021).

### 3.4.2. Meso-level – influences in the internal hospital environment

**3.4.2.1. Physical disposal infrastructure (COM-B category “physical opportunity”).** One key influence related to the physical disposal infrastructure was **access to appropriate recycling bins** (Azouz et al., 2019; Grose et al., 2012; Harding et al., 2021; Kalogirou et al., 2021; Manzi et al., 2016; Nichols et al., 2013; Petre et al., 2019; Singleton et al., 2021; Vogt and Nunes, 2014). This was mainly reported as a barrier describing appropriate bins as being absent completely or only existing in small numbers (Grose et al., 2012; Harding et al., 2021; Kalogirou et al., 2021; Manzi et al., 2016; Nichols et al., 2013; Singleton et al., 2021), alternatively, bin access could be hindered by inconvenient bin locations (Azouz et al., 2019; Singleton et al., 2021), or bins being too full (Vogt and Nunes, 2014). An additional three studies surveying anaesthetists described a **lack of recycling “facilities”** as a barrier (Ard et al., 2016; McGain et al., 2012; Petre et al., 2019), with the survey by McGain et al. (2012) even identifying it as the biggest barrier to recycling and survey results by Ard et al. (2016) placing it as the second most frequently applicable barrier. However, “facilities” was not explicitly defined as bins and was therefore considered a separate concept (McGain et al., 2012).

Related to access to bins, studies identified a **lack of space** as a barrier to recycling (Grose et al., 2012; Harding et al., 2021; Nichols et al., 2013; Nichols and Mukonoweshuro, 2017; Petre et al., 2019; Viani et al., 2016). A lack of space meant that either sufficient recycling bins could not be provided (Grose et al., 2012; Harding et al., 2021; Nichols et al., 2013; Nichols and Mukonoweshuro, 2017), or there was not enough room to store recycled waste (Grose et al., 2012; Viani et al., 2016). Being situated in aged buildings was mentioned as one contributor to the lack of space (Grose et al., 2012).

Additional challenges could concern **the recycling removal structure in hospitals**, where no processes were in place to remove recycled waste after it had been sorted in its area of generation (Kalogirou et al., 2021), or **specific bin characteristics** such as bin liners not being sufficiently sturdy leading to tearing, or bins requiring manual cleaning (Vogt and Nunes, 2014).

**3.4.2.2. Organisational resources beyond the disposal infrastructure (COM-B category “physical opportunity”).** One barrier relating to organisational resources beyond the disposal infrastructure was a **lack of information or education** on recycling (Alharbi et al., 2021; Ard et al., 2016; McGain et al., 2012; Petre et al., 2019; Singleton et al., 2021; Vatovec et al., 2013; Vogt and Nunes, 2014), including absence of appropriate guidelines or procedures (Singleton et al., 2021; Vatovec et al., 2013). In four survey-based studies, “inadequate information” (Ard et al., 2016; McGain et al., 2012; Petre et al., 2019) or a “lack of clear instructions” (Vogt and Nunes, 2014) were identified as one of the top three barriers to recycling, with it being the leading barrier for anaesthetists in Ard et al. (2016). For clarity, the provision of information or education is usually aimed at increasing an individual’s knowledge, i.e. their psychological capability (Michie et al., 2014) – a micro-level influence. However, for this review the *offering* of educational resources, most likely through the hospital, is considered a meso-level influence targeted at the opportunity to perform recycling behaviours appropriately through the provision of resources.

Another barrier in organisational resources was the absence of **organisation-wide policies** supporting recycling and other sustainability actions (Alharbi et al., 2021; Singleton et al., 2021; Tudor et al., 2007c). Moreover, a **lack of incentives or the presence of disincentives** were identified as influential, with one survey study identifying the statement “No incentive” to be a barrier to recycling for some participants (Azouz et al., 2019). Another study described how the presence of an on-site incinerator generating energy from waste “incentivised” staff to dispose of waste via the incinerator rather than recycling (Viani et al., 2016). While incentives influence individuals’ motivation (Michie

et al., 2014), for this review the *provision* of incentives is considered an environmental trigger on individuals’ motivation, which is provided by the hospital. Hence, like the provision of education and information before, incentives were considered a meso-level theme related to physical opportunity.

One survey-study of anaesthetists additionally identified “cost” as a barrier to recycling (Petre et al., 2019), which potentially could be related to **financial constraints** related to wider resourcing allocations within hospitals.

While not described in much depth, a number of studies mentioned a **lack of time** as a barrier to recycling (Ard et al., 2016; Azouz et al., 2019; Nichols and Mukonoweshuro, 2017; Petre et al., 2019; Viani et al., 2016), particularly in instances when staff were busy with a high workload (Nichols and Mukonoweshuro, 2017). A related barrier was **lack of available staff** to perform dismantling behaviours for potentially recyclable items, for example laryngoscopes (Viani et al., 2016).

