SUPPLEMENTARY TABLE 1: LITERATURE SEARCH STRATEGY

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| --- | --- |
| **OVERVIEW** |  |
| Interface: | Ovid |
| Databases: | MEDLINE Daily and MEDLINE (1946-)Ovid MEDLINE Epub Ahead of Print, In-Process & Other Non-Indexed CitationsEmbase (1974- )EBM Reviews - Cochrane Methodology Register (3rd Quarter 2012)EBM Reviews - Health Technology Assessment (4th Quarter 2016) **Note:** Subject headings have been customized for each database. Duplicates between databases were removed in Ovid. |
| Date of Search: | July 2017 |
| Alerts: | Monthly search updates until December 2017 |
| Study Types: | No limits |
| Limits: | Publication years: no limitsLanguage limit: no limits |
| **SYNTAX GUIDE** |  |
| / | At the end of a phrase, searches the phrase as a subject heading |
| MeSH | Medical Subject Heading |
| exp | Explode a subject heading |
| \* | Before a word, indicates that the marked subject heading is a primary topic; or, after a word, a truncation symbol (wildcard) to retrieve plurals or varying endings |
| adj# | Adjacency within # number of words (in any order) |
| .ti | Title |
| .ab | Abstract |
| .mp | Multi-purpose fields |
| .hw | Heading Word; usually includes subject headings and controlled vocabulary  |
| .kf | Author keyword heading word (MEDLINE & Cochrane Methodology Register) |
| .kw | Author keyword (Embase) |
| .jw | Journal word |
| .pt | Publication type |
| .tx | Text field (Health Technology Assessment database) |
| freq=# | Term must appear # number of times or more |
| ppez | Ovid database code; MEDLINE Epub ahead of print, In-Process & Other Non-Indexed Citations, MEDLINE Daily and Ovid MEDLINE 1946 to Present |
| oemezd | Ovid database code; Embase 1974 to present, updated daily |
| clhta | Ovid database code; Health Technology Assessment database |
| clcmr | Ovid database code; Cochrane Methodology Register |
| **Ovid Multi-Database Strategy** |
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| --- | --- |
| **#** | **Searches** |
| 1 | meta-analysis.pt. |
| 2 | meta-analysis/ or systematic review/ or meta-analysis as topic/ or "meta analysis (topic)"/ or "systematic review (topic)"/ or exp technology assessment, biomedical/ |
| 3 | ((systematic\* adj3 (review\* or overview\*)) or (methodologic\* adj3 (review\* or overview\*))).ti,ab,kf,kw. |
| 4 | ((quantitative adj3 (review\* or overview\* or synthes\*)) or (research adj3 (integrati\* or overview\*))).ti,ab,kf,kw. |
| 5 | ((integrative adj3 (review\* or overview\*)) or (collaborative adj3 (review\* or overview\*)) or (pool\* adj3 analy\*)).ti,ab,kf,kw. |
| 6 | (data synthes\* or data extraction\* or data abstraction\*).ti,ab,kf,kw. |
| 7 | (handsearch\* or hand search\*).ti,ab,kf,kw. |
| 8 | (mantel haenszel or peto or der simonian or dersimonian or fixed effect\* or latin square\*).ti,ab,kf,kw. |
| 9 | (met analy\* or metanaly\* or technology assessment\* or HTA or HTAs or technology overview\* or technology appraisal\*).ti,ab,kf,kw. |
| 10 | (meta regression\* or metaregression\*).ti,ab,kf,kw. |
| 11 | (meta-analy\* or metaanaly\* or systematic review\* or biomedical technology assessment\* or bio-medical technology assessment\*).mp,hw. |
| 12 | (medline or cochrane or pubmed or medlars or embase or cinahl).ti,ab,hw. |
| 13 | (cochrane or (health adj2 technology assessment) or evidence report).jw. |
| 14 | (comparative adj3 (efficacy or effectiveness)).ti,ab,kf,kw. |
| 15 | (outcomes research or relative effectiveness).ti,ab,kf,kw. |
| 16 | ((indirect or indirect treatment or mixed-treatment) adj comparison\*).ti,ab,kf,kw. |
| 17 | or/1-16 |
| 18 | exp \*Environmental Pollution/ or exp \*Environmental Pollutants/ or \*Ecotoxicology/ or exp \*Ecosystem/ or exp \*Environmental health/ |
| 19 | exp \*Hazardous substances/ and environment\*.ti,ab,kf. |
| 20 | (waste\* or pollution\* or polluting or pollutant\* or contamination\* or contaminated or environmental health).ti,kf. |
| 21 | ((hazardous or toxic or toxicity or toxin or toxins or risk or risks or impact or impacts) adj5 environment\*).ti,ab,kf. |
| 22 | (natural environment\* or soil or soils or flora or floras or fauna or faunas or renewable resource\*).ti,kf. |
| 23 | or/18-22 |
| 24 | 17 and 23 |
| 25 | methodolog\*.ti,kf,hw. |
| 26 | methodolog\*.ab. /freq=2 |
| 27 | (guideline or practice guideline or consensus development conference or consensus development conference, NIH).pt. |
| 28 | (guideline\* or standards or consensus\* or recommendat\*).ti. |
| 29 | (practice parameter\* or position statement\* or policy statement\* or CPG or CPGs or best practice\*).ti. |
| 30 | (care adj2 (path or paths or pathway or pathways or map or maps or plan or plans or standard)).ti. |
| 31 | ((critical or clinical or practice) adj2 (path or paths or pathway or pathways or protocol\*)).ti. |
| 32 | (algorithm\* and (pharmacotherap\* or chemotherap\* or chemotreatment\* or therap\* or treatment\* or intervention\*)).ti. |
| 33 | (algorithm\* and (screening or examination or test or tested or testing or assessment\* or diagnosis or diagnoses or diagnosed or diagnosing)).ti. |
