

Development of a framework to structure decision-making in environmental and occupational health: a systematic review and Delphi study

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ABSTRACT

Background: Environmental and occupational health (EOH) assessments increasingly utilize systematic review methods and structured frameworks for evaluating evidence about the human health effects of exposures. However, there is no prevailing approach for how to integrate this evidence into decisions or recommendations. Grading of Recommendations Assessment, Development and Evaluation (GRADE) evidence-to-decision (EtD) frameworks provide a structure to support standardized and transparent consideration of relevant criteria to inform health decisions. This study identifies and synthesizes available EOH decision frameworks, and evaluates the applicability and usability of an existing GRADE EtD perspective to advance the development of a tailored EOH EtD framework.

Methods: We performed a systematic review of MEDLINE, EMBASE, and Cochrane Library, and a manual search of gray literature to identify frameworks that inform decision-making about EOH exposures from the years 2011 to 2021. We abstracted and analyzed decision considerations from each framework through narrative synthesis. Next, we conducted a two-round Delphi process, engaging stakeholders from the following perspectives within environmental and occupational health: risk assessment and management, nutrition and food safety, cancer, and socio-economic analysis. Panelists rated the relevance and wording of each consideration on a 7-point Likert scale, and provided free-text comments during both phases. Considerations that did not meet predetermined thresholds were excluded.

Results: Out of 5,196 unique references, we identified 22 published reports of EOH decision frameworks. We identified another 16 frameworks in a search of gray literature, totaling 38 source frameworks. We abstracted 560 individual decision considerations from these frameworks, 104 of which may contribute additional information to the guidance, scope, context, or assessment criteria of the GRADE EtD framework. In round 1 of the Delphi study, 50 decision considerations were aggregated or removed, and 9 were aggregated or removed after round 2, for a final total of 47. No new decision considerations were added in either round. We identified several differences between decision criteria that are applied in EOH and the GRADE EtD framework, including vocabulary that is specific to EOH (e.g., toxicity, the precautionary principle), and granularity of the EOH decision considerations (e.g., detailed signaling questions to assess feasibility and resources required). However, this study did not identify any EOH decision criteria that are completely distinct from the GRADE EtD framework.

Conclusions: Findings of this mixed-methods study comprise a foundation for a GRADE EtD that is applicable for use in EOH decision-making, with implications for approaches to regulation of environmental and occupational exposures and the formulation of recommendations for interventions to prevent or mitigate undesirable health and other consequences.

Keywords: systematic review, Delphi, GRADE, decision-making, environmental health, occupational health, decision framework

HIGHLIGHTS

- The GRADE evidence-to-decision (EtD) framework may facilitate systematic and transparent decision-making in environmental and occupational health (EOH), with beneficial implications for the implementation of recommendations and regulations.
- We performed a systematic review of EOH decision frameworks and Delphi study with content experts; we did not identify any decision criteria that are completely distinct from those described in the GRADE EtD for health system and public health decisions.
- Although the main criteria for assessing different options are similar between different contexts, the nomenclature used to describe and apply criteria may represent an important barrier to decision framework generalizability.
- Tailoring of the GRADE EtD framework has the potential to improve its applicability to EOH contexts, including development of guidance for GRADE EtD framework operationalization that is specific to EOH.

INTRODUCTION

According to a 2016 report from the World Health Organization (WHO), 24% of global deaths are attributable to modifiable environmental risks. Healthier environments, including healthier workplace conditions, could prevent almost one quarter of the global burden of disease, or 13.7 million deaths per year.¹ Environmental health risks are assessed through a stepwise process involving hazard identification, dose-response assessment, exposure assessment, and risk characterization.² This process yields evidence that may be used to inform regulation of exposures that are linked to undesirable health outcomes, or recommendations for interventions to prevent or mitigate risk.³

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group was established in 2000 as an international collaboration of methodologists, guideline developers, biostatisticians, clinicians, and public health experts.⁴ The Working Group has developed and continually improved an approach to assessing certainty in the evidence to answer questions about the effect of an intervention or exposure on human health outcomes.^{5–7} The GRADE approach to evidence appraisal has been adapted by the National Toxicology Program's (NTP) Office of Health Assessment and Translation (OHAT), the Navigation Guide, and WHO, among other stakeholders, to support efforts to answer questions about the effects of environmental or occupational exposures.^{7–10}

Certainty in the estimates of effects of exposures is one important consideration among several that should inform policymaking, regulation, priority-setting, or selection of one intervention over an alternative. Prior studies have applied the GRADE approach for assessment of certainty of evidence in EOH, described a framework for developing informative EOH research questions and facilitating interpretation of the directness of findings, and formulated an instrument for risk of bias assessment for non-randomized studies of exposures.^{3,7,11} Beyond its approach for assessing the certainty in the estimates, the GRADE Evidence-to-Decision (EtD) frameworks are intended to support groups in making informed judgments about the pros and cons of different options, and to provide a structure for recording and reporting these judgements, including reasons for disagreement.¹² The main decision criteria comprising the GRADE EtD framework may be informed by prompting questions (“detailed judgements”) that facilitate discussion and clarify the information used to inform the main criteria judgments. The GRADE EtD framework also includes scope and context criteria that are intended to help groups pre-specify the perspective, setting, and stakeholders that establish the conditions under which the decision will be made. The intended result is an evidence-informed recommendation or decision that is transparent and can be fully explained to stakeholders.^{13–17}

GRADE EtD frameworks have been tested and applied to five perspectives: individual clinical decisions, population-level clinical decisions, health system and public health decisions, coverage decisions, and tests.^{18–27} However, the GRADE EtD framework is rarely used in the context of environmental and occupational health (EOH).⁷ As EOH decision-makers often rely on low certainty evidence to inform decisions that will impact broad stakeholder populations, we hypothesized that the GRADE EtD may facilitate systematic and transparent consideration of additional criteria with beneficial implications for the development and implementation of EOH recommendations and regulations.

This project aims to further explore EOH decision-making by comparing existing EOH decision frameworks and the GRADE EtD to identify any gaps in content, structure, or terminology that may present opportunities to improve the suitability of the GRADE EtD for use in EOH. We also aimed to elicit feedback from subject matter experts to evaluate the relevance of decision considerations that we identified through a systematic review, and to identify any considerations that were not evident in the literature. A subsequent manuscript will present the final EtD framework and provide guidance on its use.

METHODS

Systematic review

Protocol and search strategy

We conducted a systematic review of decision-making frameworks used in environmental and occupational health that updates and extends a prior review by Norris, et.al. on the of the same subject, followed by a narrative synthesis of the criteria and detailed judgments described in the included frameworks.^{19,27} Throughout, we adopted an inductive approach to identify considerations that are used to inform EOH decision-making, building on the deductive approach used to develop our foundational decision framework, the GRADE EtD for health system and public health decisions.

The systematic review protocol was registered on PROSPERO (CRD42022316686) and results are reported in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) format.^{28–30} **(Figure 1)** The search strategy was developed in consultation with an experienced health sciences librarian using a combination of free (keywords) and controlled (MeSH) vocabularies and translated into the following databases: MEDLINE via PubMed, EMBASE, and Cochrane Library. **(Supplement A)** The search was restricted to materials published in English within 10 years prior to the starting date of the review (September 26, 2021) to capture frameworks published both before and after publication of the GRADE EtD that are plausibly still in use. Additionally, we conducted a manual search of gray literature, including websites of government, professional, and public health organizations that produce health guidelines and the federal register. We used the Himmelfarb Health Sciences Library Environmental and Occupational Health Research Guide and the “Grey Matters” tool to identify a comprehensive list of sources for this search.^{31,32} Additionally, the search strategy used, number of results returned for screening, and number of documents included for each source was documented.³³ **(Supplement B)** Wherever possible and applicable, the grey literature search strategy was consistent across sources.

Study selection

We included primary reports or systematic reviews of frameworks, tools, or templates for making decisions or formulating recommendations, or for priority-setting of interventions or exposures in public health. By employing an inclusive search strategy, we aimed to identify a

comprehensive set of frameworks within the subset of environmental and occupational health. We excluded sources that did not have relevance to EOH decision-making, evaluated the effectiveness of specific EOH interventions, or described a framework that is focused exclusively on economic analyses, evidence appraisal, risk assessment, or hazard identification. If multiple documents reported on the same framework, exact duplicates were excluded and duplicated reports of the same framework were only included once, unless they reported on unique criteria or detailed judgements not found in other publications or sources. Two reviewers (EJ, JK, NP, ES) independently screened each title, abstract, and full text in duplicate. At all stages of the review, disagreements were resolved through discussion or by consulting a third reviewer.