**3.4.2.3. Social infrastructure within the organisation (COM-B category “social opportunity”).** Moving to the social context in which hospital waste recycling occurred, other staff were an important social influence. On the one hand **unsupportive staff** could act as a barrier to recycling (Ard et al., 2016; McGain et al., 2012; Petre et al., 2019, 2020; Vatovec et al., 2013), with three surveys of anaesthetists identifying “staff attitudes” among the top three barriers to recycling (Ard et al., 2016; McGain et al., 2012; Petre et al., 2019). Other studies described staff as apathic when it comes to recycling (Petre et al., 2020), or described instances, where a recycling program faced challenges due to certain staff contaminating recycling waste with hazardous waste items (Vatovec et al., 2013). On the other hand, individual staff could also facilitate recycling if they displayed a key interest in the issue and brought about change, hence acting as **supportive champions** (Petre et al., 2020; Singleton et al., 2021).

Furthermore, the lack of **leadership or hospital administration support** was reported as a barrier to recycling (Ard et al., 2016; McGain et al., 2012; Petre et al., 2019) with a survey of anaesthetists by Petre et al. (2019) reporting lack of hospital-wide or local level leadership support as the biggest barrier to recycling. Looking at the opposite pathway of introducing change bottom-up, staff felt unable to make their **suggestions to improve recycling heard at higher levels** within the organisation (Kalogirou et al., 2021).

### 3.4.3. Micro-level - Influences directly linked to individual hospital staff

**3.4.3.1. Individual reflective motivation (COM-B category “reflective motivation”).** One barrier related to the reflective motivation of individuals consisted in **concerns about infection control** when recycling items (Ard et al., 2016; Azouz et al., 2019; McGain et al., 2012; Petre et al., 2019). Two studies, which identified such a concern, specified further that it referred to the perceived risk of contaminating non-infectious waste with infectious materials when recycling (McGain et al., 2012; Petre et al., 2019).

Furthermore, studies identified **pro-environmental considerations** as a facilitator or at least an influential factor on recycling (Tudor et al., 2007a, 2007c; Vatovec et al., 2013). One study (reported across multiple papers) found a positive statistical association between a self-perception as an environmentally friendly individual and workplace recycling (Tudor et al., 2007a, 2007c) while another described how “environmental concerns” have led to the recycling of certain items (Vatovec et al., 2013).

The **existing evidence base on the effectiveness of recycling** was identified as influential, with one study finding a barrier in the perceived lack of evidence that supports recycling (Ard et al., 2016). Meanwhile another study quotes one participant expressing willingness to participate in recycling efforts as long as they were “proven to be effective” (Nichols and Mukonoweshuro, 2017, p. 132).

Finally, one study found a negative statistical association between the statement “I have no interest in recycling” and the performance of workplace recycling behaviour, indicating a positive relationship between an **interest in recycling** and waste recycling behaviour (Tudor et al., 2007a).

**3.4.3.2. Individual psychological capability (COM-B category “psychological capability”).** Three studies identified a **lack of knowledge** as a barrier to recycling (Azouz et al., 2019; Hu et al., 2022; Nichols and Mukonoweshuro, 2017). One survey-based study even reported that respondents perceived “Not knowing what can be recycled” as the biggest barrier to recycling (Azouz et al., 2019). The other two studies also described staff facing issues around distinguishing between recyclable and non-recyclable items, especially when they lacked knowledge around indicators that signify the recyclability of materials (Nichols and Mukonoweshuro, 2017), or when plastic materials with different recycling potential appear visually similar or the recyclability of an item differs depending on the location (Hu et al., 2022).

**3.4.3.3. Individual physical opportunity (COM-B category “physical opportunity”).** One barrier related to the individual physical opportunity concerned the **properties of the actual recycling item itself**, in that it could contain non-recyclable components, like food (Tudor et al., 2005).

**3.4.3.4. Individual behaviour (COM-B category “behaviour”).** Finally, a behavioural component could be identified as influential on recycling behaviour. Tudor et al. (2007a) found that staff who **recycle at home** were also more likely to recycle at work. Harding et al. (2021) identified **sorting mistakes** of other actors in the recycling chain as a barrier. Specifically, they describe from a recycler perspective, how non-recyclable items being present in recycling bags can lead to the content of the entire bag not being recycled.

### 3.5. Location of influences in the multi-level framework and COM-B model

Overall nine studies reported influences on the macro-level, 16 studies identified influences on the meso-level and 10 studies included influences on the micro-level. Furthermore, the 27 identified influences on hospital waste recycling represented the following COM-B components: “physical opportunity” (reported in 21 studies), “social opportunity” (7 studies), “reflective motivation” (7 studies), “psychological capability” (3 studies) and “behaviour” (2 studies). The COM-B components “automatic motivation” and “physical capability” were not identified in the data.

Most identified influences related to the COM-B component “physical opportunity” (16 influences reported across 21 studies), particularly on the meso-level (11 influences across 15 studies), followed by the macro-level (4 influences across 9 studies) and the micro-level (1 influence in 1 study).

## 4. Discussion

To our knowledge, this is the first systematic review to investigate barriers and facilitators to hospital waste recycling. It reviewed 24 quantitative, qualitative and mixed methods primary studies, reported in 28 papers, on barriers and facilitators to hospital waste recycling in high-income countries published in English since 1999.