| 34 | or/25-33 |
| 35 | 24 and 34 |
| 36 | (environment\* adj5 sustainabilit\*).ti,ab,kf. |
| 37 | (environment\* adj2 (assess\* or impact\* or outcome\* or implication\* or consideration\*)).ti,ab,kf. |
| 38 | carbon footprint\*.ti,ab,kf. |
| 39 | or/36-38 |
| 40 | 17 and 39 |
| 41 | exp technology assessment, biomedical/ and exp \*environment/ |
| 42 | ((health technology assessment or HTA or HTAs) and environmental\*).ti,ab,kf. |
| 43 | ((health technology assessment or HTA or HTAs) adj7 environment).ti,ab,kf. |
| 44 | 35 or 40 or 41 or 42 or 43 |
| 45 | 44 use ppez |
| 46 | meta-analysis/ or systematic review/ or meta-analysis as topic/ or "meta analysis (topic)"/ or "systematic review (topic)"/ or exp technology assessment, biomedical/ |
| 47 | ((systematic\* adj3 (review\* or overview\*)) or (methodologic\* adj3 (review\* or overview\*))).ti,ab,kf,kw. |
| 48 | ((quantitative adj3 (review\* or overview\* or synthes\*)) or (research adj3 (integrati\* or overview\*))).ti,ab,kf,kw. |
| 49 | ((integrative adj3 (review\* or overview\*)) or (collaborative adj3 (review\* or overview\*)) or (pool\* adj3 analy\*)).ti,ab,kf,kw. |
| 50 | (data synthes\* or data extraction\* or data abstraction\*).ti,ab,kf,kw. |
| 51 | (handsearch\* or hand search\*).ti,ab,kf,kw. |
| 52 | (mantel haenszel or peto or der simonian or dersimonian or fixed effect\* or latin square\*).ti,ab,kf,kw. |
| 53 | (met analy\* or metanaly\* or technology assessment\* or HTA or HTAs or technology overview\* or technology appraisal\*).ti,ab,kf,kw. |
| 54 | (meta regression\* or metaregression\*).ti,ab,kf,kw. |
| 55 | (meta-analy\* or metaanaly\* or systematic review\* or biomedical technology assessment\* or bio-medical technology assessment\*).mp,hw. |
| 56 | (medline or cochrane or pubmed or medlars or embase or cinahl).ti,ab,hw. |
| 57 | (cochrane or (health adj2 technology assessment) or evidence report).jw. |
| 58 | (comparative adj3 (efficacy or effectiveness)).ti,ab,kf,kw. |
| 59 | (outcomes research or relative effectiveness).ti,ab,kf,kw. |
| 60 | ((indirect or indirect treatment or mixed-treatment) adj comparison\*).ti,ab,kf,kw. |
| 61 | or/46-60 |
| 62 | exp \*pollution/ or exp \*pollutant/ or \*environmental exposure/ or exp \*environmental impact/ or \*ecotoxicology/ or \*exp biota/ or exp \*environmental health/ |
| 63 | (waste\* or pollution\* or polluting or pollutant\* or contamination\* or contaminated or environmental health).ti,kw. |
| 64 | ((hazardous or toxic or toxicity or toxin or toxins or risk or risks or impact or impacts) adj5 environment\*).ti,ab,kw. |
| 65 | (natural environment\* or soil or soils or flora or floras or fauna or faunas or renewable resource\*).ti,kw. |
| 66 | or/62-65 |
| 67 | 61 and 66 |
| 68 | methodolog\*.ti,kw,hw. |
| 69 | methodolog\*.ab. /freq=2 |
| 70 | (guideline\* or standards or consensus\* or recommendat\*).ti. |
| 71 | (practice parameter\* or position statement\* or policy statement\* or CPG or CPGs or best practice\*).ti. |
| 72 | (care adj2 (path or paths or pathway or pathways or map or maps or plan or plans or standard)).ti. |
| 73 | ((critical or clinical or practice) adj2 (path or paths or pathway or pathways or protocol\*)).ti. |
| 74 | (algorithm\* and (pharmacotherap\* or chemotherap\* or chemotreatment\* or therap\* or treatment\* or intervention\*)).ti. |
| 75 | (algorithm\* and (screening or examination or test or tested or testing or assessment\* or diagnosis or diagnoses or diagnosed or diagnosing)).ti. |
| 76 | or/68-75 |
| 77 | 67 and 76 |
| 78 | (environment\* adj5 sustainabilit\*).ti,ab,kw. |
| 79 | (environment\* adj2 (assess\* or impact\* or outcome\* or implication\* or consideration\*)).ti,ab,kw. |
| 80 | carbon footprint\*.ti,ab,kw. |
| 81 | or/78-80 |
| 82 | 61 and 81 |
| 83 | exp biomedical technology assessment/ and environment\*.ti,kw. |
| 84 | ((health technology assessment or HTA or HTAs) and environmental\*).ti,ab,kw. |
| 85 | ((health technology assessment or HTA or HTAs) adj7 environment).ti,ab,kw. |
| 86 | 77 or 82 or 83 or 84 or 85 |
| 87 | 86 use oemezd |
| 88 | exp \*Environmental Pollution/ or exp \*Environmental Pollutants/ or \*Ecotoxicology/ or exp \*Ecosystem/ or exp \*Environmental health/ |
| 89 | exp \*Hazardous substances/ and environment\*.ti,ab,kf,tx. |
| 90 | (waste\* or contamination\*).ti,kf. |
| 91 | (pollution\* or polluting or pollutant\* or contaminated or environmental health).ti,ab,kf,tx. |
| 92 | ((hazardous or toxic or toxicity or toxin or toxins or risk or risks or impact or impacts) adj5 environment\*).ti,ab,kf,tx. |
| 93 | (natural environment\* or soil or soils or flora or floras or fauna or faunas or renewable resource\*).ti,ab,kf,tx. |
| 94 | (environment\* adj5 sustainabilit\*).ti,ab,kf,tx. |
| 95 | (environment\* adj2 (assess\* or impact\* or outcome\* or implication\* or consideration\*)).ti,ab,kf,tx. |
| 96 | carbon footprint\*.ti,ab,kf,tx. |
| 97 | environment\*.ti,kf. |
| 98 | environmental\*.ab,tx. |
| 99 | or/88-98 |
| 100 | 99 use clhta |
| 101 | 99 use clcmr |
| 102 | 45 or 87 or 100 or 101 |
| 103 | remove duplicates from 102 |

