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Environmental impact of single-use versus reusable flexible endoscopes: a systematic review

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Abstract: The increasing use of single-use flexible endoscopes raises concerns about their environmental impact. This systematic review includes 18 studies comparing single-use and reusable endoscopes based on quantitative analyses on their environmental impact. Types included are bronchoscopes, cystoscopes, duodenoscopes, gastroscopes, laryngoscopes, and ureteroscopes. The number of available studies differs by endoscope type, with cystoscopes and bronchoscopes being most frequently assessed (seven and four studies). Findings indicate that the environmental impact depends on the specific endoscope type, with single-use cystoscopes being favorable, while for duodenoscopes, data suggest the reusable option to be more sustainable. However, results are highly study-dependent, influenced by regional circumstances such as transport distances, waste management, and reprocessing assumptions. Further quantitative data from underrepresented regions could help close remaining knowledge gaps for gastroscopes and laryngoscopes, and innovative material-saving technologies may help reduce the carbon footprint of disposable devices where indispensable.

Keywords: single-use, disposable, reusable, flexible endoscopy, endoscopy, carbon footprint, environmental impact

1 Introduction

In Germany, the healthcare sector represents the fourth largest contributor to raw material consumption, with an increase of almost 80% between 1995 and 2016 [1]. Concerns regarding safety and hygiene have led to the widespread use of disposable equipment and devices, contributing to this high resource demand. With conventional endoscopes being regarded as hard to clean, disposable alternatives have become increasingly popular. However, in recent years, environmental sustainability has gained more attention within the medical sector, motivating research into the environmental impact of these complex, resource-intensive devices.

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Since 2018, several comparative studies on disposable versus reusable endoscopes have been published, many of them providing quantitative Life Cycle Assessments (LCA), and the data base is steadily growing. The current state of knowledge has been particularly well-documented through literature reviews for bronchoscopes [2, 3], as well as for cystoscopes and ureteroscopes [4–8]. In addition, Martins et al. have collected studies related to the carbon footprint of endoscopic instruments and procedures [9].

The environmental impact of single-use versus reusable endoscopes is determined by multiple factors incorporated into LCA, including transportation distance from the production site, the mass of the materials used, local waste processing practices, and the resource consumption of the reprocessing of the reusable endoscopes. As a result, different study settings lead to varying conclusions on which option has lower environmental impact, usually determined in terms of carbon footprint.

Extending the current state of research, this review aims to provide an overview of studies comparing the environmental impact of all common types of flexible endoscopes, thereby updating the reviewing literature in this rapidly evolving field. The findings will help determine whether for certain types of endoscopes, the reusable option is favorable, while for others, the disposable option demonstrate advantages.

2 Methods

The literature search was conducted across PubMed, Web of Science and Scopus, including studies published until mid of March 2025. Keywords were defined based on preliminary unsystematic research, and the common types of endoscopes were researched. The search string applied was: ("single-use" OR "disposable" OR "one-use")

AND

("life cycle" OR "LCA")

AND

(bronchoscope* OR laryngoscope* OR gastroscop* OR duodenoscop* OR cystoscop* OR ureterscop* OR urethrosco* OR colonoscop* OR choledochoscop* OR enteroscop* OR endoscop*)

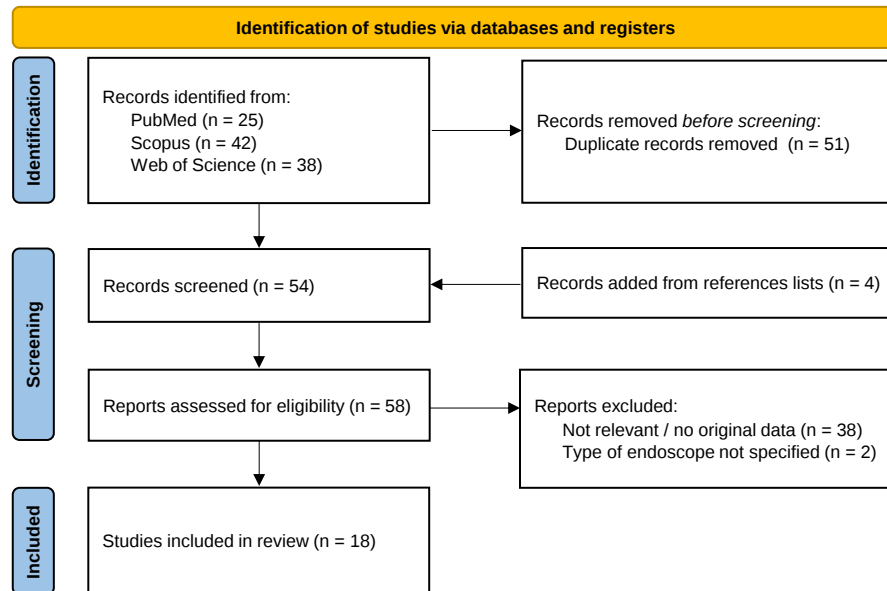


Figure 1: PRISMA flowchart illustrating the search strategy.

