International Journal of Technology Assessment in Health Care, 34:3 (2018), 317–326.

doi:10.1017/S0266462318000351

Method

ENVIRONMENTAL IMPACT ASSESSMENT OF A HEALTH TECHNOLOGY: A SCOPING REVIEW

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Introduction: The Health Technology Expert Review Panel is an advisory body to Canadian Agency for Drugs and Technologies in Health (CADTH) that develops recommendations on health technology assessments (HTAs) for nondrug health technologies using a deliberative framework. The framework spans several domains, including the environmental impact of the health technology(ies). Our research objective was to identify articles on frameworks, methods or case studies on the environmental impact assessment of health technologies.
Methods: A literature search in major databases and a focused gray literature search were conducted. The main search concepts were HTA and environmental impact/sustainability. Eligible articles were those that described a conceptual framework or methods used to conduct an environmental assessment of health technologies, and case studies on the application of an environmental assessment.
Results: From the 1,710 citations identified, thirteen publications were included. Two articles presented a framework to incorporate environmental assessment in HTAs. Other approaches described weight of evidence practices and comprehensive and integrated environmental impact assessments. Central themes derived include transparency and repeatability, integration of components in a framework or of evidence into a single outcome, data availability to ensure the accuracy of findings, and familiarity with the approach used.
Conclusions: Each framework and methods presented have different foci related to the ecosystem, health economics, or engineering practices. Their descriptions suggested transparency, repeatability, and the integration of components or of evidence into a single outcome as their main strengths. Our review is an initial step of a larger initiative by CADTH to develop the methods and processes to address the environmental impact question in an HTA.

Keywords: Scoping review, Environmental impact, Health technology assessment

INTRODUCTION

A health technology assessment (HTA) is commonly defined as a multidisciplinary approach used to evaluate medical, social, economic, and ethical issues related to the use of a health technology in a systematic, transparent, unbiased, robust manner (1). The Canadian Agency for Drugs and Technologies in Health (CADTH) is a pan-Canadian organization that conducts HTAs to help healthcare decision makers make informed decisions about the optimal use of health technologies. In particular, CADTH's Medical Devices and Clinical Interventions program identifies and develops HTAs related to medical, surgical, and dental devices, procedures, and diagnostics to address its customers' needs.

CADTH also produces Optimal Use (OU) reports, which are HTAs that encompass recommendations (1). The Health Technology Expert Review Panel (HTERP) is an advisory body to CADTH that develops guidance or recommendations on nondrug health technologies using a deliberative framework (2).

The deliberative framework spans several domains, such as the need, benefits, harms, patient preferences, and economic impact, implementation issues, and legal and ethical considerations that are evaluated in an HTA. The environmental impact (e.g., resource use, water issues, gas emissions, carbon footprint to transport a technology, toxicity, waste management, and inefficient use of a technology when it is not applied to its maximum potential and recycling schemes) of the health technology in question is another component that is part of the deliberative framework (2). This approach is aligned with HTA's broad definition that includes the intended as well as the unintended consequences of a health technology (3). Furthermore, the environmental impact may be another dimension for consideration in the assessment of a health technology due to new policies on environmental consciousness and systems' sustainability.

There are examples of organizations that are beginning to incorporate aspects of environmental impact into their healthcare decision making. For example, the Government of Sweden has been considering a plan to introduce a voluntary eco-classification or green premium for generic drugs as a way of encouraging a

*Author Mackenzie Shaheen has been retroactively added to the original published article. An addendum notice detailing this change was also published (DOI: 10.1017/S0266462318000673).

The authors thank Dr. Sohail Mulla for his review of the draft protocol. The authors would like to acknowledge Mackenzie Sheehan for her contributions to the earlier drafts of the manuscript and data extraction of the tables. *Funding source:* The authors did not receive additional funding to conduct the scoping review.

more environmentally friendly production and packaging of medication (4). It is important to note that generic drugs are usually an attractive option for the payers due to their lower costs and same effectiveness not necessarily for their environmental sustainability.

Moreover, managed care consortium in California, Kaiser Permanente, launched an environmental impact initiative as it pertains to company decision making (5). It developed and has begun using a Sustainability Scorecard, which requires their suppliers to provide environmental data for $1 billion worth of medical equipment and products used in their hospitals, medical offices, and other facilities. This scorecard allows Kaiser Permanente to evaluate the sustainability of each medical item that they purchase, while also encouraging suppliers across the industry to provide environmentally friendly products for the healthcare sector (5).