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| **OTHER DATABASES** |
| PubMed | A limited PubMed search was performed to capture records included in the Systematic Reviews Methods subset (sysrev\_methods [sb]) that deal with the environment. Same MeSH and keywords used as per environmental section of MEDLINE search, with appropriate syntax. |  |

# Grey Literature

|  |  |
| --- | --- |
| Dates for Search: | June/July 2017 |
| Keywords: | Environment; health technology assessment; health technology |
| Limits: | No limits |

Relevant websites from the following sections of the CADTH grey literature checklist *Grey Matters: a practical tool for searching health-related grey literature* (<https://www.cadth.ca/grey-matters>) will be searched:

* Health Technology Assessment Agencies
* Databases (free)
* Internet Search

The Institute of Health Economics’ *Health Technology Assessment on the Web: 2016* (<http://www.ihe.ca/publications/health-technology-assessment-on-the-net-2016>) will also be searched.

**SUPPLEMENTARY TABLE 2: DESCRIPTION, STRENGTHS AND LIMITATIONS OF FRAMEWORKS/METHODS AS PER THE AUTHORS**

| **First author** | **Name and Description of Framework/Methods** | **Strengths of Frameworks/Methods as per the Authors**  | **Limitations of Frameworks/Methods as per the Authors** |
| --- | --- | --- | --- |
| Suter, 2017, USA(24) | Weight of Evidence Framework-Inferring QualitiesWoE has 3 steps:* Evidence is assembled
	+ Search literature
	+ Design and conduct studies
	+ Screen
	+ Categorize
	+ Derive evidence
* Evidence is weighted
	+ Weight relevance
	+ Weight strength
	+ Weight reliability
	+ Combine weights
* Body of evidence for each alternative result is weighed, and the weighed alternatives are compared.
	+ Integrate evidence
	+ Interpret bodies of evidence
	+ Explain ambiguities and discrepancies

The properties of the evidence are weighed based on the relevance, reliability, and strength.The standard tool used to weigh the evidence is the scoring table. The individual components of the evidence for a hypothesis are scored with respect to the properties and the overall weight. The judgements of evidence that are heterogeneous tend to be subjective, but guidance on scoring can also be developed. | * WoE provides increased confidence in the results as all the relevant and reliable evidence is reviewed.
* WoE is a formal process that involves the consideration of all relevant evidence.
* WoE increases transparency of the assessment.
 | * WoE can be time consuming and resource intensive.
* WoE process may be unclear or complex to some readers. The summary of findings or conclusions, therefore, may be presented upfront or the main body of the report. Details or large WoE tables can be presented in the appendix.
 |
| Suter, 2017, USA(25) | Weight of Evidence Framework-Inferring Quantities(see Suter(24) for description of the 3 steps in the process)If the quantitative estimates from multiple data sets are relevant and reliable, they can be pooled in a meta-analysis.The best estimate can also be derived from the weights of high quality studies when the relevance or reliability of the estimates varies across the studies.The estimates can be weighted and meta-analyzed to derive a single point estimate or it can be weighted to identify the highest quality estimate. | * Linking both the qualities and quantities reduces the risk of answering the incorrect questions; helps to ensure that relevant data are being assessed and provides a context for the quantitative results.
* The process provides some flexibility compared with the standard method that can result in more accurate results.
* This approach can provide increased accuracy, transparency, defensibility, flexibility, and confidence in the results of the assessment.
 | * The flexibility can imply subjectivity and inconsistent methods. These risks can be minimized with a standard WoE framework
 |
| Hall(19) | The data are first integrated according to LoEs, and then are scored or categorized on the basis of both their relevance within a LoE and their reliability. **Definitions of key terms:** * ***Reliability criteria:*** The inherent quality of an effect value in a test report or publication relating to: (1) a clearly described experimental design to allow for the study to be repeated independently, (2) the way the experimental procedure were performed, and (3) the reporting of the results to provide evidence of the reproducibility and accuracy of the findings.
* ***Relevance criteria:*** Relevance assessment can be divided into 3 categories:regulatory relevance (fit for purpose to the regulatory framework, protection goal, and assessment endpoints),biological relevance (i.e., related to the test species or response function), and exposure relevance (i.e., related to the exposure route or dynamics).

Studies that are found to be both reliable and relevant should carry the greatest weight in the risk assessment. Highly relevant and reliable studies may be used as the primary information, and those studies with mixed scores (medium relevance and reliability) provide corroborative support, whereas studies with low scores for both reliability and relevance should likely only be used qualitatively rather than quantitatively, or not used at all. This depends on both the regulatory context and the amount of data available as well.The body of evidence should be presented visually, using either a matrix for categorical scores, or a graph, if continuous values are derived when assessing the reliability and relevance of individual studies. Each study is plotted within the line of evidence to which it belongs according to its relevance as the abscissa and reliability as the ordinate. **The WoE assessment process should involve the following steps:** * Review protection goals and develop the framework for the risk assessment (i.e., problem formulation, assessment endpoints, risk hypothesis).
* Develop an a priori protocol for transparency and consistency. It may be desirable to develop a process whereby these protocols are published, peer-reviewed, or open to stakeholder consultation to further enhance the clarity in the approach taken.
* Perform a well-documented literature search and gather other regulatory studies conducted for the assessment according to a systematic review process. If any preliminary screening is performed, then justification needs to be provided and documented, as well as assurance that compliance standards have been met.
* Assess relevance and reliability of individual selected studies (i.e., using a rubric or scoring system).
* Integrate and evaluate the evidence according to predetermined specific LoE. For an effects characterization, LoEs can be divided into broad generic study types.
* Integrate and evaluate the evidence across LoEs to help understand the relative importance of individual LoEs to the risk hypothesis or assessment endpoints. The end result is a characterization of the credibility of the overall body of evidence with regard to the original hypothesis.
* Prepare an assessment of uncertainty that considers each step during the LoE assessment and identifies the influence of uncertainty on the overall conclusions. The uncertainties should be summarized at the conclusion of the assessment.

***Note:*** *The choice of methods for each step is open to adaptation.* | * When conducted cooperatively with all stakeholders, the authors suggest that this improved WoE process will lead to more transparent risk assessment and management decisions, identifying remaining uncertainties and any additional testing needs.
* The framework should also facilitate reproducible assessments of data across different regulatory requirements.
* Performing the assessment using the recommended graphical approach provides a means to visually assess and communicate the credibility (reliability and relevance of available individual studies), quantity, diversity, and consistency of the evidence.
* The graphical format allows one to examine the overall suite of data available, and thus the ability to easily discern trends in the data and potentially sensitive taxonomic groups.
* The graphical format is also helpful in deriving an expression of the confidence in the conclusions of the integration of the information.

Performing sensitivity analyses excluding different clusters of studies (i.e., high reliability, low relevance) could be especially useful to detect how these may influence the conclusions of the WoE assessment. | * Several barriers have hampered the widespread, consistent use of WoE methods in general, especially in the context of evaluating data from both ecotoxicological and environmental studies. Such barriers include: lack of guidance or lack of familiarity with existing guidance, the differing goals dictated by regulatory frameworks, the additional time and resources required, and the desire for consistency and recalcitrance toward change.

Though the streamlined nature of this revised WoE methodology, in combination with its unique graphical format, should ideally help to overcome several of the limitations seen with traditional WoE, the connotations associated with the tradition WoE methodology may negatively influence researchers’ willingness to endorse this method, thus hindering widespread usage. |
| Livoreil(23) | Detailed steps for systematic searching for environmental evidence are provided. The following steps are described:Planning the search:* + Establishing a test-list
	+ Identifying search terms
	+ Identifying relevant sources of articles
	+ Choosing bibliographic management software
	+ Addressing the need for grey literature
	+ Submitting the search strategy in the protocol for peer-review

Conducting the search* Prioritizing bibliographic sources
* Building the search string
* Assessing retrieval performance
* Refining the results
* Searching the grey literature
* Additional approaches: hand-searching, snowballing, and citation searching

Managing references and reporting the search* Keeping track of the search strategy and recording results
* Reporting the final search strategy and findings

Updating and amending searches:* Do you have access to the original search strings, sources, and can you read these files (proper software available)?
* Was the original search protocol adequate and appropriate or does it need revising?
* Do you know when the initial search took place and which time boundaries were set up at the time? If not, can you contact the authors to get those details?
* If relevant, do you have similar details regarding searches in grey literature?
* If relevant, do you access to the sources of documents (e.g., database platforms), including institutional websites, subscriptions?
* Will the same languages be used?
 | * This paper provides an in depth description of how to best perform and manage systematic searches specifically for environmental evidence
* Detailed steps and instructions are provided for each phase of the systematic search
* The guidance is aimed at all those who intend to conduct systematic evidence synthesis

Examples of databases and grey literature tools are provided | * Results of the literature search are also dependent on how the publications are categorized in the databases
 |
| Marsh(13) | **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
 | **Measuring the environmental impact (3 alternative strategies):**1. LCA potentially considers the implications of resources used throughout the care pathway.
2. EEIOA is relatively efficient (in comparison to process analysis), and represents an interdependence between different parts of the economy, providing insights into inputs required to deliver one unit of output in a particular sector.
3. Process analysis has the ability to overcome some of the key challenges presented with LCA and EEIOA methods. This method offers greater accuracy and ability to discriminate between treatments (in comparison to EEIOA).