The search strategy and selection process are illustrated in Figure 1 according to the PRISMA scheme (PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses). After removing duplicates, the results were screened, and four additional sources were identified through reference lists and review articles. Studies were subsequently excluded if meeting one of the exclusion criteria:

- Lack of original quantitative data comparing single-use and reusable medical endoscopes
- Absence of environmental aspects in the comparison (e.g., studies focusing solely on cost analysis)
- Not considering flexible endoscopes (e.g., studies on rigid laryngoscopes, laparoscopes, or capsule endoscopes)
- Type of endoscope not specified
- Abstract not available in English or German

Examples of excluded studies included reviews, research focusing on the environmental impact of anesthetic gases, and replies / letters to publications without original data. Two papers presented a quantitative comparison of the ecological impact of single-use vs. reusable endoscopes, however, the types of endoscopes were not specified, leading to their exclusion [10, 11].

3 Results

18 studies were included into the review. Among these, a total of seven papers focused on cystoscopes, four on bronchoscopes, three on duodenoscopes, and two on ureteroscopes.

Gastrosopes and flexible laryngoscopes were each addressed in a single study. No studies were found on colonoscopes, choledochoscopes and enteroscopes. An overview of the reviewed papers is provided in Table 1.

4 Discussion

For certain types of flexible endoscopes, there appears to be a greater demand for comparative data on their environmental impact, particularly for cystoscopes. Notably, this is also the type for which single-use devices yield the most favorable results. A possible reason for the differing number of studies could be the greater clinical relevance of sterility in certain procedures – such as when entering the mostly sterile ureter and bladder. In these cases, the guaranteed sterility of a disposable endoscope may be of higher importance than, for example, during gastrointestinal procedures, where sterility requirements are comparatively lower. This may have led to wider spread and more discussions regarding the environmental impact of disposable cystoscopes and ureteroscopes. For colonoscopes, choledochoscopes and enteroscopes, the lack of comparative data may be due to the limited availability of disposable options for these specific types.

While existing studies clearly suggest choosing the disposable option for cystoscopes, the opposite is the case for duodenoscopes, among others. The difference may be explained by the different sizes (length and diameter) of the devices, creating different waste volumes during incineration. Therefore, based on the existing literature, the decision to use a

Table 1: 18 reviewed studies comparing the environmental impact of flexible endoscopes. The column "Lower Impact" indicates the type of endoscope with lower environmental impact as concluded by the respective study.

Scope	Authors	Year	Ref.	Study Setting	Type of Assessment	Lower impact
Bronchoscopes	Massart et al.	2024	[12]	France	GHG emissions in clinical setting	Reusable
Bronchoscopes	Bringier et al.	2023	[13]	France	LCA	Reusable
Bronchoscopes (combined with double-lumen tube)	Sørensen et al.	2023	[14]	Denmark	LCA	Single-use
Bronchoscopes	Sørensen et al.	2018	[15]	Denmark	LCA	Single-use
Cystoscopes	Bertolo et al.	2024	[16]	Italy	In-clinic CO ₂ emissions, waste volume and water consumption	Single-use
Cystoscopes	Jahrreiss et al.	2024	[7]	(not stated)	LCA	Single-use
Cystoscopes	Wombwell et al.	2024	[17]	Australia	LCA	Single-use
Cystoscopes	Baboudjian et al.	2023	[18]	France	LCA	Single-use
Cystoscopes	Kemble et al.	2023	[19]	United States	LCA	Reusable
Cystoscopes	Boucheron et al.	2022	[20]	France	In-clinic waste volume and water consumption	Single-use
Cystoscopes	Hogan et al.	2022	[21]	Ireland	CO ₂ emissions and solid waste volume	Single-use
Duodenoscopes	López-Muñoz et al.	2025	[22]	Spain	LCA	Reusable
Duodenoscopes	Le et al.	2022	[23]	United States	LCA	Reusable
Duodenoscopes	Hernandez et al.	2021	[24]	(not stated)	LCA	Reusable
Gastrosopes	Kidane et al.	2024	[25]	United States	LCA	Reusable
Laryngoscopes	Pioche et al.	2024	[26]	France	LCA	Reusable
Ureteroscopes	Thöne et al.	2024	[27]	Germany	LCA	Reusable
Ureteroscopes	Davis et al.	2018	[28]	Australia	LCA	Comparable

disposable or reusable endoscope should take into account the type, rather than relying on general recommendations. For scenarios where reusable gastrointestinal endoscopes, which are typically quite large, are not an option, future research could focus on reducing the mass of the material per device, affecting the environmental impact from disposal. A promising approach are soft everting robots, where the insertion tube of the endoscope is replaced by a thin plastic foil [29].

As previously described, LCA on the same type of product are based on different assumptions and conditions, leading to differing conclusions. While some groups incorporated the transportation distance from Malaysia to Europe for the single-use cystoscope [17, 19, 21], others assumed a generalized shipment distance of 500 km to France for both devices [18] or considered only the in-house carbon footprint [16, 20]. These transportation distances also vary depending on the country in which the endoscopes are used, which is usually also the country the respective study refers to. Additionally, local waste disposal methods have an impact: in some countries, landfilling

is still a common practice [17, 21], whereas other studies assume that all waste is incinerated [12, 14]. Therefore, even studies with seemingly contradicting outcomes may both be valid within their specific context.

To address gaps in the existing data base, further quantitative data should be gathered across diverse local study settings, particularly for gastrosopes and flexible laryngoscopes. This includes underrepresented regions such as South America, Africa, and particularly Asia, as none of the reviewed studies have yet considered these geographical contexts.

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