In hospitals, one source of waste comes from clinical care. For instance, operating rooms in North America are responsible for approximately 20 to 33 percent of total hospital waste, and the problem may be more exacerbated with the use of disposable items (6). Some hospitals, therefore, are moving toward more environmentally friendly alternatives. As these alternatives can be more expensive due to the smaller markets and raw materials used, organizations can purchase items in bulk to lower the costs (6). The Children's Hospital of Eastern Ontario in Canada is forming a partnership with the Canadian Coalition for Greener Healthcare (7) to develop an eco-friendly procurement strategy. Other Canadian hospitals are also becoming more socially responsible by either switching to reusable items or incentivizing more environmentally friendly options (6).

To ensure that the environmental impact question is appropriately addressed in an HTA, it is important to be aware of existing frameworks and methods. A scoping review that identifies and describes the frameworks and methods available to help make an informed assessment of a health technology's environmental impact was conducted. Case studies that described an assessment on the environmental impact of a health technology were also relevant. The findings can provide some insight on whether frameworks or methods exist to address the environmental impact of a technology in HTAs.

METHODS

This protocol was developed *a priori* and was followed throughout the conduct of the scoping review.

Information Sources and Literature Search Strategy

A literature search was conducted on key resources including Medline, Embase, PubMed, the Cochrane Methodology Register, the Health Technology Assessment (HTA) database, Canadian and members of the International Network of Agencies in Health Technology Assessment, as well as a focused Internet search for grey literature. The main search concepts were HTA and environmental impact/sustainability. No publication date limits or language limits were applied. A detailed literature search strategy can be found in Supplementary Table 1.

Eligibility Criteria

Eligible articles were those that described a conceptual framework or methods used to conduct an environmental assessment of health technologies, including the strengths and limitations of the framework or methods. Publications were also considered for inclusion if they presented a case study for the application of an environmental assessment of a health technology.

Screening and Selecting Studies for Inclusion

In accordance with the scoping review protocol utilized by Levac et al. (8), two independent reviewers (J.P. and M.S.) screened titles and abstracts of all citations retrieved from the literature search, using the aforementioned eligibility criteria.

The full texts of all citations deemed to be potentially eligible by either reviewer were retrieved. The reviewers then independently reviewed the full texts, using the same selection criteria as above and compared their list of included and excluded reports. Any disagreements were resolved through discussion until consensus was reached, involving a third reviewer when necessary (8;9). Documents deemed to be eligible by both reviewers, with or without third-party adjudication, were included (9).

Reviewers used Microsoft Excel to facilitate title and abstract screening, as well as full-text study selection. The study selection process is presented in a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart (10).

Data Collection and Abstraction

A standardized data abstraction form was used to extract data from the included articles. Relevant information included the study characteristics (e.g., first author name, publication year, country, and affiliated organization[s], type of publication), scope, and objectives. Additional data extracted include a description of the framework or methods used to conduct an environmental assessment of a health technology, and the strengths and limitations of the framework or method. If a case study was presented, the population, intervention, comparator(s), outcomes, study setting, framework or methods used to illustrate its application, the results, and overall conclusions were extracted.

Data abstraction were performed by one reviewer (M.S.), and verified by a second reviewer (G.D.A.). The data abstraction form was piloted on a random sample of two to three included articles, and modified as required. As an additional data cleaning step, a third reviewer verified all changes made by the second reviewer, to ensure data accuracy.

Methodological Quality Assessment

As our main objective was to identify and describe frameworks or methods used to perform or case studies of an environmental assessment for a health technology and not to test a hypothesis, a formal quality assessment or critical appraisal of the included articles was not conducted. Not appraising the methodological quality or risk of bias of the included articles is consistent with guidance on scoping review conduct (8;9;11;12).

Data Analysis

One reviewer (J.P.) conducted a descriptive analysis of the frameworks or methods used for an environmental assessment of a technology, and a second reviewer verified the results (G.D.A.). The data extracted were reviewed, categorized, and organized to synthesize common methodologies. The results were then compared and interpreted to identify underlying themes and patterns from the environmental assessment frameworks or methods.

RESULTS

Research Quantity Available

A total of 1,710 citations were identified in the literature search. Following screening of titles and abstracts, 1,685 citations were excluded and twenty-five potentially relevant reports from the electronic search were retrieved for full-text review. Three potentially relevant publications were retrieved from hand searching. Of these potentially relevant articles, fifteen publications were excluded for various reasons (Figure 1), while thirteen publications met the inclusion criteria and were included in this scoping review (13–23).