**Evaluation methodologies (3 alternative strategies):**1. Many HTA agencies are already familiar with the CUA process
2. CBA has been regularly used to inform decision making since the 1960s; including within environmental policy. Evidence base necessary to support the application of CBA to environmental outcomes is well established.
3. MCDA is commonly used in environmental assessments, and has recently received much attention in health care circles for its ability to support valuation and decision making in the context of multiple outcomes.
 | **Measuring the environmental impact (3 alternative strategies):**1. With LCA, it is important that the assessment of environmental impact considers the implications of resources used throughout the care pathway. However, for example, in the Healthcare Energy Impacts Calculator, the tool does not capture all the environmental impacts of healthcare, just those associated with energy impacts at the point of care, by specifically only estimating the environmental characteristics of electric power, using publically-available data generated at a sector level. The limited availability of environmental data, at each intermediary level of the life-cycle process, is a key technical challenge that serves as a barrier to making this method plausible to execute accurately and comprehensively.
2. EEIOA provides only a narrow picture of environmental impact because it focuses on carbon emissions; it provides data only at a sector level. Given that the purpose of HTA is to evaluate health technologies, a method is required that can estimate the variation in environmental impact between different types of health care expenditure.
3. Performing a process analysis of environmental impacts generated across the life cycle of a product demands a large amount of data. Thus, this technique requires significant effort to collect the data for all the resource use associated with a single treatment pathway, as would be covered in a single HTA. Furthermore, if performing estimates of the effects on the management of disease, the environmental impact needs to be estimated for both the existing and potential substation technology, to do a proper comparison of existing methods versus alternatives. Thus, the time consuming and technical task of process analysis would essentially have to be done twice, doubling the time and resource burden.

**Evaluation methodologies (3 alternative strategies):**1. CUA is likely to pose a number of technical challenges; further work required to determine the feasibility of using this method. If deemed feasible, this approach would still have the limitation of not capturing the broader, non-health benefits of reduced environmental impacts.
2. Models of the economic value of environmental outcomes are subject to significant uncertainty and debate (i.e., SCC). If the CBA is to draw on SCC estimates, further work is required to determine policymakers’ preferred SCC methods. If the preferred method is to model the impacts of environmental gains and then estimate the monetary value of these impacts, the technical challenges of modeling these impacts need to be addressed. Alternatively, monetary variations could be elicited for the environmental impacts, though this would place the burden of understanding the implications of these environmental impacts on those participating in the valuation exercise. Also, CBA is not widely accepted among HTA agencies- this limited uptake may reflect the challenges associated with placing a monetary value on nonmarket goods such as health or environmental effects.
3. Valuation of environmental impacts within an MCDA can take place either before or after modelling the implications of the impacts on, for instance, health. Incorporating such impacts places the burden of understanding the value of change in environmental outcomes on the stakeholders involved in the MCDA. Application of MCDA to HTA is very limited, to date. The novelty of MCDA presents obstacles to its use in HTA, in part due to the lack of established best practices to guide its application.
 |
| Marsh(18) | ***Conceptual Framework/Methodological Report***The economic model adapted to the environmental impact extends the capacities of 1) treatment-related costs, as well as 2) disease management and complications-related costs, by estimating the carbon intensities generated by both, and thus the amount of carbon dioxide emissions. A treatment has both direct and indirect impacts on the environment. Direct effects are generated as a consequence of the raw materials consumed, as well as waste and emissions generated during the manufacturing, distribution, and use of the treatment. Indirect effects are generated as a result of a treatment’s health outcomes, which will impact a patient’s need for other treatments and services, each of which generates environmental impacts through its manufacture, distribution, and use. Both types of environmental impact are considered by the model.The IMS CORE diabetes model, a validated patient-simulation model, was used to assess the impact of the treatments on healthcare costs and health-related quality of life (HRQL) over a 30-year time horizon.***Case Study of Environmental Assessments of a Technology****Health technology assessed:* Insulin treatment for T2DM is the focus of this case-study assessment. Specifically, the model considers two treatment regimens: an OAD medication, and the addition of basal insulin therapy to this OAD regimen.*Study settings:* The case study was developed from a United Kingdom payer perspective.*Framework or method used:* The authors adapted an existing clinical-economic model to include environmental outcomes (CO2 emissions) to predict the consequences of adding insulin to an OAD regimen for patients with T2DM over 30 years, from the United Kingdom payer perspective. A scenario analysis was performed to explore the impact of parameter uncertainty.The model offered one approach for incorporating environmental outcomes into health economic analyses, to support a decision-maker’s objective of reducing the environmental impact of health care.  | * This study reports a simple method for incorporating environmental impacts into a health economic analysis, and provides a detailed application of this model to the subject of a potential HTA (insulin treatment).
* The technique of estimating the CO2 emissions generated by the associated healthcare resources using CO2 intensity, as performed in the case study; is not specific to the IMS CORE model. That model was used because it is a validated health economic model that fits the diabetes exemplar case study; the same approach could be applied to other health economic models.
 | * Data on environmental impact in a form that could be incorporated into the model was only available for CO2 emissions; this is incredibly limiting to only the effects on the environment that are seen at the point-of-care directly (as opposed to throughout the product life-cycle), and to only one means of environmental impact.
* CO2 emissions data were not available at a sufficiently disaggregated level to isolate the impact of individual treatments. Specifically, CO2 intensity data are available only for top-level healthcare resource categories, such as acute and primary care services and pharmaceuticals. Because these categories cannot yet be directly mapped to the relevant diabetes-related complications, the authors used the general healthcare CO2 intensity data to estimate CO2 emissions. These CO2 intensity data capture only a portion of the environmental impacts associated with HCRU and do not reflect the variation in environmental impact of HCRU for different types of complications.
* Further work is required to generate better estimates of the CO2 intensity of healthcare resource use that are specific to the treatment pathways for specific complications, and to generate measures of environmental impacts beyond just CO2 emissions.
* Although service-specific CO2 intensity estimates could improve the accuracy of the model, they would be insufficient to produce an accurate estimate of the environmental impact of new technologies (if a technology has yet to be adopted, its CO2 emissions will not be reflected in CO2 intensity data).
* The model does not discuss or suggest how environmental data should be incorporated into healthcare decision making, and thus, how those data should best be presented to decision makers. Further, there is little evidence on how decision makers will use data on the environmental impact of treatments.
 |
| Mupepele(15) | Within this method of evidence assessment, the reliability of a study is characterized by its study design and the quality of its implementation; both features are evaluated. Overarching steps in the evidence assessment tool process: 1. Identification of study question, design, and outcome.
2. Assessing a level of evidence based on the underlying study design and calculating a quality score based on the quality checklist.
3. Determining the final level of evidence supporting the outcome by downgrading the originally assigned level of evidence according to the quality score.