In terms of identified barriers and facilitators, this review identified 27 influences on hospital waste recycling. They covered the COM-B categories “physical opportunity”, “social opportunity”, “reflective motivation”, “psychological capability” and “behaviour” and could be grouped to nine themes across hospitals’ macro-, meso- and micro-level. The reviewed literature shows that influences on hospital waste

recycling are most prevalent in the physical opportunity of performing recycling behaviours, particularly with regards to the meso- and macro-level. These influences work in conjunction with other influences relating to the social opportunity on the meso-level and reflective motivation, psychological capability and behaviour on the micro-level. Of interest is that this review also identified one barrier concerning the physical opportunity on the micro-level, which consisted of the recycling item itself, in that it could contain non-recyclable components, thereby restricting the opportunity to perform any recycling behaviour. While it was generally expected for “physical opportunity” influences to manifest on the meso- and macro-level, rather than the micro-level, this finding aligns with Macklin et al. (2023), who included the “waste item” and its properties as a micro-level influence in their multi-level framework on household waste recycling.

Barriers were a lot more prevalent in the reviewed literature than facilitators, with the most dominant barriers, i.e. barriers most frequently reported in the included studies, relating to difficulties accessing appropriate recycling bins and a lack of information or education on recycling.

The findings in this systematic review on barriers and facilitators to hospital waste recycling bear some resemblance to the scoping review by Aboueid et al. (2023) on influences on healthcare sustainability. While there are some differences in individual influences between both reviews, overall Aboueid et al. (2023) also identified influences related to the individual level of healthcare staff (i.e. the micro-level in this review), the institutional level of the healthcare organisation (i.e. the meso-level in this review), and influences on levels beyond individual healthcare organisations (i.e. the macro-level in this review). Additionally, they found some influences in a category termed “other”, such as patient preferences. They recognise the importance of addressing individual-level influences, but like this review with its prevalence of influences related to “opportunity” on the meso-level, they stress the necessity of the healthcare organisation providing an environment that allows individual healthcare professionals to behave sustainably. Like this review, they also identify the role of leadership as one important influence in this context. They furthermore note that the absence of a supportive infrastructure and policy environment can hinder the establishment of sustainability in healthcare organisations (Aboueid et al., 2023). These influences resemble this review’s macro-level influences related to systems outside the hospital dealing with recycling, such as a lack of recyclers (Hu et al., 2022), as well as the influential effect of legislation or regulations supportive of recycling (Bailey et al., 2004; Nichols et al., 2013; Petre et al., 2020; Singleton et al., 2021).

### 4.1. Opportunities for using a more nuanced terminology

The introduction section of this review identified a wider thematic focus of review-level studies on healthcare as opposed to hospital settings (e.g. Aboueid et al., 2023) and sustainability or waste management topics instead of a specific focus on the waste management option of recycling (e.g. Lattanzio et al., 2022; McGain and Naylor, 2014). A similar situation was encountered in some of the primary studies included in this review. First, only two thirds of included studies were undertaken exclusively in a hospital or hospital-and-home setting. The remaining third of the studies were conducted in a wider healthcare (or healthcare-and-home) setting. These studies did not always allow for a clear distinction between barriers and facilitators related to recycling in hospitals versus other non-hospital settings (e.g. Manzi et al., 2016; Nichols et al., 2013). However, they were included to not omit potentially relevant influences on recycling behaviours. A similar second challenge was faced around the distinction between data referring to barriers and facilitators to recycling versus influences on waste management or sustainability more broadly. Some studies, for example, report influences on “sustainability” or “waste management” without specifying which sustainability or waste management option, such as reducing, reusing or recycling, they refer to (e.g. Dilly and Shanklin,



2000; Petre et al., 2020). This led to three studies meeting the inclusion criteria for this review from which no recycling-specific data could be extracted (Dilly and Shanklin, 2000; Nichols and Manzi, 2014; Theofanidis et al., 2008). It should be noted, that some barriers and facilitators might indeed refer to all waste management options and various healthcare settings and the use of a more general terminology might serve the purpose of an individual study. However, a clear use of terminology around settings and waste management options, where possible, would improve the usefulness of these insights for researchers and practitioners who seek information on one specific waste management option or setting.

#### 4.2. Implications for improving hospital waste recycling behaviour

Based on the findings of this review, we make suggestions at the meso- and micro-level for hospitals to improve their waste recycling. This is followed by a brief reflection on implications at the macro-level:

##### 4.2.1. Meso-level

To address the findings relating to physical opportunity at the meso-level, hospitals should provide staff with a functioning disposal infrastructure, including easily accessible and fit for purpose recycling bins as well as the logistical set up to empty these bins. If space limitations exist, this could be addressed by clever design solutions for bins that maximise the use of the available space.

Beyond the physical disposal infrastructure, hospitals should also provide sufficient resources such as education around recycling to increase staff knowledge as well as supporting policies, staff incentives, budget, staff time and availability.

Hospitals need to complement this supportive physical environment with a supportive social environment for performing hospital waste recycling behaviours. This requires support from leadership and/or change champions, opportunities for bottom-up improvement suggestions and the presence of supportive colleagues.

##### 4.2.2. Micro-level

To address micro-level influences, hospitals need to reduce concerns about infection control when recycling hospital waste, provide evidence to its effectiveness and tap into existing pro-environmental dispositions or interest in recycling. Moreover a link between recycling behaviour at home and work (Tudor et al., 2007a), suggests the possibility to draw on insights from research on contextual behavioural spillover (Nilsson et al., 2017). This avenue of research suggests that people might be more inclined to perform a behaviour if they are already performing the same behaviour in another context (Nilsson et al., 2017).