Of the publications reviewed at the level of full text, two reports presented a framework to incorporate environmental assessment in HTAs (13;8), two presented methods to conduct an evidence synthesis of environmental assessments (17;22), and the remaining papers addressed methods to assess the environmental impact of a technology, but not limited to health technologies. Upon review of these publications, the authors agreed these methods and frameworks can also lend themselves to the environmental assessment of a health technology. One study described both a method to assess the environmental impact of a health technology and presented a case study to illustrate an example (18).

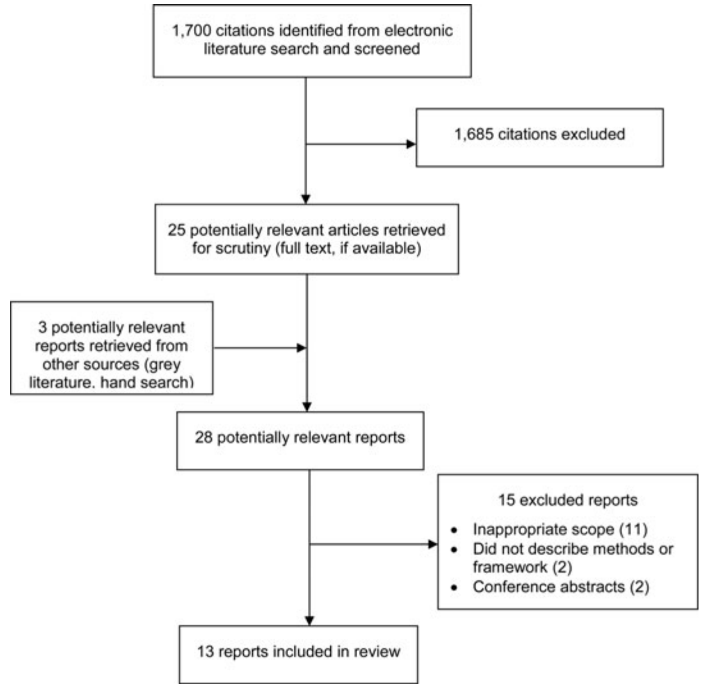

Figure 1. Selection of included studies.

Summary of Study Characteristics

Year of Publication and Country of Origin. The reports were published between 1979 (20) and 2017 (19;24;25). The majority of reports were published from 2009 onward (Table 1) (13–15;17–20;22;24;25). One study was published in 1979 (20) and another in 1980 (21).

In line with the location of corresponding authors, six reports were written in the United States (14;17;20;21;24;25), three in the United Kingdom (16;22), one each, in the United States, the United Kingdom, and Denmark (13), Germany and the United Kingdom (15), in the United Kingdom and United States (18), and in the United States, the United Kingdom, Germany, and Belgium (19).

Scope and Objectives. Four papers centered on the conduct of syntheses of environmental evidence (15;16;22;23). More specifically, one study presented recommendations on conducting information retrieval for ecological research syntheses (16), one guideline by the Collaboration for Environmental Evidence (CEE) described the methods for a systematic review (SR) on environmental evidence (22), and one study described a tool to critically appraise ecosystem services and conservation studies (15). Livoreil et al. published an updated version of the guidance on how to execute a systematic literature search (23).

Two papers described methods that can be incorporated in an HTA to estimate the environmental impact of health technologies (13;18), and one study illustrated an example on how to apply the method described in an HTA (18).

A set of papers described a taxonomy of weight-of-evidence (WoE) practices for environmental risk assessments and related areas (14). and proposed a streamlined strategy to integrate outcomes available in the evidence that can be applied in existing WoE methods (19). Suter et al. described the steps involved for inferring qualities and quantities in WoE (24;25).