**LoE hierarchy to rank study designs according to their evidence:** Differences in study designs typically translate into weak or strong evidence. The framework presents a LoE hierarchy ranking; classifying study designs according to their evidence (pyramid has very strong evidence at LoE1 to weak evidence at LoE4, with internally ranked sublevels a, b, and c. Overall, the evidence decreases in strength starting at Review, Studies with a reference/control, Observational studies, and Studies without underlying data. **Critical appraisal of the implementation of the study design:** Assesses the implementation of the study design, specifically the methodological quality, the actual realization of the study design, and its reporting- study quality may lead to downgrading in the evidence hierarchy. This model includes a quality checklist for conservation and ecosystem services (the first of its kind)*.* | This method includes a critical appraisal to check for an appropriate implementation and methodological quality of study designs. Thus, the model does not overestimate the results of deficiently implemented meta-analyses and controlled studies. Also, rating the strength of evidence clarifies the reliability of research results and, thus, the strength of conclusions, decisions, or recommendations drawn from that research. Further, the paper describes who should use this evidence assessment tool (intended audience). | A main argument against hierarchies is that they are rigid and only consider the study design to assign a level of evidence; it has also been argued that controlled trials are not always more reliable than observational studies. Also, in some areas of science, causality cannot be established, and hence the reliability achieved remains lower than in areas where it can. Every system is unique, and the external validity of studies is low. Generalizability of results is problematic in ecosystems; general evidence may not apply, due to particular circumstances.  |
| Hong(28) | The article describes and characterises the attributes of “green chemistry”, as defined Anastas and Warner, as the totality of activities that reduce or eliminate the generation and use of substances harmful to human health and environment in the design and production process, and application of chemical products. The 12 principles of green chemistry are as follows: minimizing waste generation, maximizing synthetic production efficacy, using less hazardous chemical synthesis methods, using low-toxicity chemical product design, minimizing the use of auxiliary substances such as solvents, minimizing energy consumption, maximizing the use of renewable raw material, minimizing the use of derivatives, using catalysts with high selectivity, designing products degradable into innocuous materials at the end of their function, preventing the formation of hazardous substances through real-time monitoring, and selecting materials with low risk for accidents. The evaluation technique to assess a technology’s adherence to these principles consists of a selection of multiple overarching indices, further composed of various proxy variables. The four indices are: 1. **Environment:** Defined as the sum of GHGs and hazardous substances reflecting the international and local factors, respectively. Definitions and formulas for the calculations of the sub-concepts of GHGs, hazardous substances (health hazard factors and environmental hazard factors) are described in the text.
2. **Safety:** Industrial chemical accidents such as explosion and fire. This can be quantified by checking the R-Phrase of each chemical substance involved in the production process (raw material, products/by-products, and emissions) against the reference scale.
3. **Resource:** Energy consumption as a social factor. Improvement of resource consumption means efficacious production of chemical products by minimizing the depleting resources, i.e. reduction in waste generation.
4. **Economy:** Economic feasibility of green chemistry technologies. Although this factor is not included in the 12 principles of green chemistry, it is considered essential to include the economic aspect in the green technology assessment technique, in order to make green chemistry more attractive to the industry.

Each of these 4 indices is extracted as a value, allowing a quantitative assessment of greenness. | The assessment technique established in this study will 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, which can greatly contribute toward gaining a competitive advantage in the global market. | * The methodology encompasses solely a quantitative assessment of the level of compliance with the principles of green chemistry; there are no recommendations for how to interpret/analyze these results and integrate them into a wider assessment of the technology.

The calculation of the level of environmental sustainability of a technology was specifically developed based on the level of compliance with the principles of green chemistry put forth by Anastas and Warner; the framework relies on these principles, rather than coming up with their own definition/qualities, independent of this definition from 1998. |
| Bayliss (16) | **The ten recommendations are as follows:** 1) Plan for information retrieval at an early stage: spreading the net wider2) Identify and use sources of help: getting beyond peer-reviewed literature3) Clearly define the question to be addressed4) Ensure that provisions for managing, recording and reporting the search are in place5) Select an appropriate search type6) Identify sources to be used: data networks and repositories7) Identify limitations of the sources: less sophisticated searches 8) Ensure that the search vocabulary is appropriate: evolving vocabulary 9) Identify limits and filters that can help direct the search10) Test the strategy to ensure that it is realistic and manageable In addition to the central ten step framework, the paper identifies and describes: * An overview of the different stages of the systematic review process
* Some challenges in ecological information retrieval and potential solutions from medicine
* Some forms of bias that may be encountered in the ecological information retrieval process and steps that can be taken to counter them
* Question components of the PICO/PECO and SPICE mnemonics with hypothetical examples
* Some types of search resources and examples that may be relevant for information retrieval for ecological syntheses
 | * These recommendations may be of value for other disciplines where search infrastructures are not yet sufficiently well developed; broad applicability.
* Identification and retrieval of information is a crucial part of any synthesis activity, as it identifies relevant studies for inclusion and can help reduce biases by ensuring that all relevant data are identified, thus improving the validity of the findings.
* Most synthesis methods used in ecology have been adapted from techniques developed in medicine. As research synthesis methods are increasingly used in ecology and environmental management, new challenges in environmental management are being encountered because of differences in the ways in which ecological information is recorded, published and reported. The paper includes a detailed section (*see Table 1, pg. 139)* that describes some key challenges in ecological information retrieval, and the potential solutions drawn from medicine, ultimately aiming to lead towards improved search strategy in this discipline as well.
* The authors recognize that the methods for information retrieval in ecology need to be considered in the context of the sources and data available at present, as opposed to being based on an ‘ideal’ body of literature in alignment with evidence-based practice; allows the framework to be more realistic and applicable for current implementation.