##### 4.2.3. Macro-level

While addressing intervention suggestions related to the meso- and micro-level likely fall within the sphere of influence of individual hospitals, this review also identified a number of influences in the environment outside the hospital, i.e. the macro-level. On the procurement side, this referred to the importance of designing products that allow to be recycled at their end of life. On the disposal side, this related to functioning systems outside the hospital which are dealing with recycling, such end-markets and the presence of recyclers, as well as legislation and cost structures for waste disposal in favour of recycling. Addressing these influences likely falls outside of the sphere of influence of individual hospitals. Instead these influences can be addressed by policymakers through the creation of legislation/regulation and favourable market conditions for recycling, or by other macro-level actors such as product manufacturers, by designing recyclable products.

It should be noted that other potential influences on hospital waste recycling may exist in the macro-level that were not dominant themes in relation to recycling across the included studies. These include regulations and legislation for dealing with hospital waste more generally as well as country-level recycling practices. Future research could explore

these additional factors.

#### 4.3. Strengths and limitations

One methodological strength of this review is its comprehensive and systematic search and study screening strategy. However, limiting the included studies to publications in English language and the academic literature means that some relevant studies might have been missed. Furthermore, it is possible that relevant studies were published prior to the cut-off date of 1999. But given the slow growth of the body of literature on healthcare waste management prior to this review's cut-off date compared to after (Ranjbari et al., 2022), this possibility seems unlikely.

Another strength of this review is its nuanced focus. To our knowledge this is the first systematic review to specifically investigate barriers and facilitators to recycling behaviour (as opposed to reduction, reusing or broader sustainability behaviours) in a hospital setting (as opposed to broader healthcare settings). While it is possible that some additional influences on hospital waste recycling could have been captured in the larger scope of sustainability and waste management, such a less specific scope would have made it difficult or impossible to ascertain a link between these broader scope influences and recycling specifically. Instead, the nuanced investigation of barriers and facilitators to hospital waste recycling in this review allows for targeted knowledge generation and can support researchers and practitioners, who are looking particularly for insights on barriers and facilitators to the waste management option of recycling in a hospital context. Following the Behaviour Change Wheel (Michie et al., 2014) as one well-established behaviour change approach (Hagger et al., 2020), insights from this investigation into behavioural influences of hospital waste recycling can contribute to the first phase of intervention design, which is to understand the behaviour in question (Michie et al., 2014). Knowledge of what hinders or facilitates behavioural performance of recycling in hospitals can subsequently be used as a starting point for intervention design. Such a tailored approach increases the likelihood of success of an intervention (Michie et al., 2014), specifically relevant to hospital waste recycling. However, research has also shown that barriers and facilitators to hospital waste management can differ between individual hospitals (BehaviourWorks Australia, n.d.), suggesting that a further exploration into locally relevant behaviours, barriers and facilitators in a given hospital context will be beneficial. The summary of influences generated in this review can serve as a useful starting point for such a further exploration.

A final strength and theoretical contribution of this review is the combination of the COM-B model with a multi-level framework. While this combination has been applied in a number of recent studies (e.g. Caperon et al., 2019; Hunter et al., 2020; Nguyen et al., 2022; van Kasteren et al., 2020; Yin et al., 2022), it is a novel approach to summarise barriers and facilitators to hospital waste recycling. Similar to the findings of others (Caperon et al., 2019), by using this combination, it was possible to explore influences in the "physical opportunity" component of the COM-B model in a more nuanced manner than using the COM-B model alone. A sole reliance on the COM-B model would have resulted in 16 influences related to physical opportunity, while the addition of a multi-level framework allowed for a distinction between these influences showing that four of them related to the wider external environment outside the hospital, i.e. the macro-level, 11 were situated in the internal hospital environment, i.e. the meso-level, while one referred to the individual micro-level. Conversely, adding the COM-B model to a multi-level framework allowed to distinguish the otherwise rather broad "micro-level" into micro-level influences related to individual reflective motivation, psychological capability, physical opportunity and behaviour. Besides the theoretical clarity this combination offered, it also resulted in a readily understandable, logically organised summary of identified influences to hospital waste recycling (Table 2). Such a summary can facilitate any further practical application of this

research to improve hospital waste recycling. For example, it allows relevant actors in each of the micro-, meso- and macro-settings to focus on the review findings relevant to them, while still having visibility of the role of actors in the other levels. In light of these insights, further research into influences of behavioural performance might benefit from combining the COM-B model with a multi-level framework, especially in instances where there exist many influences relating to different levels of the “opportunity” to perform a behaviour or where many “micro-level” influences are present.

## 5. Conclusion

This systematic review investigated barriers and facilitators to hospital waste recycling in high-income countries. It shows that hospital waste recycling is influenced by a number of barriers and facilitators on different levels of the hospital environment, including the external hospital environment, the internal hospital environment as well as individual hospital staff. Most influences related to the “physical opportunity” of recycling behaviour. Barriers were a lot more prevalent in the literature than facilitators, with the most dominant barriers relating to difficulties accessing appropriate recycling bins and a lack of information or education on recycling. The findings suggest that hospitals need to provide staff with an environment conducive to recycling, including suitable recycling infrastructure and resources, if they wish to maximise existing recycling potential.