Table 1. Study Characteristics

First author, year, country of publication, and reference number	Conceptual framework/ methodology/case study	Objective(s) of report	Name of framework/methods or case study illustrated
Suter, 2017, USA (24)	Conceptual framework/methodological report	To describe the framework for WoE of qualitative evidence that includes the systematic accumulation of information and generation of evidence, the weighting of the evidence, and the weighting of the body of evidence.	WoE for environmental assessments
Suter, 2017, USA (25)	Conceptual framework/methodological report	To describe the framework for WoE of quantitative evidence that includes the systematic accumulation of information and generation of evidence, the weighting of the evidence, and the weighting of the body of evidence.	WoE for environmental assessments
Hall, 2017, Germany, United States, Belgium, United Kingdom (19)	Conceptual framework/methodological report	The main overall objective for the study is to improve the methods used in risk assessments when evaluating single or multiple LoE. Specifically, the authors of the framework propose a streamlined strategy to integrate outcomes from several LoEs, with the goal of avoiding overlap and double accounting of criteria used in reliability and relevance with that used in current WoE methods.	WoE for assessment of ecotoxicological effects in regulatory decision making
Livoreil, 2017,United Kingdom (23)	Conceptual framework/methodological report	To provide guidance on the optimal search structure as the basis on which any evidence synthesis should be built	CEE Guidelines for Systematic Reviews in Environmental Management
Marsh, 2016, United States, United Kingdom, Denmark (13)	Conceptual framework/ methodological report	To outline the arguments for, and methodological implications of, incorporating environmental impacts into HTAs.	Measuring the environmental impact of health technologies (3 alternative strategies): 1) LCA 2) EEIOA 3) Process analysis of environmental impacts across the life cycle Evaluation methodologies (3 alternative strategies): 1) "Enriched" CUA 2) CBA 3) MCDA
Marsh, 2016, United Kingdom, United States (18)	Conceptual framework/methodological report and Case study of environmental assessment for a health technology	To describe a model to estimate the environmental impacts generated by an individual health technology, to illustrate how environmental impacts could be incorporated into HTAs, and to describe the challenges this approach is likely to pose.	Incorporation of Environmental Outcomes into a Health Economic Model: Carbon Dioxide Emission Estimations
Mupepele, 2016, Germany, United Kingdom (15)	Conceptual framework/methodological report	To provide an evidence assessment tool that provides a clear appraisal guideline to score the reliability of individual studies.	Evidence Assessment Tool for Ecosystem Services and Conservation Studies

Table 1. Continued

First author, year, country of publication, and reference number	Conceptual framework/ methodology/case study	Objective(s) of report	Name of framework/methods or case study illustrated
Hong, 2015, Korea (28)	Conceptual framework/methodological report	1) To promote the design and use of zero- or low-toxic chemical materials, and minimizing the production and emission of hazardous chemical substances by means of ecofriendly production process management. The evaluation of the level of compliance with the principles of green chemistry has been carried out only at a qualitative level, exposing the limitations in quantifying the greenness compared to the state prior to the implementation of green chemistry technologies. 2) To develop an evaluation technique that enables a quantitative assessment of the greenness of green chemistry technologies. The study also tests the validity of the assessment technique, by quantitatively assessing the greenness achieved in a case of material reutilization through the application of green chemistry. The assessment technique established in the study may potentially serve as a useful reference for setting the direction of industry-level and government-level technological research and design, and for evaluating newly developed technologies.	Techniques for Green Chemistry Technology Assessment
Bayliss, 2014, United Kingdom (16)	Conceptual framework/methodological report	To present ten recommendations for anyone considering undertaking information retrieval for ecological research syntheses, in order to aid in reduction of biases in the dataset retrieved, increase search efficiency, and improve reporting standards.	Checklist for Planning and Undertaking Systematic Information Retrieval for Ecological Syntheses
Collaboration for Environmental Evidence (CEE), 2013, United Kingdom (22)	Conceptual framework/methodological report	The guidelines are primarily aimed at those teams intending to conduct a CEE SR; however, they are guidelines only and do not replace formal training in SR methodology. The authors aim to have these guidelines be of use to those considering commissioning a SR and stakeholders who may become involved in their planning. Also, these guidelines set a standard for the conduct of SRs and are therefore intended for decision makers using evidence from SRs and wishing to understand the nature of the SR process.	Guidelines for Systematic Reviews and Evidence Synthesis in Environmental Management
Powers, 2012, United States (17)	Conceptual framework/methodological report	To describe the process of the CEASS framework, and how it builds upon and incorporates other available tools and approaches. It also describes this method's current application at the U.S. Environmental Protection Agency, and suggests how it could be extended in evaluating a major issue such as the sustainability of biofuels.	CEASS framework
Linkov, 2009, United States (14)	Conceptual framework/methodological report	To explore current application of WoE methods, with a focus on human health and ecological risk assessment. The goal of this study is to characterize current WoE practices within risk assessment and related areas. One of the intended purposes of this review paper is to encourage a dialogue on the subject of WoE among risk analysts and managers, with the expectation that such a dialogue will lead to advances in the development and use of quantitative WoE methods.	WoE
Porter, 1980, United States (21)	Conceptual framework/methodological report	1) To summarize the current state of these methodologies for the interested but uninvolved professional 2) To direct critical attention to emerging issues in the performance of impact assessment.	Integrated Environmental Impact Assessment for Technologies