Data management and abstraction

Search results were exported to Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org) to remove duplicates, screen sources, and document reasons for exclusion at the full-text stage (**Figure 1**). We used Google Forms to develop and pilot a standardized abstraction tool (**Supplement C**). If any data items were missing from or ambiguous in the published (or public) framework, we abstracted and analyzed the available information at face value, making as few assumptions as possible about the intent of the framework developer.

Using the piloted tool, we abstracted data from the included sources such as the publication year and venue, study design, geographical location, topic(s), characteristics of the developer(s), intended user(s) and audience, funding sources, development methodology, limitations, decision criteria and signaling questions, use and risk of bias assessment of supporting evidence, and intended application of the recommendations (**Supplement C**). Abstraction was performed by one researcher and reviewed by a second (EJ, JK, NP, ES). We did not perform a quality appraisal of the frameworks, as this review is concerned with identifying all relevant criteria for EOH decision-making irrespective of the quality of the studies in which they are reported.

Data coding & analysis

We conducted a narrative analysis using textual descriptions and tabulation to systematically describe the characteristics of the included frameworks. For the individual decision considerations abstracted from the included frameworks, we designed a coding strategy to map

abstracted considerations onto the decision criteria presented in the GRADE EtD for health system and public health decisions. With this approach, we aimed to identify (a) the potential existence of an EOH decision framework that would make tailoring of the GRADE EtD framework redundant, (b) whether any EOH frameworks introduce a theme that is not part of the GRADE EtD, thereby necessitating its extension, and/or (c) whether components within the EOH frameworks could inform tailoring of the GRADE EtD to the specifics of EOH decision-making contexts (**Figure 2**).

Each of the GRADE EtD framework assessment criteria (Problem, Desirable effects, Undesirable effects, Certainty of evidence, Values, Balance of effects, Resources required, Cost effectiveness, Equity, Acceptability, Feasibility) served as a code that could be applied to the abstracted decision considerations¹² (**Supplement E**). Examples of this process are presented in **Table 1**.

During the initial phase of coding, two members of the research team (PW, ES) independently applied codes to a pilot set of 100 abstracted decision considerations. Any discrepancy in application of the codes was counted as a disagreement and discussed to facilitate increased consistency in coding decisions between the researchers. After the initial calibration exercise, remaining considerations were coded by one researcher and reviewed by a second (PW, ES). In cases of disagreement, the reviewing researcher could apply additional codes to a consideration, but existing codes were not removed. We selected this inclusive approach to coding to account for multiple plausible interpretations of the same information.

We applied as many of the codes as could reasonably be related to each decision consideration, hereafter referred to as “items.” We prospectively defined an “item” as the smallest unit of each framework, meaning the most detailed or granular description of a decision criterion (**Table 2**). Some items encompassed multiple EtD criteria and vice versa; rather than selecting a single, best fitting code for each item, we assigned as many codes as needed. Items were also labeled as “guidance” if they were normative statements or statements about the process for making decisions (e.g., “minimize harm to the general population,” “protect human rights and individual autonomy”); items were coded as “no code” if they had no plausible correlate within the assessment criteria or detailed judgements of the GRADE EtD framework.

During the second phase of the coding process, three members of the research team (PW, RM, ES) reviewed and discussed all items that were coded to each of the GRADE EtD assessment criteria, including items for which a code was not identified. Additional codes were applied to

items that may inform guidance about implementing or operationalizing the GRADE EtD in EOH contexts, inform tailoring of the GRADE EtD scope and context criteria, or comprise new judgements for a GRADE EtD assessment criteria to which they were coded in the first round. These items, collectively coded as “unique,” were de-duplicated and organized into a consolidated set of items for further refinement through a Delphi process.

We summarized the coding applied to the identified detailed judgments with descriptive statistics (e.g., frequencies, percentages) using R Statistical Software (v4.1.2; R Core Team 2021).^{34–36} The data set and code we used for this analysis are available at:

<https://github.com/esenerth/GRADE-EOH-EtD>.

Delphi study

During the second phase of the project, we selected an electronic Delphi process to elicit additional information from subject matter experts because it prevented more outspoken or apparently senior participants from dominating a group discussion and therefore influencing others, permitted broader geographic representation than an in-person format, accommodated inclusion of diverse stakeholder perspectives, and provided an established method for reaching consensus.

Study design

Results of the systematic review and narrative synthesis underwent further analysis through structured stakeholder input to identify any EOH decision considerations that are not evident in the published or gray literature. Additionally, panelists were instructed to recommend reorganization, consolidation, and/or rewording of the decision criteria and detailed judgments as the basis for development of an integrated decision framework that will be applicable to EOH. This prospective Delphi study has been conducted and reported according to published guidance.^{37–40}

Stakeholder panel

Stakeholders were recruited by the research team based on a matrix describing characteristics of anticipated users of an EOH decision framework and/or consumers of EOH recommendations.³⁷ Prospective panelists received an invitation via email detailing the objectives, anticipated process, and timeline of the study. The panel was appointed after

ensuring consent to participate and balanced representation across gender, geographical settings, institutional contexts, and topical expertise. Prior to convening the panel, we collected information on intellectual and financial relationships from participants and did not identify any conflicts that would necessitate recusal for any portions of the process.

Study procedures

Panelists received instructions and survey materials via email; the survey was developed and fielded in Excel (Version 16.67; Microsoft, 2022). (**Supplement TK**) Panelists rated criteria and detailed judgements abstracted and consolidated from the systematic review and narrative synthesis, along with criteria and detailed judgements from the GRADE EtD framework as presented in GRADEPro (gdt.gradeapro.org), on a 7-point Likert scale in the following domains: agreement with inclusion of the consideration (1 = strong disagreement; 7 = strong agreement), agreement with the wording of the consideration (1 = strong disagreement; 7 = strong agreement). The questionnaire also included multiple opportunities for free text comments: suggestions for revision of the wording, suggestions for additional guidance, other comments on the criteria or detailed judgements, and addition of any new criteria or detailed judgements. Questionnaires were completed independently, and panelists were not provided with any information about how others had voted in the prior round. (**Supplement TK**)

Panelists were recruited based on a purposive sample developed by the research team and through “snowball sampling” of invitees. We aimed to recruit between 15 and 25 total panelists comprising target users of the GRADE EtD for EOH, participants with expertise in GRADE methods, and participants with expertise in several subspecialties of environmental and occupational health. Delphi literature recommends engaging between 10 and 18 participants per panel for optimal group dynamics and achieving consensus within a feasible number of rounds.⁴¹ The first round of the Delphi exercise began in March 2022 and lasted 14 days. Participants were sent up to three reminders to complete the questionnaire. The second round began in June 2022 and used a modified questionnaire based on iterative feedback and consensus during Round 1. This round also lasted 14 days, with up to three reminders.

Analysis plan

Survey responses were anonymized by one member of the research team (ES) and processed by three members of the research team (ES, PW, RLM) during a series of virtual meetings. The

primary outcome was attainment of consensus on the inclusion and wording of each criterion and detailed judgment. Responses, including panel demographic characteristics, were analyzed using descriptive statistics: counts and percentages, mean (standard deviation), median (interquartile range) and range.⁴² Items that received a median rating of >6.9 automatically advanced to the next round; items that received a median rating of <4.9 were removed. Items with median scores in between these values and/or items demonstrating large variability in rating (i.e., IQR >2) were discussed during the consensus meetings, including qualitative analysis of free text comments. These were coded into four categories: “scope (item should be more specific to environmental health, or subtypes of interventions or other policies), redundancy (addressed within or duplicated by another criterion or item), new (new decision consideration proposed by the respondent), and clarity (the content of the item is unclear to the respondent).

Ethics

This project did not involve any data collection from human subjects or biological specimens. We collected and analyzed existing data from published or public sources. According to the Hamilton Integrated Research Ethics Board (HiREB), this project does not require ethics review and is granted a waiver from the TCPS2 (2018) Article 2.5 as of January 24, 2022. Findings may be published and/or presented as quality improvement information.