The combination of the COM-B model with a multi-level framework allowed for a nuanced distinction of the COM-B category “opportunity” as well as the multi-level framework category of the “micro-level”. It furthermore supported the organisation of identified influences to hospital waste recycling in an easily accessible manner. Moving forward, the identified influences in this review can serve as a starting point to further explore their applicability in a specific hospital. Additionally, or alternatively, they can serve as a starting point to inform the design of

## Appendix A. – Search strategy

### Web of science core collection

TS=((hospital\$ OR "health service\$" OR "health care" OR healthcare OR "operating theatre\$" OR "operating theatre" OR "operating room\$" OR "operating suite\$" OR icu OR "intensive care unit\$" OR "emergency department\$" OR ward\$) AND ("waste management" OR "waste reduction\$" OR "waste separation" OR "waste segregation" OR "waste improvement\$" OR "waste impact\$" OR "refuse management" OR "refuse reduction\$" OR "refuse separation" OR "refuse segregation" OR "refuse improvement\$" OR "refuse impact\$" OR recycling OR recycle OR "resource efficiency" OR greening OR "environmental impact\$" OR "environmental sustainability" OR "environmentally friendly" OR "environmentally responsible") AND (barrier\$ OR obstacle\$ OR difficult\* OR problem\$ OR challeng\* OR constrain\* OR hinder\* OR block\* OR imped\* OR lack\* OR prevent\* OR obstruct\* OR opportunit\* OR facilitat\* OR driv\* OR enabl\* OR help\* OR factor\$ OR consequence\$ OR influenc\* OR determin\* OR predict\* OR effect OR effects OR effecting OR effected OR impact\* OR contribut\* OR link\* OR associat\* OR affect\*))

→ Timespan: 1999–01–01 to 2022–12–31 (Publication Date) | Exact search

### Scopus

TITLE-ABS-KEY (((hospital OR "health service" OR "health care" OR healthcare OR "operating theatre" OR "operating theatre" OR "operating room" OR "operating suite" OR icu OR "intensive care unit" OR "emergency department" OR ward) AND ("waste management" OR "waste reduction" OR "waste separation" OR "waste segregation" OR "waste improvement" OR "waste impact" OR "refuse management" OR "refuse reduction" OR "refuse separation" OR "refuse segregation" OR "refuse improvement" OR "refuse impact" OR recycling OR recycle OR "resource efficiency" OR greening OR "environmental impact" OR "environmental sustainability" OR "environmentally friendly" OR "environmentally responsible") AND (barrier OR obstacle OR difficulty OR problem OR challeng\* OR constrain\* OR hinder\* OR block\* OR imped\* OR lack\* OR prevent\* OR obstruct\* OR opportunity OR facilitat\* OR driv\* OR enabl\* OR help\* OR factor OR consequence OR influenc\* OR determin\* OR predict\* OR {effect} OR {effects} OR {effecting} OR {effected} OR impact\* OR contribut\* OR link\* OR associat\* OR affect\*)) AND PUBYEAR > 1998

Ovid MEDLINE(R) and Epub ahead of print, in-process, in-data-review & other non-indexed citations, daily and versions(R)

- 1 Recycling/
- 2 Waste Management/
- 3 exp hospital units/ or exp hospitals/

interventions to improve hospital waste recycling.

Finally, the detailed focus of this review on the waste management option of recycling in the healthcare setting of hospitals surfaced opportunities for the body of literature on healthcare sustainability and waste management to be more specific in their application of terminology related to differing waste management options and healthcare settings.

## CRediT authorship contribution statement

**Lena Jungbluth:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Denise Goodwin:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Fraser Tull:** Writing – review & editing, Investigation. **Peter Bragge:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

## Acknowledgement

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4 Association/

5 (hospital? or health service? or health care or healthcare or operating theatre? or operating theatre? or operating room? or operating suite? or icu or intensive care unit? or emergency department? or ward?).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]

6 (waste management or waste reduction? or waste separation or waste segregation or waste improvement? or waste impact? or refuse management or refuse reduction? or refuse separation or refuse segregation or refuse improvement? or refuse impact? or recycling or recycle or resource efficiency or greening or environmental impact? or environmental sustainability or environmentally friendly or environmentally responsible).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]

7 (barrier? or obstacle? or difficult\* or problem? or challeng\* or constrain\* or hinder\* or block\* or impeded\* or lack\* or prevent\* or obstruct\* or opportunit\* or facilitat\* or driv\* or enabl\* or help\* or factor? or consequence? or influenc\* or determin\* or predict\* or effect or effects or effecting or effected or impact\* or contribut\* or link\* or associat\* or affect\*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]

8 1 or 2 or 6

9 3 or 5

10 4 or 7

11 8 and 9 and 10

12 limit 11 to yr="1999 -Current"

## Appendix B. –Quality appraisal of included studies

The MMAT (Hong et al., 2018) classifies studies into five categories according to their study design, three of which were relevant for this systematic review: qualitative studies, quantitative descriptive studies and mixed methods studies.

All study types are assessed against two screening questions:

- S1: Are there clear research questions?
- S2: Do the collected data allow to address the research questions?

Qualitative studies are assessed against the following five criteria:

- Q1qual: Is the qualitative approach appropriate to answer the research question?
- Q2qual: Are the qualitative data collection methods adequate to address the research question?
- Q3qual: Are the findings adequately derived from the data?
- Q4qual: Is the interpretation of results sufficiently substantiated by data?
- Q5qual: Is there coherence between qualitative data sources, collection, analysis and interpretation?