The checklist is presented for use by a novice audience; thus, is accessible to a wider range of people than would otherwise be seen if the paper was designed solely for those with a background in information management or ecological research. | * In the context of ecological syntheses, the methodologies behind the literature search or information retrieval stage have not received much attention (to date); hence, this framework itself is based on a limited body of evidence and good-practice standards.
* Using rigorous methods to retrieve information for inclusion in an ecological synthesis can be challenging and resource intensive.
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| Collaboration for Environmental Evidence (CEE)(22) | **7 steps in conducting an SR:**1. **Question setting:** A process to derive a suitable question both in terms of evidence needs and feasibility of the SR.
2. **Protocol:** A plan for the conduct of the SR, setting out how each stage will be conducted. The plan is submitted to Environmental Evidence, peer reviewed and published and has a key role in maximizing transparency and minimizing susceptibility to bias.
3. **Searching:** A systematic search is conducted using a repeatable search strategy tailored to the question and likely sources of evidence.
4. **Article screening:** Articles retrieved from the search are examined for relevance to the review question using a-priori inclusion criteria and resulting in a collection of relevant studies.
5. **Critical appraisal and data extraction:** These two stages are often interlinked. In critical appraisal, studies are examined for their design and reporting standards and weighted in terms of susceptibility to bias and validity in terms of the study question. Appropriate data are extracted from each study and may be subject to further critical appraisal.
6. **Data synthesis:** Extracted data from individual studies are synthesized to form an overall view of the evidence. Synthesis can be narrative, quantitative, qualitative or a combination of these.