RESULTS

Systematic review

Search results

The search of published literature yielded 5,420 records for consideration. After removing duplicates (n=224), we reviewed the titles and abstracts of 5,196 records and excluded 4,918 that did not meet the criteria for inclusion. We reviewed the remaining 278 full texts and excluded another 255. The most common reason for exclusion was that the study did not present a decision-making framework (n=217); other excluded records presented hazard identification frameworks (n=29) or evidence appraisal frameworks (n=6). (**Supplement D**) The search of gray literature yielded 835 documents from 31 different organizations. After

assessment against the inclusion criteria, 22 published reports of frameworks and 16 frameworks from the gray literature were advanced to data abstraction (**Figure 1**).

Framework characteristics

Of the 38 included frameworks, 18 (47.4%) were developed by or for government agencies, 14 (36.8%) were developed in academic settings, 5 (13.2%) were developed by non-governmental organizations (NGOs), and 1 (3%) was developed by industry. The most common topic addressed by the frameworks was public health (n=11).^{25,43–52} Other topics included water management (n=7),^{53–59} chemical alternatives assessment (n=5),^{60–64} waste management or sanitation (n=4),^{54,56,65,66} workplace exposures (n=4),^{67–70} site remediation (n=2),^{71,72} disaster or emergency management (n=2),^{73,74} and emissions (n=1).⁷⁵ Four reports of frameworks did not specify a topic^{76–79} and two addressed both water management and sanitation (**Table 3**).^{54,56} The frameworks that contributed the largest number of items to this analysis originated from government (n=275) and academic (n=241) settings, and addressed water management (n=133) and chemical alternatives assessment (n=113) (**Table 4**). Although public health was the most common framework topic, addressed by 29% of frameworks, public health frameworks contributed a minority of items to the analysis.

Coding results

Researchers applied identical codes to 90 percent of the items during piloting. Subsequently, 89.3 percent of the items were coded identically. In the first round of coding, out of the 560 identified items abstracted from the included frameworks, 206 (36.8%) were coded to “Undesirable effects”, 174 (31.1%) were coded to “Feasibility”, 156 (27.9%) were coded to “Problem”, 104 (18.6%) were coded to “Desirable effects”, 102 (18.2%) were coded to “Acceptability”, 84 (15.0%) were coded to “Resources required”, 54 (9.6%) were coded to “Values”, 44 (7.9%) were coded to “Certainty of evidence”, 41 (7.3%) were coded to “Balance of effects”, 32 (5.7%) were coded to “Equity”, and 32 (5.7%) were coded to “Cost effectiveness” (**Figure 3, Table 4**). Most of the items had two or more codes applied. (**Figure 4**)

Twenty-three identified items were designated as “no code,” meaning they had no plausible correlation with any of the criteria nor of the detailed judgments of the GRADE EtD framework for health system and public health decisions (**Figure 3**). One framework was excluded from further analysis because it provided criteria for assessing access to health services rather than criteria for health decision-making; this framework contributed 19 items to the “no code”

category.⁶⁴ This framework could also reasonably have been excluded during the screening phase. The other 4 items coded as “no code” were identified in two frameworks and were excluded from further analysis because they described criteria for assessing the decision-making process rather than criteria for assessing alternatives.^{66,72} Ultimately all the “no code” items were excluded from further analysis for the reasons described above. Our sample did not include any items that were completely distinct from the GRADE EtD framework criteria for health system and public health decisions.

During the second phase of coding, we applied additional codes to denote items that are aligned with one or more of the GRADE EtD criteria, but also contribute additional breadth or detail to the guidance (n=2), scope and context (n=40), or detailed judgements (n=62) of the GRADE EtD criteria to which they were coded in the first round (**Table 5**). In aggregate, these items are coded as “Unique” (**Figure 2**). We observed the greatest number of unique items coded to “Problem” (n=31) and “Resources required” (n=25) (**Table 5**). Of 38 included frameworks, 28 of these contributed items that were subsequently coded as unique (**Figure 5**).

We observed variability in the total number of items abstracted from each of the frameworks (**Figure 5**). The frameworks with the greatest contribution of items were developed to address water management, chemical alternatives assessment, sanitation, and site remediation.^{54,56,59,61,64,71} These frameworks described decision considerations that are aligned with several of the GRADE EtD criteria (feasibility, desirable and undesirable effects, priority of the problem) but expressed them in a more granular form (e.g., carcinogenicity, genotoxicity, developmental toxicity, reproductive toxicity, and endocrine disruption disaggregated into separate considerations rather than a single judgment about “toxicity”).

Analysis of the distribution of items stratified by framework characteristics shows that the proportion of identified framework items coded to each GRADE EtD criterion varies by both the development organization and topic of the framework (**Table 3**). The framework developed by industry was the most polarized, with all items concentrated in the “Problem” and “Undesirable effects” criteria. Frameworks developed by or for government agencies had the greatest density of items coded to “Feasibility.” Finally, frameworks developed in academic and government settings collectively contributed most of the unique items (**Figure 6**). Chemical alternatives assessment frameworks were the most polarized of the included topics, with the greatest density of items coded as “Problem” and “Undesirable effects” (**Figure 7**). The polarization of both industry and chemical alternative frameworks is likely driven by Perez 2017, which

contributed items to both categories, and Malloy 2013, which addressed chemical alternatives assessment from an academic perspective.^{61,64} Public health frameworks had the most uniform distribution of items across the EtD criteria.

Based on the criteria that comprise the GRADE EtD, the frameworks identified by our review focused on assessing the undesirable effects of exposures, feasibility of alternatives, and magnitude or priority of the problem under consideration. The frameworks gave comparatively less attention to assessing the impact on equity and cost effectiveness of alternatives. We observed variability in the distribution of items related to each EtD criterion both in aggregate and when we stratified the data based on framework characteristics.

Delphi study

Out of a total of 42 invitations, 21 participants (50%) accepted the invitation and provided consent. One participant withdrew before completing the first round of rating. We received 20 complete responses to the round one survey and 20 complete responses in round 2. However, one round 2 response was received after feedback was compiled and processed, so was not analyzed (**Figure 8**). Demographic characteristics of the panel surveyed in each round are presented in **Table 6**. The demographic composition was similar in rounds one and two, with roughly equal distribution of male and female participants and roughly equal representation of academic or research and government or regulatory settings. Most participants in both rounds are from North America (mean 46%); Europe, Asia, Australia, Africa, and South America were also represented on the panel.

We presented a total of 106 items for rating in round one: 10 scoping criteria, 12 assessment criteria and 84 detailed judgments that may inform decisions about the main criteria. Based on panel free-text feedback and pre-specified consensus thresholds, 27 items were advanced from round one without any edits, including all the assessment criteria, and 27 items were dropped from the set. Other items were aggregated together ($n = 30$), rephrased ($n = 11$), or disaggregated into multiple items ($n = 2$) for re-rating in round two. Finally, we noted nine items that require further elaboration in the guidance for implementation of the EOH GRADE Evidence-to-Decision framework. Respondents did not propose any new decision considerations in round one. (**Table 7, Figure 9**)

In round two, we again presented 10 scoping criteria and 12 assessment criteria for re-rating by the panel. The detailed judgments disaggregated from the assessment criteria were revised,

reduced, and consolidated into 34 items for re-rating. The round two questionnaire contained 56 total items for re-rating. Based on panel free-text feedback and pre-specified consensus thresholds, 14 items were advanced from round two without any edits, and 5 items were dropped from the set. Other items were aggregated together (n = 4), rephrased (n = 9), or reorganized into a different grouping of decision considerations (n = 1). Finally, we noted two additional items that require further elaboration. Respondents did not propose any new decision considerations in round two. (**Table 7, Figure 9**)

Themes

Through this iterative process of collecting, de-duplicating, reorganizing, clarifying, and consolidating EOH decision considerations for further integration into a tailored EtD framework for EOH decision-making, we observed several themes as follows:

Accounting for broad, undefined constituencies in decision-making

Several frameworks in our sample explicitly referenced consideration of local community views and norms, interaction with various levels of government, broadly shared values in society, and values that tend to be minimized through methods used in traditionally hierarchical decision-making processes.^{25,45,51,54,56,59,69,72–77} EOH decisions frequently affect large populations and diverse stakeholders, which requires decision-makers to define the constituency for a recommendation and make determinations about which stakeholder values are considered and weighted. For example, prioritizing one problem over another may involve an implicit judgment about the values of the population.