Quantitative descriptive studies are assessed against the following five criteria:

- Q1quant: Is the sampling strategy relevant to address the research question?
- Q2quant: Is the sample representative of the target population?
- Q3quant: Are the measurements appropriate?
- Q4quant: Is the risk of nonresponse bias low?
- Q5quant: Is the statistical analysis appropriate to answer the research question?

Mixed methods studies are assessed against the following five criteria *and* the criteria from any other applicable study design (i.e. qualitative or quantitative descriptive study). For mixed methods studies, this means that studies will require multiple rows in the table below.

- Q1MM: Is there an adequate rationale for using a mixed methods design to address the research question?
- Q2MM: Are the different components of the study effectively integrated to answer the research question?
- Q3MM: Are the outputs of the integration of qualitative and quantitative components adequately interpreted?
- Q4MM: Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?
- Q5MM: Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?

This review additionally provided an overall assessment for included studies. Following Wong et al.'s (2020) approach, the following assessment rules were applied: 5/5 criteria = high; 4/5 criteria = medium; 3 or fewer/5 criteria = low. For mixed methods studies the lowest overall assessment was used because “the overall quality of a mixed methods study cannot exceed the quality of its weakest component” (Hong et al., 2018, p. 7).

Finally, for some studies explanatory comments have been added as footnotes.

Study	Study design	S1	S2	Q1qual/ Q1quant/ Q1MM	Q2qual/ Q2quant/ Q2MM	Q3qual/ Q3quant/ Q3MM	Q4qual/ Q4quant/ Q4MM	Q5qual/ Q5quant/ Q5MM	Overall assessment
Alharbi et al. (2021)	Qualitative	Yes	Yes	Yes	Yes	Can't tell	Can't tell	Can't tell	Low
Ard et al. (2016)	Quantitative	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Azouz et al. (2019) <sup>1</sup>	Quantitative	Yes	Yes	Yes	Can't tell	Yes	No	Yes	Low
Bailey et al. (2004)	Qualitative	Yes	Yes	Yes	Yes	Can't tell	Can't tell	Can't tell	Low
Burbridge et al. (2019)	Qualitative	Yes	Yes	Yes	Yes	Can't tell	Can't tell	Can't tell	Low
Dilly and Shanklin (2000)	Quantitative	Yes	Yes	Can't tell	Can't tell	Can't tell	Yes	Yes	Low
Grose et al. (2012), Nichols et al. (2013) <sup>2</sup>	Qualitative	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Grose et al. (2012)	Qualitative	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Nichols et al. (2013)	Qualitative	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Harding et al. (2021)	Qualitative	Yes	Yes	Yes	Yes	Can't tell	Can't tell	Can't tell	Low
Hu et al. (2022) <sup>3</sup>	Mixed methods	Yes	Yes	No	Yes	Yes	Yes	No	Low
	Qualitative			Yes	Yes	Can't tell	Can't tell	Can't tell	
Kalogirou et al. (2021)	Qualitative	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Manzi et al. (2016)	Qualitative	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
McGain et al. (2012)	Quantitative	Yes	Yes	Yes	Yes	Yes	No	Yes	Medium
Nichols and Manzi (2014)	Qualitative	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Nichols and Mukonoweshuro (2017)	Qualitative	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Petre et al. (2019)	Quantitative	Yes	Yes	Yes	Can't tell	Yes	No	Yes	Low
Petre et al. (2020)	Quantitative	Yes	Yes	Yes	No	Yes	No	Yes	Low
Singleton et al. (2021) <sup>4</sup>	Qualitative	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Theofanidis et al. (2008) <sup>5</sup>	Quantitative	No	Can't tell	No	Can't tell	Can't tell	Yes	Can't tell	Low
Tudor et al. (2005) <sup>6</sup>	Qualitative & Unclear	Yes	Can't tell	Yes	Can't tell	Can't tell	Can't tell	Can't tell	Low
Tudor et al. (2007a, 2007b, 2007c, 2008b) <sup>7</sup>	Mixed methods	Yes	See individual papers	Yes	Yes	Yes	Yes	See individual papers	Low-medium
	Qualitative			Yes	Yes	Yes	Can't tell	Yes	
	Quantitative			Yes	Yes	See individual papers	Yes	See individual papers	
Tudor et al. (2007a)	Quantitative	Yes	Yes	Yes	Yes	Yes	Yes	No	Medium
Tudor et al. (2007b) <sup>8</sup>	Quantitative	Yes	No	Yes	Can't tell	No	Can't tell	No	Low
Tudor et al. (2007c) <sup>9</sup>	Mixed methods	Yes	Yes	Yes	Yes	Yes	Yes	Can't tell	Low
	Qualitative			Yes	Yes	Yes	Can't tell	Yes	
	Quantitative			Yes	Can't tell	Yes	Can't tell	Can't tell	
Tudor et al. (2008b) <sup>10</sup>	Mixed methods	Yes	Yes	Yes	Yes	Yes	Yes	Can't tell	Low
	Qualitative			Yes	Yes	Yes	Can't tell	Yes	
	Quantitative			Yes	Can't tell	Yes	Can't tell	Yes	
Tudor et al. (2008a)	Qualitative	Yes	Can't tell	Yes	Yes	Can't tell	Can't tell	Can't tell	Low
Vatovec et al. (2013)	Qualitative	Yes	Yes	Yes	Yes	Can't tell	Yes	Yes	Medium
Viani et al. (2016)	Qualitative	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Vogt and Nunes (2014) <sup>11</sup>	Quantitative	No	Can't tell	Yes	Can't tell	Can't tell	Can't tell	Can't tell	Low

<sup>1</sup> This study includes a survey on barriers to recycling in the operating room, as well as the evaluation of a "recycling improvement program". Only the survey component of this study was relevant for our review question, hence only this component has been appraised using the MMAT.