**Writing of the SR report:** Written using a specific CEE template that ensures high reporting standards for transparency and repeatability. The report is submitted to Environmental Evidence, peer reviewed and (if accepted) published in the journal and archived on the CEE website. | The paper included resources on all of the following supplementary domains: * A rationale for addressing the need for evidence (identifying the evidence to inform decision making);
* A discussion on the various working groups to include in the review process;
* An assessment of the costs and benefits of performing such a review (suggests when a review may or may not be appropriate);
* The process of moving from a research question to a reviewable problem (question generation and formulation);
* The specific details of the search and review planning and implementation process;
* The development of a review protocol (including sample templates); and
* A description of the critical appraisal process
 | * Overall, it is noted that SRs can only be accurate assessments of the evidence base when they are up to date. As soon as the search is completed the reliability of an SR as a synthesis of ‘all available evidence’ begins to decline. The rate of decline is dependent on the rate of publication of new studies and so varies from subject to subject. An outdated SR may be misleading, so they should periodically be updated.
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| Powers(17) | As a meta-assessment approach, the CEASS framework combines various features and outcomes of existing assessment methods, including life-cycle based approaches, decision support techniques, cost−benefit analysis, and other such tools, along with the basic risk assessment paradigm. The CEASS framework provides a systematic framework for organizing complex information, in order to support decision-making. Additionally, the model embodies a structured process for reaching transparent judgments about the implications of such information. The CEASS and process methods are described: **CEASS Framework:**The framework begins with the ***product life cycle*** (cradle-to-grave; includes research and design, processing, manufacture, storage/distribution, use, and disposal/recycling of the technology). Next, the possibility of releases of the primary material of interest and associated materials to ***environmental media*** (air, water, sediment, soil) must be considered for each stage of the product life cycle. The framework also considers the ***environmental conditions*** that could affect the fate of these primary and secondary substances, namely physical, chemical, biological, and social factors. The type and magnitude of both direct and indirect effects on various receptors and other types of impacts are evaluated in relation to ***exposure-dose*** potential by all relevant pathways. Exposure and uptake can be cumulative (involving multiple associated substances) and/or aggregate (involving a single substance via multiple pathways), and can affect humans, other biotia, or abiotic resources. The ***impacts*** of the technology could be deemed desirable or undesirable depending on the specific context or an individual’s perspective, and may include an evaluation of aesthetic changes, ethical-legal-social concerns, or sustainability, for example. CEASS Process: The CEASS process is designed to yield transparent judgments about the implications of information contained in the CEASS framework. Compiling information in the CEASS framework is a fundamental first step. Next, the information in the framework isreviewed based on (1) the scope of a CEASS, (2) the completeness andaccuracy of information in the framework, and (3) theimplications of information and information gaps compiled ina CEASS framework document.The goal is not to identify every concern pertaining to an issue, butto determinepriorities among information gaps (for researchplanning) or“risk trade-offs”(for risk management). | * As commonly applied in evaluating health risks of specific chemicals, the RA paradigm lacks the scope of LCA. Whereas an LCA may focus in detail on emissions associated with the “cradle-to-grave” stages of a product’s existence, RA typically limits the exposure analysis component of risk characterization to the use of a chemical or product and may disregard “upstream” (e.g., manufacturing, distribution) or “downstream” (e.g., disposal or recycling) stages of the life cycle. On the other hand, LCA does not typically have the temporal or spatial resolution of RA, nor does it usually quantify risks in the manner of RA. Thus, the CEASS framework functions to combine the positive attributes of both RA and LCA, increasing efficiency.
* Whereas risk assessment (RA) and LCA typically focus on quantitative data and analyses, CEASS accords consideration to both quantitative and qualitative information.
* CEASS differs from most LCAs in including environmental fate, exposure-dose, and human health, ecological, and other impacts as equal, integral components of the basic CEASS framework
* CEASS shares the inherently comparative nature of cost−benefit analysis; the goal of CEASS is to provide risk managers a clear sense of the most important trade-offs related to a technology option.
* Any assessments and research plans may point to a multitude of concerns or possible actions, but the CEASS provides a means of prioritizing for both research planning and risk management purposes.
* The CEASS framework not only includes results of previous assessments and analyses (for example, the results of a completed LCA can be incorporated into the CEASS framework), but it also enables seemingly contradictory or inconsistent results to be weighed in reaching an overall judgment.
* Although still being refined and extended, the CEASS framework has already been used in implementing recommendations related to risk assessment research.
* For issues such as emerging technologies, which may have relatively limited information available, the implications may point to gaps and uncertainties in the extant knowledge base, thus providing guidance to decision makers such as research planners and risk managers. Conversely, for more mature issues that have a substantial scientific knowledge base, the focus of the CEASS process may be to provide guidance to risk managers in deciding which risks and benefits warrant more attention.
* The CEASS framework helps address challenges related to scope and transparency: Collective judgment based on diverse perspectives (heterogeneity in the areas of technical expertise and institutional affiliations of the persons participating in the judgment process) is a key feature of the CEASS process. Some judgements may be improved by having broader participation than afforded by a small set of narrowly focused experts, and as well, such a process allows greater transparency.
* Although a great deal of information is often included in LCAs and RAs, the basis for deciding which factors are given more weight or attention and how assumptions are made or justified is often not explained in any detail. By using a formal procedure that provides an explicit record of key facts, values, and other information cited by the participants themselves and an objective measure of the participants’ collective judgment of priorities (i.e. a rank-order list derived from a multi-voting process), the CEASS process makes the resulting assessment much more transparent.
* As a means for identifying priorities for research planning and risk management, the CEASS framework provides a basis for moving beyond analysis to action.
 | * If the judgement process is not performed using a structured procedure that ensure all participants have an equal opportunity to contribute their views, the typical discussion style that frequents most round-table dialogues may end up being dominated by a select few outspoken participants, even when monitored by a designated facilitator.
* Various formal methods can be used for the purpose of reaching group decisions, and but it should be noted that some analytic methods (e.g., expert elicitation) can be rather labor-intensive, which may effectively limit the number of participants who can be used in reaching a collective judgment.
* Regardless of the method employed, care should be taken to avoid making assumptions that can lead to premature structuring of the judgment process, which is especially a concern with newly emerging or data-limited issues.
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| Linkov(14) | WOE is a framework for synthesizing individual lines of evidence, using methods that are either qualitative (examining distinguishing attributes) or quantitative (measuring aspects in terms of magnitude) to develop conclusions regarding questions concerned with the degree of impairment or risk. Various methods within WOE*:* * **Listing Evidence:** Presentation of individual lines of evidence without attempt at integration.
* **Best Professional Judgement:** Qualitative integration of multiple lines of evidence.
* **Casual Criteria:** A criteria-based methodology for determining cause and effect relationships.
* **Logic:** Standardized evaluation of individual lines of evidence based on qualitative logic models.
* **Scoring:** Quantitative integration of multiple lines of evidence using simple weighting or ranking.
* **Indexing:** Integration of lines of evidence into a single measure based on empirical models.
* **Quantification:** Integrated assessment using formal decision analysis and statistical methods.
* Though all WOE methods may include both qualitative and quantitative considerations, the methods are listed above by increasing quantification (from listing evidence to quantification). The paper listed various WOE applications, in the context of application area and by the manner of use within the human health and ecological risk assessment process.
 | * The concept is familiar, and therefore potentially easy to communicate to decision-makers and the public. The main advantage of MCDA-based WOE integration is its documented and repeatable method of integrating lines of evidence, as well as its ability for evaluating the sensitivity of the conclusions to changes in the specific parameters or logic used to perform the integration. Quantitative WOE methods provide transparency in decision-making, and an opportunity for consensus building.
 | * WoE is often used in a descriptive way, without sufficient proof for an argument. Dissatisfaction over the ‘interpretation of science’ frequently results from concerns about the lack of sufficient objectivity, certainty, transparency, repeatability, and consistency in the approaches used to integrate lines of evidence in reaching conclusions about environmental risks. This review showed that Best Professional Judgement (BPJ) is the most widely used method used within WOE, but does not lend itself to transparency or repeatability except in simple cases. Also, although qualitative analysis of individual lines of evidence (or even quantitative analysis using Scoring, Indexing, and Statistical methods) can be powerful for informing a decision process, they do not include options for quantitatively integrating decision-maker values and judgement; thus, consideration of stakeholder values is not explicitly taking place. Most qualitative WOE methods found in this review lack a process for discussing and recording a particular weight, thus losing the transparency provided to stakeholders.
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| Porter(21) | * The article presents a simple model of the ten components that should be accomplished in almost any assessment. Note that emphases will vary according to factors such as the type of study, scale of effort, and major interests. Also, these activities do not follow a linear sequence, hence they are displayed in no significant order:
* **Problem definition/Bounding:** One first must determine the nature and scope of the study, and to question whether it should truly be completed in its proposed form. This scoping activity will allow for the study focus to be defined, and the breadth and depth of coverage determined, based on objectives and available resources. A preliminary microassessment can help focus and bound the study.
* **Technology Description:** An empirical activity that underpins the assessment. This component of the assessment demands a substantial proportion of study resources, particularly in a technology-oriented assessment. For novel technologies, description may best be begun by specifying the level of emergence of the technology involved (i.e., from scientific insight to widespread adoption). The description should extend beyond functional description to consider alternative implementations, related technological and socioeconomic factors, and potential uses.
* **Technology Forecast:** Attempts to anticipate the character, intensity, and timing of changes in technologies. Forecasts should be synthesized on the basis of documented data, relationships and assumptions. Forecasts should be synthesized on the basis of documented data, relationships, and assumptions.
* **Social Description:** Descriptions of the state of society must concentrate on those aspects of society that interact with the subject of study. Both quantitative indicators and qualitative social descriptors can prove useful in this empirical inquiry. Expert opinion measurement and demographic data gathering may be pertinent.
* **Social Forecast:** Seeks to synthetically represent the most plausible future configurations of certain dimensions of a society, or to project changes in social parameters likely to interact with a technological development. It is one of the least developed and least credible assessment components. Provision of a range of qualitative, alternative futures in the form of scenarios is a typical approach.
* **Impact Identification:** Refers to the products of the interaction between a development and its societal context. Direct impacts are those effects directly attributable to the development; higher order impacts are the products of direct effects. Impacts could be classified along disciplinary lines (i.e., environmental, psychological), or they could be classified according to affected parties. Selection of the more important impacts for further study is essential; this may be well-served by obtaining perspectives from outside experts, stakeholders and policymakers.
* **Impact Analysis:** Links the identification of significant impacts to their evaluation and the development of effective policy to deal with them. This may include such areas as environmental modelling, cost-benefit analysis, and various future-oriented modelling techniques.
* **Impact Evaluation:** Integrates the impact analyses to enable comparison of alternatives and assist in policy analysis. Evaluation criteria should include utility, equity, and non-materialistic values. This component is highly normative, and can be performed qualitatively and/or using such quantitative techniques as decision analysis and policy capture.
* **Policy Analysis:** Compares alternatives for implementing technological developments and for dealing with desirable and undesirable consequences of these. Unless study sponsors oppose, explicit policy recommendations are usually desirable if the assessors can convince the users of their credibility and balance. Policy analysis is a most important component