Delphi panelists emphasized the importance of specifying the stakeholders who are the subject of consideration (e.g., when making a judgment about whether an intervention is acceptable to key stakeholders, “stakeholders at different levels may have various concerns on the intervention impacts, options, consequences, etc., try to specify the support from stakeholders with more details such as types.”). They also questioned whether the values, engagement, or awareness of a population should factor into decision-making about exposures or interventions to mitigate exposures with established harmful effects (e.g., “Thinking about hazardous exposures, I’m not sure this should be factored in.”)

Consent

In scenarios where broad awareness of an EOH problem and decision alternatives cannot be assumed, consent may be a relevant consideration across several criteria. For example, when assessing whether a problem is a priority, frameworks in our sample described community involvement and advocacy as an indicator of urgency that could inform prioritization of certain questions or problems over others. When assessing acceptability, the frameworks described compulsion, coercion, and individual autonomy as considerations. When assessing feasibility, frameworks were concerned with whether or not the legal and regulatory context could provide an enforcement mechanism for a recommendation or threshold.

Timing

Timing is considered when assessing priority of the problem (e.g., bioaccumulation potential or persistence in the environment of an exposure), the resources required (e.g., age of equipment, institutional knowledge of workers), and the desirable and undesirable effects of different options (e.g., time for a potentially beneficial intervention to reach full effectiveness compared to an alternative). Specifically, EOH decision-makers often balance short-term undesirable effects (e.g., increased stress) and long-term desirable effects (e.g., reduction in community incidence of emphysema). Conclusions may differ depending on which time point is considered the most important.

The precautionary principle

Several frameworks in our sample were concerned with operationalizing the precautionary principle in EOH decision-making. For example, the likelihood of false negatives versus false positives as a consideration as part of the desirable and undesirable effects of alternatives (e.g., “it is more important to avoid false negatives than false positives,” “timing is at least as important as being right”). The precautionary principle is also present in detailed judgments about values, which assess the risk tolerance of various stakeholder groups (e.g., “risk acceptance”), and acceptability.

Social and environmental justice

Delphi panelists suggested broadening the equity criterion to include consideration of the geographical dimensions of an intervention or exposure and issues of social justice/injustice (e.g., “There are environmental exposures that impact communities where the community has no say, e.g. wind turbine facilities. This can be viewed as social injustice. Furthermore, in this scenario, a landowner may directly benefit because the turbine is on their property, a neighbor

who lives closer to the turbine may get nothing.”) Social and environmental justice considerations were also apparent in our sample of EOH decision frameworks (e.g., “Social justice and equality: How is social justice and/or equality addressed? What is the duration of remedial works and are there issues of intergenerational equity? Are the impacts/benefits of works unreasonably disproportionate to particular groups?”)

Barriers to operationalizing the framework

The EOH decision frameworks in our sample tended to forefront granular and context-specific decision considerations, often in the form of highly specific lists. For example, several frameworks provided what they appear to consider to be a comprehensive list of stakeholder perspectives to consider as part of the acceptability criterion, resources to consider when assessing the required resources, and toxicities to consider when assessing the undesirable effects of an exposure and priority of the problem. This specificity may be intended to minimize variation in operationalization of the frameworks or provide sufficient guidance to support implementation in a particular decision context, but also may limit their generalizability. The result is a patchwork of EOH decision frameworks that are each applicable to specific contexts, topics, or scenarios, but no prevailing framework of broad utility. (**Table 3**)

Feedback from Delphi panelists was also focused on barriers to consistent operationalization of the framework. For example, panelists requested static definitions or quantitative thresholds for terms such as “extraordinary” and “important” when these were used to qualify decision considerations (e.g., “Does the problem constitute an extraordinary event?”). These instances were noted for future development of guidance. Panelists also suggested re-wording or reorganization to improve generalizability of considerations that had been abstracted from frameworks developed with a specific context in mind (e.g., “Extent to which funding for intervention is a city or county priority compared with other rivaling priorities” should be revised to remove terms with limited applicability such as “county” and replaced with general terms such as “local.”) Finally, panelists highlighted scenarios where specific detailed judgments would not apply and noted that they were uncertain about how to respond if a judgment was not relevant or applicable to a given scenario.

DISCUSSION

Statement of the principal findings

These results suggest that the GRADE EtD framework is applicable for use in EOH decision-making (e.g., determination of an allowable level or threshold of an exposure, alternatives assessment, or recommendation of an intervention to prevent or mitigate an exposure). However, as mentioned in the development of the original GRADE EtD frameworks, some criteria may be more or less relevant depending on the specific decision context.

One key modification in our proposed framework is broadening the scope of the GRADE EtD health equity criterion to include considerations beyond health equity. Unequal distribution of environmental burdens and benefits is a feature of social, political, and economic systems. The natural and built environment, including workplaces, are key sites whereby “resources like knowledge, money, power, prestige, and social connections are transformed into the health-related resources that generate patterns of morbidity and mortality.”⁸⁰ EOH decision-makers often must account for both immediate (proximal) and indirect (distal) factors associated with health outcomes. Deliberate consideration of the socio-political and economic context is important to recognize when an intervention or option may perpetuate or increase inequity, as these conditions are instrumental in shaping patterns of exposure. Failure to consider context may result in “interventions [with targets] that are resistant to change for unrecognized reasons.”⁸⁰ Social context is partially accommodated in other EtD criteria, such as values, acceptability, feasibility, but also should be accommodated in equity to account for disparities that are immediately connected to health outcomes, as well as further upstream from these outcomes.

Other assessment criteria underwent minor modification through changes to their composite detailed judgments. These changes incorporate concepts that were surfaced from the EOH literature and confirmed by the Delphi process. Examples are consideration of irreversibility when judging the priority of a problem and consideration of time span for sustainability when assessing feasibility. Finally, detailed judgments informing the “Resources” and “Cost-Effectiveness” criteria were simplified and consolidated based on feedback from the panel that more granular or specific prompts were difficult to interpret and had limited applicability. The GRADE EtD framework for EOH and accompanying guidance are presented in the companion to this manuscript (**CROSS REF - TK**).

Strengths and weaknesses of the study

This work is intended to support an exhaustive and transparent process for development of an EtD framework that is suitable for EOH decision-making. We used a rigorous methodology to

systematically identify and screen decision-making frameworks, adopting an inclusive approach to capture all decision factors that could be relevant to EOH. Our analysis is grounded in an established framework, the GRADE EtD for health system and public health decisions. Through narrative synthesis, we were able to summarize and analyze factors and criteria that are not readily explored using other techniques. For example, we used thematic analysis to identify relationships between the sampled frameworks and the GRADE EtD for health system and public health decisions.

This systematic review was limited to frameworks that exist in the published or public domain and does not include proprietary, confidential, or undocumented frameworks that may be used for EOH decision-making. This potentially reduced the size of our sample and the perspectives represented therein. Judgments about inclusion or modification of EOH decision criteria made by this research team are inherently subjective and may not be replicable. Further, our interpretations of ambiguous EOH decision criteria are informed by associated written material made available by framework developers, but also involve subjective judgment. Statistical analysis of the association between framework characteristics and decision considerations is also limited by our sample size. These results are intended to be hypothesis-generating rather than conclusive. Further development and validation of a proposed EtD framework for EOH is outside the scope of this study.

Further, we have minimal certainty in the reliability of the Delphi study results, meaning that another panel may receive the same questionnaires and provide different responses. Additionally, our panel is not completely representative of intended users; some geographical regions, agencies, and perspectives are not represented because of logistical constraints. Although an important feature of the Delphi process, attainment of consensus does not necessarily mean that a single correct opinion or judgment has been discovered. Instead we have identified concepts that one group considers to be important for EOH decision-making. Finally, decisions made by the research team about how to implement vague or contradictory feedback from the panel are inherently subjective.

Relation to other studies

This work extends ongoing efforts to develop a systematic approach to collect, synthesize, and evaluate scientific evidence linking environmental exposures to health outcomes.^{3,7,8,11,27} We have aimed to address the juncture where scientific evidence is used to inform policy, regulation, and other, similar decisions in EOH.

Additionally, our findings contribute to a growing body of literature on usage of the GRADE EtD frameworks.^{27,81–88} We found that most of the EOH decision considerations in our sample were related to more than one of the GRADE EtD criteria. This finding reflects three forms of ambiguity: multiple plausible interpretations of the EOH framework terminology, lumping of multiple concepts within one EOH decision consideration, and the inter-relatedness of the GRADE EtD criteria themselves. Context-specific tailoring of the GRADE EtD detailed judgements and guidance has the potential to provide additional clarity and structure to support operationalization of the framework.