<sup>2</sup> The MMAT FAQs Q11 (<http://mixedmethodsappraisaltoolpublic.pbworks.com/w/page/71030694/FAQ>) suggest to assess papers reporting on the same study as a single study as opposed to assessing them separately.

<sup>3</sup> This study includes interview data (qualitative) and PPE procurement and usage data (quantitative). Procurement/usage data cannot be appraised using the MMAT, hence only the qualitative and mixed methods sections of the MMAT were used.

<sup>4</sup> This study includes interview data on pharmaceutical waste management, as well as a survey on environmental attitudes (using the New Ecological Paradigm). Only the interview component of this study was relevant for our review question, hence only this component has been appraised using the MMAT.

<sup>5</sup> Even though we responded with "No" and "Can't tell" to the screening questions, we attempted to appraise the study with the MMAT because it is an empirical study (drawing on a survey). While the research questions were not clearly stated in this paper, the title suggests it is describing Greek nurses' views on sustainable management of hospital waste. We assessed the paper assuming this is its objective.

<sup>6</sup> This study includes data on barriers to recycling and reuse in the healthcare sector. This data was collected through "informal discussions with staff members" and "market research" (no further information is provided how this market research was conducted). Furthermore the study includes a waste audit which aims to answer research questions, which are not the focus of this review. Only the "informal discussions" and "market research" components of this study were relevant for this review, but since there was no detailed information about the market research, only the "informal discussions" component has been appraised using the MMAT.

<sup>7</sup> The MMAT FAQs Q11 (<http://mixedmethodsappraisaltoolpublic.pbworks.com/w/page/71030694/FAQ>) suggest to assess papers reporting on the same study as a single study as opposed to assessing them separately. When attempting to do so, it became apparent that in case of the Tudor et al. papers this approach was not feasible because the research questions in the individual papers were too different. In particular the research questions in Tudor et al. (2007a) and Tudor et al. (2007b) were



different from each other and different from Tudor et al. (2007c) and (2008b), while the research questions in Tudor et al. (2007c) and (2008b) were deemed similar enough (at least in parts) for a combination of the assessments. The following approach was taken: For the qualitative and mixed methods assessment (except for Q5MM) for Tudor et al. (2007c) and (2008b): The combined data says “yes” as long as one of both papers provided the required details to answer the question. For the quantitative assessment criteria Q1quant, Q2quant and Q4quant of all four papers: The combined data says “yes” as long as one of the four papers provided the required details to answer the question. This is based on the reasoning that all four studies use the same data (including the same sampling strategy, sample and response rate). For the assessment criteria S2, Q3quant, Q5quant and Q5MM, each paper needed to be assessed individually because the assessment changed depending on the research question asked by each paper.

<sup>8</sup> This paper also includes a waste audit which cannot be appraised using the MMAT.

<sup>9</sup> This paper also includes a waste audit which cannot be appraised using the MMAT.

<sup>10</sup> This paper also includes a waste audit which cannot be appraised using the MMAT.

<sup>11</sup> Even though we responded with “No” and “Can’t tell” to the screening questions, we attempted to appraise the study with the MMAT because it is an empirical study (drawing on a survey). However, since the research questions of this study are not clearly stated, we could not answer Q3quant. and Q5quant.