Table 1. Continued

First author, year, country of publication, and reference number	Conceptual framework/methodology/case study	Objective(s) of report	Name of framework/methods or case study illustrated
Trevorrow, 1979, United States (20)	Conceptual framework/methodological report	1) To illustrate technology assessment 2) To provide an informative description of TA in the context of nuclear waste management.	The article briefly describes various methods and tools for performing TA: 1) Risk/benefit 2) Systems analysis 3) Input-output analysis 4) Trend analysis 5) Modeling and simulation 6) Scenarios and games 7) Fault tree analysis 8) Public participation 9) Social impacts

CBA, cost-benefit analysis; CEE, Collaboration for Environmental Evidence; CEASS, comprehensive environmental assessment; CUA, cost-utility analysis; EEIOA, environmentally extended input-output analysis; LCA, lifecycle assessment; LoE, lines of evidence; MCDA, multi-criteria decision analysis; SR, systematic review; TA, technology assessment; WoE, weight of evidence.

One study discussed a comprehensive environmental assessment (CEASS) as a holistic way to manage complex information, and to structure input from diverse stakeholder perspectives to support environmental decision making for the near- and long-term (17).

One described and reviewed some cases that involved the examination of an individual nuclear waste management technology by a recognized technology assessment (TA) method (20).

Another study described a model to conduct an integrated environmental assessment of a technology (21).

FRAMEWORKS OR METHODS

Overview of Frameworks/Methods

Incorporation of Environmental Impact in an HTA. To measure the environmental impact of a technology in an HTA, Marsh et al. recommend a life cycle assessment (LCA) of the technology, environmentally extended input-output analysis (EEIOA) to estimate carbon emissions generated by each unit of output in a sector, and the process analysis technique involves a detailed analysis of the environmental impacts across the life cycle, including the use of raw materials and energy consumption (13). The evaluation methodologies described were a cost−utility analysis (CUA), cost−benefit analysis (CBA) and multi-criteria decision analysis (MCDA). MCDA is a framework or tool used to address complex decisions that involve multiple criteria. It elicits from decision makers how they trade off outcomes when making decisions to determine the most preferred treatment option (Supplementary Table 2) (13).

In another publication, Marsh et al. demonstrated how environmental outcomes, such as carbon dioxide emissions, can be incorporated in an economic model for a single health technology. The example used included estimates for both the direct and indirect impacts on the environment in the IMS CORE Diabetes model for type 1 and type 2 diabetes, which is a validated patient-simulation model. The authors adapted the current model to estimate the carbon dioxide emissions level with the addition of insulin to an oral antidiabetic treatment in patients with type 2 diabetes over a 30-year period from the United Kingdom payer perspective (18).

Evidence Synthesis of Environmental Assessment of a Technology. Bayliss and Beyer provide an overview of the different stages of the SR process, suggestions on how to address potential biases in the ecological information retrieval process, question components of the population, intervention/exposure, comparator/control, outcome, and study design (PICOS and PECOS), setting, perspective, intervention, comparator, and evaluation method (SPICE) mnemonics and some types of resources related to information retrieval for ecological syntheses (16).

The CEE outlined seven steps in conducting SRs in environmental management. They include question setting, protocol development, literature searching, article screening, critical appraisal of the individual studies, and data extraction and syntheses, and report preparation of the SR (22). Livoreil et al. outlined the steps and details on the search for the evidence. They include planning, conducting, managing, reporting, and updating and amending a search (23).

The main components of the evidence assessment tool for appraisal of ecosystem services and conservation studies as described by Mupepele et al. involves the identification of the study question, design and outcome, an assessment of the level of evidence captured in a framework of hierarchy ranking, and a critical appraisal of the implementation of the methodological quality and realization of the study design (15).