Meaning of the study: possible explanations and implications for stakeholders

Abstracted contextual information may explain some of the observed similarities and differences between EOH decision frameworks and the GRADE EtD. Many frameworks in our sample were developed to address specific topics and decision types (e.g., platform decommissioning), and are thus inherently specific to the perspective taken by their developers. Examining the distribution of detailed judgements across types of developers and topics provides insight into which criteria are most frequently considered or consistently deemed relevant by EOH stakeholders from a variety of perspectives. Differences we observed in the detailed judgments across perspectives could also be explained by varying degrees of familiarity with the GRADE EtD framework among EOH framework developers. When stratified by framework characteristics, our data describe trends in alignment with the GRADE EtD and in turn, identify which types of decision-makers may be more or less amenable to adopting an EOH EtD framework.

During both phases of the project, we also aimed to detect considerations that may be specific to EOH decisions and are not necessarily encompassed within existing GRADE EtD framework perspectives. Although we identified information to augment the GRADE EtD framework and guidance, our results do not support the addition of any new decision criteria to the GRADE EtD for health system and public health decisions to improve its suitability for EOH decision scenarios.

The GRADE EtD framework provides latitude for decision-makers to determine the level of detail of the considerations that they deem relevant to each of the assessment criteria, provided that the process is transparently reported. For example, it may be helpful for an EOH EtD to emphasize certainty of values and certainty of acceptability as considerations where values and acceptability are expected to be key drivers of a recommendation. Disaggregating these

considerations could be useful to describe uncertainty about or variability in stakeholder preferences when making a decision that will affect a broad or undefined population. Finally, the cross-cutting themes – time, consent, and the precautionary principle – may inform tailoring of the wording of guidance for assessment criteria and implementation considerations to make the GRADE EtD more applicable in EOH settings. In particular, decision-makers may find it useful to incorporate the precautionary principle as an explicit consideration when assessing the desirable effects, undesirable effects, and balance of effects of the options under consideration.

Unanswered questions and future directions

Feedback from the Delphi panel indicated the need for additional guidance for GRADE EtD implementation to facilitate uptake among EOH decision-makers, especially those who are less familiar with the GRADE approach. This could include principles for ethical or equitable decision-making, definitions of terminology used within the GRADE EtD framework, and additional options for signaling questions that are relevant to specific contexts informed by considerations identified by this study. Subsequent research can include the development and pilot testing of implementation guidance with relevant stakeholders.

CONCLUSIONS

The proposed GRADE EtD for EOH resulting from this study is similar to its foundational framework, the GRADE EtD for health system and public health decisions. Our work thus far has served to validate and extend the constructs of the GRADE EtD to a new perspective. Findings of the Delphi process also indicate that the literature is reasonably comprehensive of EOH decision considerations. This work represents another step towards development of an EtD to advance decision-making in EOH. Future work will pilot test the proposed framework, present a final version, and provide guidance for its application.

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Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram

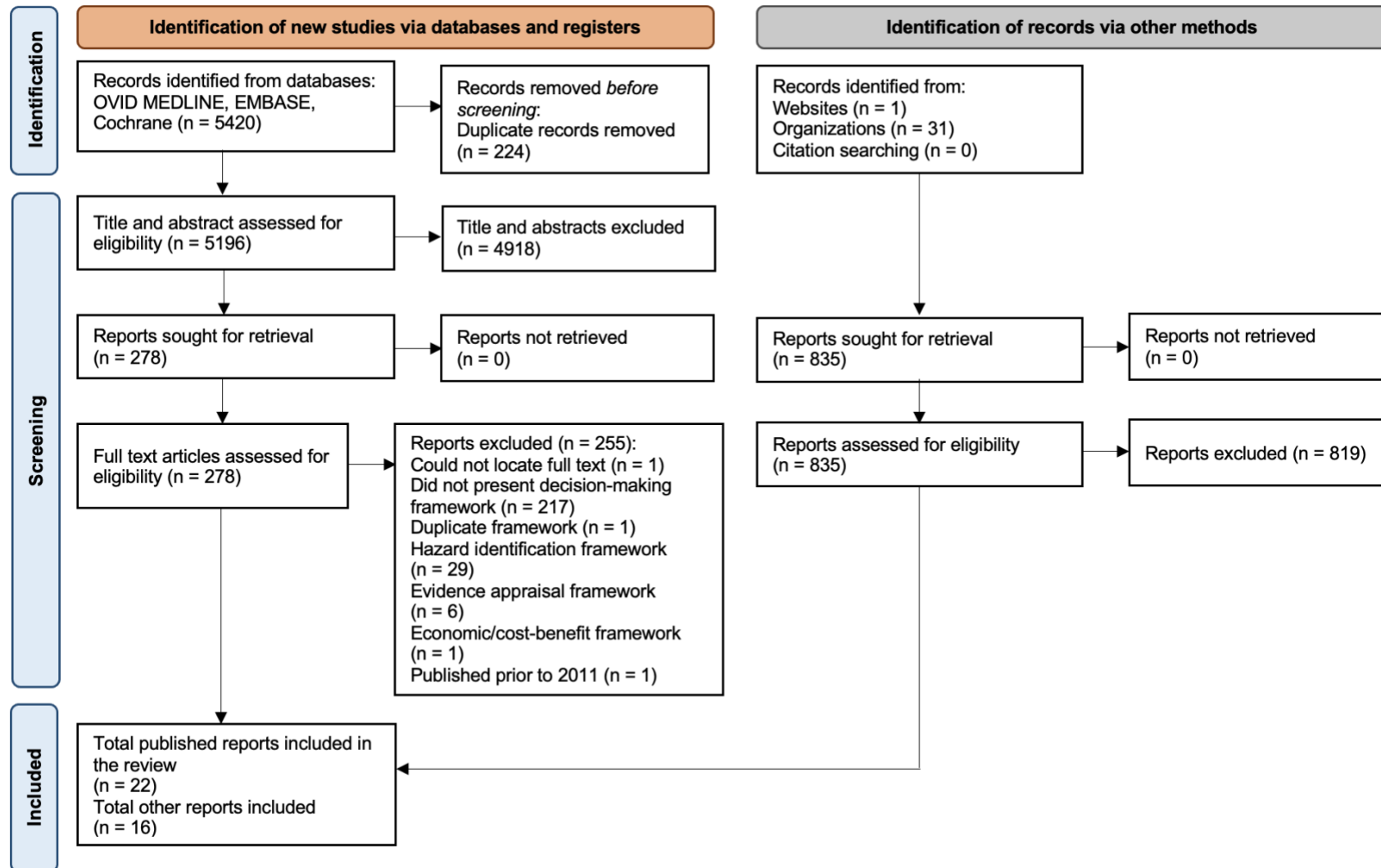


Table 1. Example round 1 coding decisions

Identified Decision Consideration	Code(s) Applied	Rationale
Do any of the proposed interventions feature courses of action that may be against the law?	Feasibility	Maps to detailed judgement, “Are there important legal or bureaucratic or ethical constraints that make it difficult or impossible to cover the intervention?”
People's reaction: Is there public reaction due to risk, odor, noise, etc.?	Acceptability	Maps to detailed judgments, “Are there key stakeholders that would not accept the distribution of the benefits, harms and costs?” and, “Are there key stakeholders that would not accept the costs or undesirable effects in the short term for desirable effects (benefits) in the future?”
Contaminant source: Hazard inventory and information on severity of hazards	Problem Undesirable Effects	Maps to detailed judgments, “Are the consequences of the problem serious?” (Problem) and main criteria judgment, “How substantial are the undesirable anticipated effects?” (Undesirable Effects)

Table 2. Glossary of terms

Term	Definition
<i>Assessment criteria/on*</i>	Decision factors that are intended to facilitate comparison of alternatives (Problem, Desirable effects, Undesirable effects, Certainty of evidence, Values, Balance of effects, Resources required, Cost effectiveness, Equity, Acceptability, Feasibility)
<i>Decision criteria/on</i>	Factors that should be considered when making a decision or a recommendation
<i>Decision framework</i>	A structured presentation of factors and information to consider when making a decision or a recommendation
<i>Detailed judgement*</i>	An optional prompt intended to facilitate discussion and clarify the information used to inform the assessment criteria judgments
<i>Item</i>	A prompt or signaling question within an EOH decision framework; corresponds to the GRADE EtD framework detailed judgment in level of granularity
<i>Scope and context criteria/on*</i>	Background information, such as the setting and stakeholders, that describes the circumstances under which a decision will be made.