**Communication of Results:** Effective communication requires significant efforts to facilitate information exchange to and from study users. Study utility can be enhanced by early identification of the intended audience, carefully considered interaction over the course of the study, attention to user perceptions of a credible assessment, and uses of a variety of dissemination means. | * This protocol identifies both the issues requiring evaluation, as well as those concerned with the advancement of the field. Also, the authors identify 10 component tasks of assessment, which allows observers of impact assessment to look for their presence, or a sufficient rationale for their absence. The authors note that only through such detailed attention will professional standards of good practice emerge; thus, this model encourages such progression.
 | * Impact assessment must also progress in terms of integrating professional contributions with those in the public, and with the concerns of assessment users (i.e., policymakers); currently the model only accounts for those performing the assessment themselves.
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| Trevor(20) | * **Risk/benefit:** Risk is the probability of receiving an exposure multiplied by the consequences of that exposure. Benefit is the kilowatt hours of energy generated. To determine the significance of risk/benefit ratios for nuclear waste management, they must be compared with the risk/benefit ratios of other parts of the fuel cycle. They must also be compared with the risk/benefits rations for non-nuclear means of generating energy (i.e., risk of mining or transport of coal).
* **Systems analysis:** Identifies the elements of a set and describes the relations among them. The scale of its application in waste management has ranged from the study of a single facility to the study of global problems.
* **Input-output analysis:** Normally used to account for the distribution of goods and services from a given economic sector to all other economic sectors. An analogue that has been used in preliminary stages of nuclear waste management planning, but not presented in documented form, is accounting for the distribution of the complex set of radioactive isotopes throughout all wastes of the fuel cycle.
* **Trend analysis:** Projections have been made of the amounts of electricity to be generated in the future by nuclear energy and of the accompanying amounts of radioactive wastes. Environmental impacts, storage volumes, and costs are estimated from the expected trends.
* **Modelling and simulation:** Physical and mathematical modelling and simulation examples include tests of physical properties of models of solidified high-level waste, or geological storage environments, for example. Treatment operations have been tested on simulated combustible wastes and simulated high-level wastes, with non-radioactive but chemically similar elements substituted for highly radioactive elements expected in real waste.
* **Scenarios and games:** The primary application of scenarios and games in nuclear waste management evaluation has been to attempt to foresee accidental failures or deliberate abuses of operations, to identify their consequences, and to plan prevention or counteraction.
* **Fault tree analysis:** Conducted to predict reliability and sequences of accidental events for a number of operations of the nuclear fuel cycle. The failure events considered are those that could lead to uncontrolled introduction of the wastes into the environment. Some such events have been assigned judgemental probabilities to allow comparison of the risks of various disposal alternatives.
* **Public participation:** The authors suggest thatpublic participation in nuclear energy issues represents perhaps the broadest such participation to be found in any governmental activity.
* **Social impacts:** For nuclear waste management, the primary measures of social impact have been radiation exposure, the costs of risk-averting equipment, and the uses of labour, capital, land, and resources to handle and dispose of radioactive wastes.
 | * **Risk/benefit:** The method is simple in that it only contains two factors/dimensions; using a simple mathematical process (multiplication) to arrive at an estimate.
* **Systems analysis:** The various technologies available for waste management and their interrelations have been identified in a waste management system for handling all wastes, from their origin to final disposal.
* **Input-output analysis:** The application of input-output techniques has been outlined in some detail, also for the broad field of assessing environmental impact of energy production systems. Thus, this methodology is more well-known than others, increasing its familiarity with researchers.
* **Trend analysis:** Appears to be an important method of analysis, as evidenced by frequent updating. The process of DELPHI, when applied to the method of trend analysis, allows for iterative survey to decrease the variance of estimates produced, and also seems helpful in estimating the characteristics and volumes of wastes at this stage of uncertainty.
* **Modelling and simulation:** Both physical and mathematical modelling have been used in this instance extensively.
* **Scenarios and games:** Method can be applied in this case to: preventing environmental insult by accidental failure of equipment and procedures, and also to estimate the probabilities and consequences of such actions as sabotage or theft of the most toxic radioactive wastes for blackmail or terrorist threats. This theoretical analysis also allows for the consideration of how one’s geographical location impacts their risk/benefits ratio, with respect to nuclear energy.
* **Fault tree analysis:** Recent efforts in this field of development have involved the assembly of computer programs that will produce computer-drawn fault tree diagrams based on the logic description input by the analyst. Such developments will perhaps facilitate the ease-of-use of this method, and increase its practicality as a method of assessment.
* **Public participation:** Procedures have been developed to simplify public participation; facilitating the discussion process. It is noted, however, that such opportunities for public participation make it possible to identify the consequences of technology applications in terms that are meaningful to those likely to be affected.

**Social impacts:** There has been an increased demand for the assessment of the social impacts of a technology; there are many different focus areas and specific questions/situations that could be assessed from a social perspective. | * **Risk/benefit:** It has been suggested that a standard for maximum permissible radiation dose from various nuclear industry operations might be defined by setting it equal to other hazards. However, this basis for a standard would depend on developing some generally accepted means of comparing radioactive with non-radioactive hazards, which would require time and additional effort.
* **Systems analysis:** The concept of waste management operations as a global system is getting increasing attention, but has not been developed in detail.
* **Input-output analysis:** Complete accounting of the environmental effects of waste management requires that all radioactivity be accounted for. This can be described through the process of linear programming, though this method in general adds a high degree of detail and additional labour.
* **Trend analysis:** Due to frequent revisions in the sales, construction, and licencing of nuclear reactors, there has been the requirement of frequent revisions in analyses of expected trends in the generation of nuclear wastes. Ensuring that the values utilized within a trend analysis are up-to-date requires frequent and reliable observation, which may prove challenging to maintain. Also, although energy is currently generated by light-water reactors (LWRs), a complete fuel cycle that includes final disposal of all resulting waste types has yet to be established. In many cases, the characteristics and amounts of waste types have never been established by experience. Yet current efforts on EIA and TA must be based on estimates of these characteristics. Further, the technique of survey has been used liberally to obtain estimates from companies planning commercial ventures and from other evaluators, though errors may be 20% for some estimates, and greater than 100% for others.
* **Modelling and simulation:** The mathematical model ORIGEN computer code describes the extremely complex and variable compositions of spent fuel in terms of its elements and radioactivities. Though very widely used, the implementation of such a model may in part be dependent on securing staff with the specialized knowledge, training, and resources to undertake such an analysis; thus, this framework is applicable for use by a narrower audience.
* **Scenarios and games:** This model is very conceptual in nature, and does not play a role in providing a quantitative assessment of the true environmental outputs associated with a technology. This technique is applied in the analysis of unique circumstances, rather than traditional/regular use.
* **Fault tree analysis:** It is difficult to accurately estimate probabilities because of the absence of an empirical basis. This has impeded general acceptance of this technique in waste management assessment.
* **Public participation:** In licensing and rule-making hearings, the public may be represented by special interest groups that have studied the issues thoroughly. However, the question of whether such groups really represent the public interest remains unresolved.
* **Social impacts:** A main difficulty in performing this type of assessment is due to the lack of quantitative measure. Many of these social questions being debated are less tangible and far more theoretical and ethics-based, making it so that a definitive answer based on data is significantly less likely to be possible.
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CBA=cost-benefit analysis; CEE=Collaboration for Environmental Evidence; CEASS=comprehensive environmental assessment; CO2=carbon dioxide; CUA=cost-utility analysis; EEIOA=environmentally extended input-output analysis; GHG=greenhouse gas; HCRU=health care resource use; HRQL=health-related quality of life; HTA=health technology assessment; LCA=lifecycle assessment; LOE=lines of evidence; MCDA=multi-criteria decision analysis; OAD=oral antidiabetic; PICOS/PECOS= population, intervention/exposure, comparator/control, outcome, and study design, SCC= social costs of carbon; SPICE= setting, perspective, intervention, comparator, and evaluation method; SR=systematic review; RA=risk assessment; TA=technology assessment; T2DM=type 2 diabetes mellitus; WoE=weight of evidence.