Environmental Assessment of a Technology. WoE is a framework used to synthesize and weigh the evidence from multiple data sources with qualitative and quantitative methods (19). Three main steps involved in the WoE approach are the assembly of the evidence, and weight of evidence and of the body of evidence for each alternative result. The weighted alternatives are then compared (24;25). The methods within WoE include: a presentation of individual lines of evidence, quantitative integration of multiple lines of evidence, determining cause and effect relationships, a standardized evaluation of individual lines of evidence based on qualitative logic models, simple weighting or ranking of multiple lines of evidence, an integration of lines of evidence into a single measure based on empirical models, and an integrated assessment using formal decision analysis and statistical methods (14).

Another paper on WoE indicated that studies that were deemed to be highly relevant and reliable should be assigned the highest weight in the risk assessment. As well, studies with medium relevance and reliability provide support, and studies with low relevance and reliability can be used qualitatively in the risk assessment or not at all (19). Estimates from multiple data sets can be pooled in a single estimate if they are relevant and reliable (25).

The CEASS framework is an integration of other risk assessment methods, including life-cycle based approaches, decision support techniques, and CBA. The framework considers the releases of the primary and associated materials under assessment, as well as physical, chemical, biological, and social factors. Furthermore, the exposure-dose and uptake that can affect humans, other biotia, or abiotic resources are part of the framework (17).

Trevorrow and Steindler's study presented a description of a TA in the context of nuclear waste management (20). The methods highlighted are as follows: risk/benefit, systems analysis, input–output analysis, trend analysis, modeling and simulation, scenarios and games, fault tree analysis, public participation, and social impacts. In summary, the assessment incorporates the exposure, costs, systems perspectives, estimation for reliability and failures, input from the public, and social impact on nuclear waste management (20).

The ten components in an integrated environmental assessment of technology include problem definition/bounding, a technology description, a technology forecast that aims to predict and synthesize the character, intensity, and timing of changes in technologies, descriptions of the state of society with respect to its relationship with the technology(ies) in question, and social forecasts that intend to predict changes in society. Additional components involve impact identification, analysis (e.g., environmental modeling and CBA), and evaluation to compare the alternatives and support policy analysis to identify the pros and cons of alternatives for implementing technological developments. Porter and Rossini indicated that policy analysis was a most important component in the model, and stressed the importance of the communication with the target audience over the course of the study (21).

Strengths of Frameworks/Methods as Described by the Authors

Aspects of several frameworks and methods previously described incorporate familiar concepts (e.g., input-output analysis, modelling and simulation) and are comprehensive (e.g., public participation and consideration of social impact) (20). consideration of social impact) (20). In the HTA field, there is also familiarity with CUA and CBA methods and, to a lesser degree, to feed the needs of information of MCDA models. Furthermore, LCA considers the implications of resources throughout the technology lifecycle, and EEIOA estimates the carbon emissions generated by each unit of output in a sector (13).

MCDA-based WoE is straightforward to communicate with decision makers and the public. One of its main advantages lies in the integration of lines of evidence and the ability to evaluate the sensitivity of conclusions to changes in specific parameters or logic used to perform the integration (14). The combination of qualitative and quantitative data helps to ensure that relevant data are assessed and provides some context for the quantitative results (25).

The critical appraisal method allows for the opportunity to rate the strength of evidence to clarify the reliability of the search results and the strength of conclusions, decisions, or recommendations from the results (15).

The CEASS framework is a transparent approach that incorporates both quantitative and qualitative information and various stakeholder perspectives in the analysis. It also presents the trade-offs and prioritization related to different technology options (17).

Limitations of Frameworks/Methods as Described by the Authors

It is not uncommon that the availability of environmental data across the lifecycle process for a technology is insufficient, so it can be a challenge to deliver accurate and comprehensive results for LCA and process analysis. Furthermore, EEIOA may be narrow in scope as it concentrates on carbon emissions at the sector level, CUA may not capture nonhealth benefits, and the use of MCDA for HTAs is still rather limited even though the use is increasing (13).

There are concerns about the lack of sufficient objectivity, certainty, transparency, repeatability, and consistency in the approaches used to integrate lines of evidence on environmental risks as there is no scientific consensus on the most appropriate integrative approach (14). Conversely, a formal application of the standard WoE approach can enhance the accuracy, transparency, defensibility, flexibility, and confidence in the results of the assessment (24;25). Hierarchies of evidence can be rigid and controlled trials may not always be more reliable than observational studies, generalizability of results is problematic in ecosystems, and may not always apply to specific circumstances (15).