* Language specific to the GRADE EtD framework

Table 3. Characteristics of included EOH decision-making frameworks

#	Author, Year	Framework Title	Development Organization	Topic	Reported Decision Criteria
1	Adar, et al., 2020	Multi-criteria decision-making (MCDM) prioritization of the treatment and disposal methods of wastes	Academic	Sanitation	<ul style="list-style-type: none"> ◇ Technology ◇ Cost ◇ Environmental ◇ Social/ergonomics
2	Anonymous, 2014	EPA Framework for Human Health Risk Assessment to Inform Decision Making	Government	Unspecified	<ul style="list-style-type: none"> ◇ Laws and regulatory requirements ◇ Economic analyses ◇ Sustainability ◇ Technological considerations ◇ Political considerations ◇ Public and social considerations
3	Anonymous, 2018	Health Quality Ontario Health Technology Assessment (HTA) Decision Determinants Framework	Government	Public health	<ul style="list-style-type: none"> ◇ Overall clinical benefit ◇ Consistency with expected societal and ethical values ◇ Value for money ◇ Feasibility of adoption into the health system
4	Anonymous, 2019	Scottish Intercollegiate Guidelines Network (SIGN) guideline methodology	Government	Public health	<ul style="list-style-type: none"> ◇ Is this question a priority? ◇ How sure are we that any given option will work? ◇ Balancing benefits and harms ◇ How do patients value the different outcomes? ◇ Equity ◇ Costs and benefits
5	Anonymous1, 2020	Procedures for the CADTH pan-Canadian Oncology Drug Review	Government	Public health	<ul style="list-style-type: none"> ◇ Overall clinical benefit ◇ Alignment with patient values ◇ Cost effectiveness ◇ Feasibility of adoption into health systems

#	Author, Year	Framework Title	Development Organization	Topic	Reported Decision Criteria
6	Anonymous ² , 2020	WHO Evidence to Decision (EtD) table	Government	Public health	<ul style="list-style-type: none"> ◇ Policy importance ◇ Desirable effects ◇ Undesirable effects ◇ Evidence certainty ◇ Balance of effects ◇ Generalizability ◇ Equity ◇ Acceptability ◇ Resources required ◇ Feasibility ◇ Sustainability
7	Anonymous, unknown year	CDC ACIP Evidence to Recommendations Framework	Government	Public health	<ul style="list-style-type: none"> ◇ Problem ◇ Benefits & harms ◇ Values ◇ Acceptability ◇ Resource use ◇ Equity ◇ Feasibility of adoption into health systems
8	Bernstein, 2015	California Natural Resources Agency Decision Framework for Platform Decommissioning in California	Government	Water management	<ul style="list-style-type: none"> ◇ Legal/regulatory ◇ Environmental/ecological ◇ Feasibility/cost ◇ Liability ◇ Cost
9	Burger and Gochfeld, 2020	Department of Energy Consortium for Risk Evaluation with Stakeholder Participation (CRESP) template of information needs for decision-making about delaying remediation on contaminated lands to protect human health	Government	Site remediation	<ul style="list-style-type: none"> ◇ Management, planning, and implementation ◇ Source term, pathways, and methods of exposure ◇ Risks and receptors ◇ External drivers

#	Author, Year	Framework Title	Development Organization	Topic	Reported Decision Criteria
10	Cappuyns, 2016	Sustainable Remediation Forum - United Kingdom (SuRF-UK)	NGO	Site remediation	<ul style="list-style-type: none"> Human health and safety Neighbourhood and locality Communities & community involvement Uncertainty & evidence
11	Carande-Kulis, 2012	CDC Guidelines and Recommendations Primer	Government	Public health	<ul style="list-style-type: none"> Quality of the evidence Benefits vs. harms Values and preferences of the target audience Resources
12	Deveau, et al., 2015	Potential sources of variability in science and policy decisions taken during the establishment of occupational exposure limits (OELs)	Academic	Workplace	<ul style="list-style-type: none"> Risk science decisions Risk policy decisions
13	Dorman, et al., 2014	National Academies Framework to Guide Selection of Chemical Alternatives	NGO	Chemical alternatives assessment	<ul style="list-style-type: none"> Physiochemical properties Life cycle thinking
14	Felknor, et al., 2019	NIOSH BNI method	Government	Workplace	<ul style="list-style-type: none"> Burden Need Impact
15	Garfi and Ferrer-Marti, 2011	General criteria for water and basic sanitation projects	Academic	Water management / Sanitation	<ul style="list-style-type: none"> Technical Social Economic Environmental
16	González-Lorenzo, et al., 2015	Proposed conceptual framework to support vaccine adoption and coverage decisions in a health system	Academic	Public health	<ul style="list-style-type: none"> Vaccine characteristics Impact of immunization program Values and preferences Resource use Equity Feasibility

#	Author, Year	Framework Title	Development Organization	Topic	Reported Decision Criteria
17	He and Hung, 2012	Groupe de Recherche en Économie et Développement International (GREDI) Vehicle Emissions Policymaking Criteria	Academic	Emissions	<ul style="list-style-type: none"> ◇ Cost of implementation ◇ Effectiveness ◇ Effect time ◇ Political or public acceptability ◇ Administer-ability ◇ Degree of deviations from the existing system
18	Kayman and Logar, 2016	Framework for Training Public Health Practitioners in Crisis Decision-Making	Academic	Disaster/emergency	<ul style="list-style-type: none"> ◇ Ethical considerations ◇ Political considerations ◇ Logistical considerations
19	Krahn, et al., 2018	Ontario Decision Framework	Government	Public health	<ul style="list-style-type: none"> ◇ Contextual factors ◇ Health system feasibility ◇ Benefits and harms ◇ Economics ◇ Patient-centered care
20	Malekpour, et al., 2013	Sanitation options evaluation criteria and their indicators	Academic	Sanitation	<ul style="list-style-type: none"> ◇ Exposure to health hazards ◇ Accessibility ◇ Reliability
21	Malloy, et al., 2013	Alternatives analysis methodology	Academic	Chemical alternatives assessment	<ul style="list-style-type: none"> ◇ Physical chemical hazards ◇ Human health impact ◇ Ecological impacts ◇ Environmental impacts ◇ Technical feasibility ◇ Economic feasibility
22	Marazzi, et al., 2020	Earthwatch Institute (Europe) MCDA approach to consumer-based actions to reduce plastic pollution in rivers	NGO	Water management	<ul style="list-style-type: none"> ◇ Feasibility ◇ Economic impacts ◇ Environmental impact ◇ Other environmental unintended consequences ◇ Potential scale of change

#	Author, Year	Framework Title	Development Organization	Topic	Reported Decision Criteria
					◇ Evidence of impact
23	Mitchell, et al., 2013	United States Army Corps of Engineers Framework for Exposure-Based Chemical Prioritization	Government	Chemical alternatives assessment	◇ Chemical properties ◇ Life cycle properties
24	Moermond, et al., 2012	RIVM Revised Annex XIII of REACH	NGO	Chemical alternatives assessment	◇ Persistence ◇ Bioaccumulation ◇ Toxicity
25	Morley, et al., 2017	NIOSH Proposed Ethical Framework for Decision-making about Employee Monitoring	Government	Workplace	◇ Justification ◇ Optimization ◇ Minimization of harm ◇ Ethical values
26	Mullen, et al., 2020	Decision criteria used in PHEIC determinations	Academic	Disaster/ emergency	◇ Constitutes an extraordinary event ◇ Public health risk to other states via international spread ◇ Requires a coordinated international response ◇ Sustained community transmission ◇ Gaps in knowledge due to novel agent or limited response experience ◇ Impending mass gathering ◇ Threat to eradication ◇ Complex response settings
27	Naman and Gibson, 2015	Analysis of the Decision-Making Process for Water and Sewer Services in North Carolina	Academic	Water management / sanitation	◇ Financing ◇ Government support ◇ Existing infrastructure ◇ Community engagement ◇ Public health
28	Pang, et al., 2017	Harmful algal bloom management framework	Academic	Water management	◇ Human health