### Appendix C. – Additional details on included studies

Study	Study design*	Methods for data collection*	Country of study	Study setting	Details of hospital setting	Characteristics of participants	Level of identified influences	Influences on hospital waste recycling
Alharbi et al. (2021)	Qualitative	Interviews; Observations; Focus groups	Saudi Arabia	Health-care	NA	Healthcare staff and stakeholders	Recycling	Lack of policy to support recycling within organisation; Lack of information/education on recycling
Ard et al. (2016)	Quantitative	Survey	US	Hospital	Operating theatre	Anaesthetists	Recycling	Lack of information/education on recycling; Lack of facilities (not specific to bins); Unsupportive staff; Lack of time; Lack of leadership or hospital administration support; Concerns about infection control; Existing evidence base on effectiveness of recycling
Azouz et al. (2019)	Quantitative	Survey	US	Hospital	Operating theatre	Hospital staff (operating theatre)	Recycling	Lack of knowledge; Concerns about infection control; Access to recycling bins; Lack of incentives/presence of disincentives; Lack of time
Bailey et al. (2004)	Qualitative	Interviews	UK	Health-care	NA	Healthcare staff and stakeholders	Recycling	Systems to deal with recycling outside hospital; Legislation/regulation outside hospital
Burbridge et al. (2019)	Qualitative	Interviews	US	Hospital	Focus on specific item	Hospital staff and stakeholders	Recycling	Product design preventing recycling
Dilly and Shanklin (2000)	Quantitative	Survey	US	Hospital	No specific setting	Hospital staff (logistics directors)	Waste management	No recycling-specific data extracted
Grose et al. (2012), Nichols et al. (2013)	Qualitative	Interviews	UK	Health-care	NA	Healthcare staff and stakeholders	Recycling	Access to recycling bins; Lack of space; Legislation/regulation outside hospital; Cost of waste treatment if not recycled
Harding et al. (2021)	Qualitative	Interviews; Observations	Belgium	Hospital	Operating theatre (plus pre- and post-usage locations of items)	Hospital staff and stakeholders	Recycling	Lack of space; Access to recycling bins; Sorting mistakes of others
Hu et al. (2022)	Mixed methods	Interviews; Procurement and material usage data	UK	Hospital	No specific setting	Hospital staff (various)	Recycling	Systems to deal with recycling outside hospital; Lack of knowledge
Kalogirou et al. (2021)	Qualitative	Interviews; Observations	Canada	Hospital	Internal medicine units and emergency room	Hospital staff (internal medicine unit and emergency room nurses)	Recycling	Access to recycling bins; Difficulties making bottom-up improvement suggestions heard at higher levels; Challenges with removal of recycling from initial sorting area
Manzi et al. (2016)	Qualitative	Interviews; Observations	UK	Health-care	NA	Healthcare staff	Recycling	Access to recycling bins
McGain et al. (2012)	Quantitative	Survey	Multiple (Australia,	Hospital	Operating theatre	Anaesthetists	Recycling	Lack of facilities (not specific to bins); Unsupportive staff; Lack of

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(continued)

Study	Study design*	Methods for data collection*	Country of study	Study setting	Details of hospital setting	Characteristics of participants	Level of identified influences	Influences on hospital waste recycling
			New Zealand, UK)					information/education on recycling; Concerns about infection control; Lack of leadership or hospital administration support
Nichols and Manzi (2014)	Qualitative	Interviews; Observations	UK	Hospital	Neonatal intensive care unit	Hospital staff (neonatal intensive care unit)	Waste management	No recycling-specific data extracted
Nichols and Mukonoweshuro (2017)	Qualitative	Interviews	UK	Hospital	Neonatal intensive care unit	Hospital staff (neonatal intensive care unit nurses)	Recycling	Lack of time; Lack of space; Lack of knowledge; Existing evidence base on effectiveness of recycling
Petre et al. (2019)	Quantitative	Survey	Canada	Hospital	Operating theatre	Anaesthetists	Recycling	Lack of leadership or hospital administration support; Lack of information/education on recycling; Unsupportive staff; Lack of facilities (not specific to bins); Financial constraints/cost; Lack of time; Lack of space; Concerns about infection control; Access to recycling bins
Petre et al. (2020)	Quantitative	Survey	Canada	Hospital	Operating theatre	Anaesthetists (department chiefs and residency program directors)	Recycling	Supportive champion; Unsupportive staff; Legislation/regulation outside hospital
Singleton et al. (2021)	Qualitative	Interviews	Multiple (Australia, UK)	Hospital	Hospital pharmacy department	Hospital staff (pharmacy)	Recycling	Access to recycling bins; Supportive champion; Lack of policy to support recycling within organisation; Lack of information/education on recycling; Legislation/regulation outside hospital; Cost of waste treatment if not recycled
Theofanidis et al. (2008)	Quantitative	Survey	Greece	Hospital	No specific setting	Hospital staff (nurses)	Waste management	No recycling-specific data extracted
Tudor et al. (2005)	Unclear	Interviews; "Market research"	UK	Health-care	NA	Healthcare staff and unclear ("market research")	Recycling	Systems to deal with recycling outside hospital; Recycling item contaminated (with non-infectious substance)
Tudor et al. (2007a, 2007b, 2007c, 2008b)	Mixed methods	Survey; Interviews; Observations; Waste audit	UK	Health-care and home	NA	Healthcare staff and stakeholders	Recycling	Recycling at home; Pro-environmental considerations; Individuals' interest in recycling; Lack of policy to support recycling within organisation
Tudor et al. (2008a)	Qualitative	Interviews; Observations	UK	Health-care	NA	Healthcare staff	Recycling	Systems to deal with recycling outside hospital
Vatovec et al. (2013)	Qualitative	Interviews; Observations	US	Health-care	NA	Healthcare staff and stakeholders	Recycling	Lack of information/education on recycling; Unsupportive staff; Pro-environmental considerations
Viani et al. (2016)	Qualitative	Interviews	Multiple (UK, Italy)	Hospital	Focus on specific item	Hospital staff (various)	Recycling	Product design preventing recycling; Systems to deal with recycling outside hospital; Lack of available staff to dismantle potentially recyclable items; Lack of space; Lack of incentives/presence of disincentives; Lack of time
Vogt and Nunes (2014)	Quantitative	Survey	Germany	Hospital and home	No specific setting	Hospital staff (various)	Recycling	Challenges related to specific bin characteristics (e.g. tearing bin liners); Access to recycling bins; Lack of information/education on recycling

\* Extracted data on study design and methods for data collection only focus on primary data pertaining to the aim of this systematic review – barriers and facilitators to hospital waste recycling.

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