The literature retrieval methods for an ecological synthesis can be challenging and resource intensive (16). Similar to SRs on health technologies, evidence syntheses are relevant as long as the individual primary studies are up to date. An outdated SR may be misleading, so they should periodically be updated (22;23).

For the CEASS framework, a structured and efficient approach is recommended to solicit input from participants in the judgement process to ensure that all perspectives are considered (17). It remains uncertain on how to appropriately present environmental data to healthcare decision makers and how they will use these data on the environmental impact of health technologies (17). If the data are not readily available, the exercise to acquire them can be labor intensive.

DISCUSSION

We conducted a scoping review of thirteen publications on the frameworks or methods used to measure the environmental impact of a technology. Two reports were published in 1980 or prior, and the remaining reports were published in 2009 onward. These figures suggested that environmental issues may be becoming more prominent in the design, production, utilization, and disposal of a technology.

Based on the frameworks and methods identified, there are several approaches to assess the environmental impact of a technology. They were categorized into three broad categories: the incorporation of an environmental impact in an HTA, evidence synthesis of environmental impact of a technology, and environmental assessment of a technology. This result can in part be related to the different foci addressed by these frameworks and methods as well as their authors, such as environmental scientists, health economists, and engineers.

Central themes to the characteristics of these frameworks and methods include transparency and repeatability, integration of components in a framework or of evidence into a single outcome, data availability to ensure the accuracy of findings, and familiarity with the approach used. The authors also cautioned that some of the methods can be labor-intensive and time-consuming to complete. Furthermore, the perspective that considers the environmental assessment of the entire lifecycle of a technology aligns with the health technology management scope that encompasses multiple technologies in a patient's clinical care pathway.

From an economic perspective, Marsh et al. indicated that the inclusion of environmental outcomes in an HTA is an important consideration as it would be in-scope for assessments that are already done from a societal perspective, and it would align with healthcare decision-makers' interest in maximizing the broader social welfare benefits and goal to improve the population health (13).

Limitations

Our scoping review is not without its limitations. The literature search of published studies and the gray literature focused on key resources in the medical field as our primary objective was to identify frameworks, methods, or case studies associated with health technologies and the environment. Although no publication date or language limits were applied, it is possible our search did not identify publications that may have been relevant to our scoping review as some publications may not be available in standard biomedical literature databases. In fact, we did not identify any studies that evaluated the environmental impact of a health technology throughout its product lifecycle. Medical devices, diagnostics, public health interventions, and drugs can also have an environmental impact in other sectors. For instance, the administration of drugs in cattle raising has been described as one of the factors that influence the increasing incidence of certain pathologies, such as antibiotic resistance (26). These aspects should be further explored in the so interconnected societies in which most citizens of the world are living.

Directions for Future Research

Our findings confirm and expand on a previous publication by Gilli on HTA in public health to protect the environment. The author concluded that methods and tools exist, but additional research is necessary to render them relevant to evaluate the impact of technologies on the environment and human health to support informed decision making (27). A structured focus group with HTA producers, decision makers, environmental scientists, clinical and biomedical engineers with an agenda and explicit objectives can help to better understand the most appropriate methods and processes to address the environmental impact question in an HTA.

An investigation of other sectors that involve an environmental assessment of technologies, such as transport and machinery, may be warranted to determine the feasibility and appropriateness of applying these processes and methods in an HTA. Moreover, HTA producers in collaboration with the decision makers can develop a checklist on how to determine the level of analysis required for the environmental assessment of the technology(ies) in question (i.e., some technologies will have more of an environmental impact than others) and at different stages of their lifecycle).

CONCLUSIONS

Health technologies play an important role in the sustainability of the environment. Our scoping review is an initial step of a larger initiative by CADTH to develop processes and methods to address the environmental impact question in an HTA. The findings in this review revealed that there are numerous perspectives in assessing the environmental impact of a technology. Each framework and methods can have different foci that are related to the ecosystem, health economics, or engineering practices. The frameworks and methods described in this review suggested transparency, repeatability, and the integration of components or of evidence into a single outcome as their main strengths. Their adoption and accuracy will depend primarily on the familiarity with the approach used and the data availability for the assessment.

SUPPLEMENTARY MATERIAL

Supplementary Table 1:
https://doi.org/10.1017/S0266462318000351.
Supplementary Table 2:
https://doi.org/10.1017/S0266462318000351.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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