#	Author, Year	Framework Title	Development Organization	Topic	Reported Decision Criteria
					<ul style="list-style-type: none"> ◇ Environmental impact ◇ Social impact ◇ Technical feasibility
29	Perez, et al., 2017	REACH-modified GreenSuite	Industry	Chemical alternatives assessment	<ul style="list-style-type: none"> ◇ Ecological ◇ Health ◇ Safety
30	Persson, 2016	Core ideas behind the precautionary principle	Academic	Unspecified	<ul style="list-style-type: none"> ◇ Value of human health and the environment ◇ Irreversibility ◇ False positives versus false negatives
31	Ramos, 2018	Human Rights-Based Approach to Farmworker Health	Academic	Workplace	<ul style="list-style-type: none"> ◇ Availability ◇ Accessibility ◇ Acceptability ◇ Quality
32	Rehfuess, et al., 2019	WHO-INTEGRATE evidence to decision framework	Government	Public health	<ul style="list-style-type: none"> ◇ Balance of health benefits and harms ◇ Human rights and sociocultural acceptability ◇ Health equity, equality, and non-discrimination ◇ Societal implications ◇ Financial and economic considerations ◇ Feasibility and health system considerations ◇ Quality of evidence
33	Resnik, et al., 2018	National Institute of Environmental Health Sciences (NIEHS) Accountability for reasonableness	Government	Unspecified	<ul style="list-style-type: none"> ◇ Publicity ◇ Relevancy ◇ Revisability ◇ Enforceability
34	Sampietro-Colom, et al., 2015	AdHopHTA	NGO	Public health	<ul style="list-style-type: none"> ◇ Health technology and technical characteristics ◇ Health problem and current use of the technology ◇ Clinical effectiveness ◇ Safety aspects

#	Author, Year	Framework Title	Development Organization	Topic	Reported Decision Criteria
					<ul style="list-style-type: none"> ◇ Ethical, organizational, social, and legal aspects ◇ Cost and economic evaluation
35	Siu, et al., 2021	US Preventive Services Task Force (USPSTF) Procedure Manual	Government	Public health	<ul style="list-style-type: none"> ◇ Detection ◇ Benefits – evidence ◇ Benefits – linkage coherence ◇ Benefits – magnitude ◇ Harms – evidence ◇ Harms – linkage coherence ◇ Harms – magnitude ◇ Overall certainty ◇ Magnitude of net benefit
36	Song and Kim, 2021	Ethical evaluation of community water fluoridation	Academic	Water management	<ul style="list-style-type: none"> ◇ Effectiveness ◇ Proportionality ◇ Necessity/least infringement ◇ Public justification
37	Williams, et al., 2020	EPA Regional Environmental Science and Sustainability Research Program (RESES) Dredged Material Decision Tool	Government	Water management	<ul style="list-style-type: none"> ◇ Biophysical environment ◇ Economy ◇ Social ◇ Governance ◇ Built environment
38	Woods, et al., 2016	Decision support for risk prioritisation of environmental health hazards in a UK city (funded by Public Health England)	Government	Unspecified	<ul style="list-style-type: none"> ◇ Mortality ◇ Morbidity ◇ Robust evidence ◇ Wellbeing ◇ Sustainability of intervention ◇ Level of regulation

Figure 2. Illustration of deductive coding process for all discovered EOH decision factors

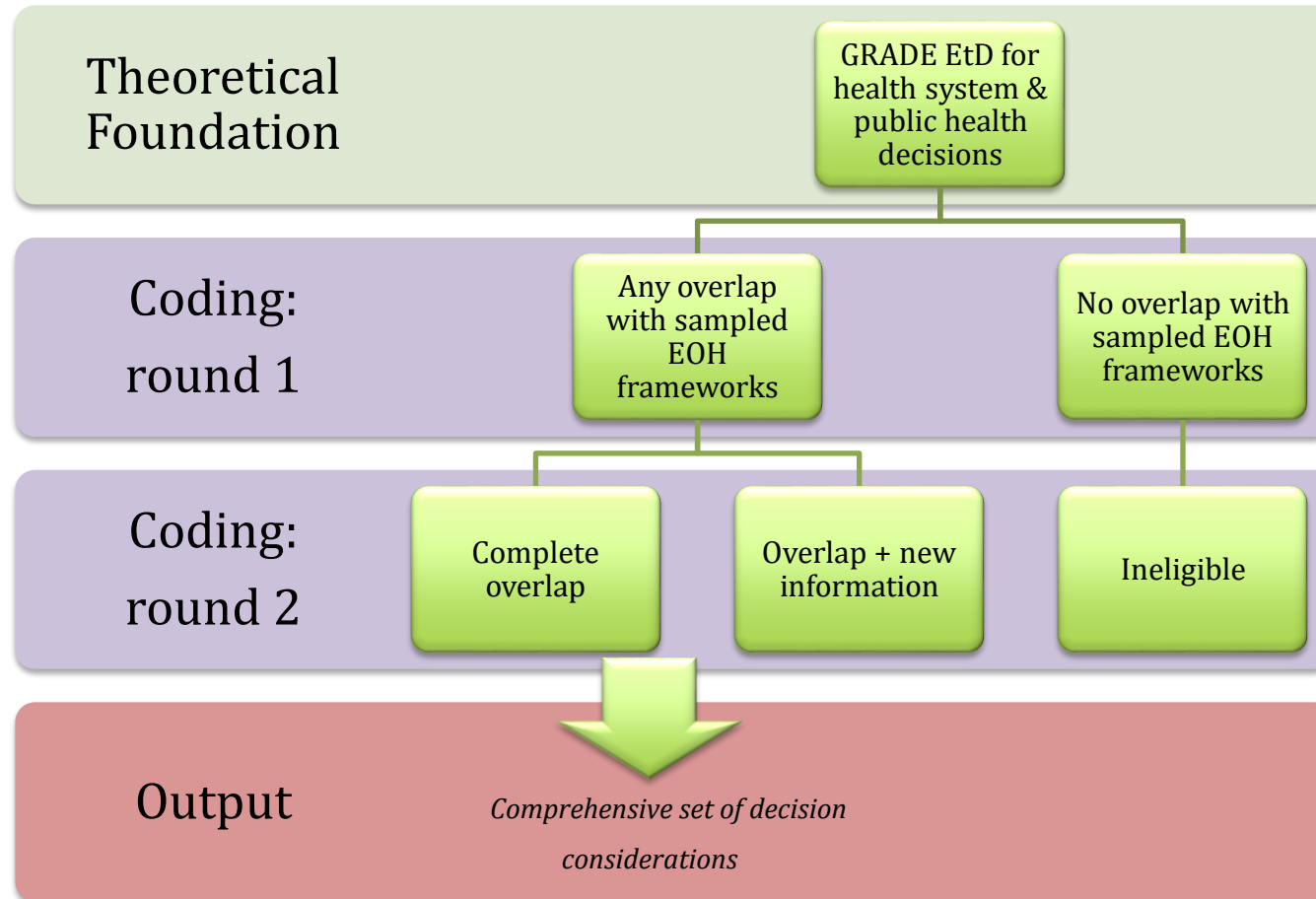


Table 4. Contingency table of discovered EOH decision factors coded to each GRADE EtD criterion by framework characteristics

Framework Characteristics (N = total frameworks, n = total detailed judgements)	Detailed Judgements (frequency / % of row total)										
	Problem	Desirable effects	Undesirable effects	Certainty of evidence	Values	Balance of effects	Resources required	Cost effectiveness	Equity	Acceptability	Feasibility
Development organization											
Government (N=18, n=275)	31 / 6.7	67 / 14.6	58 / 12.6	27 / 5.9	19 / 4.1	27 / 5.9	43 / 9.3	15 / 3.3	19 / 4.1	54 / 11.7	100 / 21.7
NGO (N=5, n=47)	10 / 12.8	13 / 16.7	20 / 25.6	3 / 3.8	4 / 5.1	3 / 3.8	5 / 6.4	3 / 3.8	1 / 1.3	10 / 12.8	6 / 7.7
Industry (N=1, n=35)	35 / 50	0 / 0	35 / 50	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Academic (N=14, n=241)	80 / 19	24 / 5.7	93 / 22.1	14 / 3.3	31 / 7.4	11 / 2.6	36 / 8.6	14 / 3.3	12 / 2.9	38 / 9	68 / 16.2
Topic											
Site remediation (N=2, n=72)	4 / 3.2	7 / 5.6	17 / 13.5	6 / 4.8	6 / 4.8	0 / 0	18 / 14.3	2 / 1.6	5 / 3.9	19 / 15.1	42 / 33.3
Water management (N=7, n=133)	17 / 6.9	49 / 20	40 / 16.3	5 / 2	12 / 4.9	19 / 7.8	16 / 6.5	7 / 2.9	5 / 2	25 / 10	50 / 20
Sanitation (N=4, n=60)	6 / 5.6	6 / 5.6	20 / 18.7	4 / 3.7	7 / 6.5	1 / 0.9	12 / 11.2	4 / 3.7	3 / 2.8	14 / 13.1	30 / 28
Workplace exposure (N=4, n=35)	2 / 8.3	2 / 8.3	2 / 8.3	3 / 12.5	2 / 8.3	2 / 8.3	0 / 0	0 / 0	1 / 4.2	8 / 33.3	2 / 8.3
Emissions (N=1, n=6)	0 / 0	2 / 22.2	0 / 0	0 / 0	0 / 0	0 / 0	1 / 11.1	1 / 11.1	0 / 0	3 / 33.3	2 / 22.2
Chemical alternatives identification (N=5, n=113)	99 / 41.6	1 / 0.4	104 / 43.7	0 / 0	8 / 3.4	2 / 0.8	11 / 4.6	2 / 0.8	0 / 0	3 / 1.3	8 / 3.4
Public health (N=11, n=132)	19 / 9.9	24 / 12.6	16 / 8.4	19 / 9.9	12 / 6.3	9 / 4.7	19 / 9.9	13 / 6.8	15 / 7.9	20 / 10.5	25 / 13.1
Emergency / Disaster (N=2, n=23)	5 / 12.8	5 / 12.8	1 / 2.6	3 / 7.7	4 / 10	4 / 10	3 / 7.7	2 / 5.1	2 / 5.1	5 / 12.8	5 / 12.8
Unspecified (N=4, n=24)	4 / 8	8 / 16	6 / 12	4 / 8	3 / 6	4 / 8	4 / 8	1 / 2	1 / 2	5 / 10	10 / 20
11											
<div><div>≥50% of row</div><div>≥10% of row</div></div> <div><div>≥40% of row</div><div>≥1% of row</div></div> <div><div>≥30% of row</div><div>0% of row</div></div> <div><div>≥20% of row</div></div>											

11

Figure 3. Summary of coding decisions for all discovered EOH decision factors

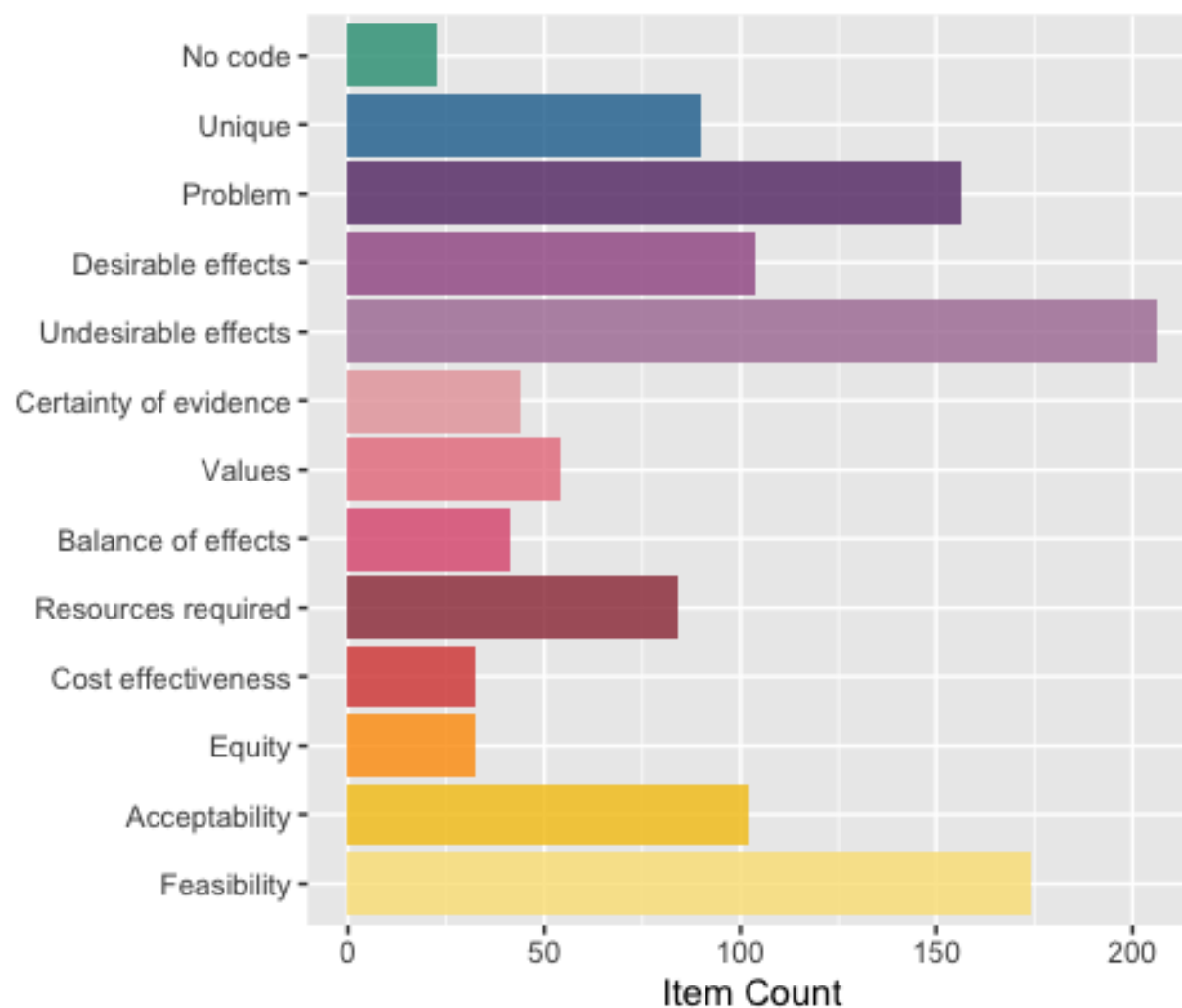


Table 5. Summary of GRADE EtD criterion codes and unique codes applied to discovered EOH decision factors

GRADE EtD Criteria (codes)	Total Discovered Items (frequency / % of total)	Redundant (frequency / % of row)	Unique: Guidance (frequency / % of row)	Unique: Scope/Context (frequency / % of row)	Unique: Detailed Judgements (frequency / % of row)
	<i>Total = 560*</i>	<i>n = 930*</i>	<i>n = 2</i>	<i>n = 40</i>	<i>n = 62</i>
<i>Problem</i>	156 / 27.9	115 / 73.7	2 / 1.3	14 / 8.9	25 / 16
<i>Desirable effects</i>	104 / 18.6	99 / 95.2	0 / 0	0 / 0	5 / 4.8
<i>Undesirable effects</i>	206 / 36.8	204 / 99	0 / 0	0 / 0	2 / 1
<i>Certainty of evidence</i>	44 / 7.9	44 / 100	0 / 0	0 / 0	0 / 0
<i>Values</i>	54 / 9.6	48 / 88.9	0 / 0	6 / 11.1	0 / 0
<i>Balance of effects</i>	41 / 7.3	41 / 100	0 / 0	0 / 0	0 / 0
<i>Resources required</i>	84 / 15.0	59 / 70.2	0 / 0	6 / 7.1	19 / 22.6
<i>Cost effectiveness</i>	32 / 5.7	27 / 84.4	0 / 0	2 / 6.3	3 / 9.4
<i>Equity</i>	32 / 5.7	27 / 84.4	0 / 0	1 / 3.1	4 / 12.5
<i>Acceptability</i>	102 / 18.2	94 / 93.1	0 / 0	6 / 5.9	2 / 2
<i>Feasibility</i>	174 / 31.1	171 / 98.3	0 / 0	3 / 1.7	0 / 0

**Multiple codes were applied to some detailed judgements; these totals include each time a detailed judgement was coded to a criterion and thus, count some detailed judgements more than once.*

Figure 4. Count of codes applied to each discovered EOH decision factor

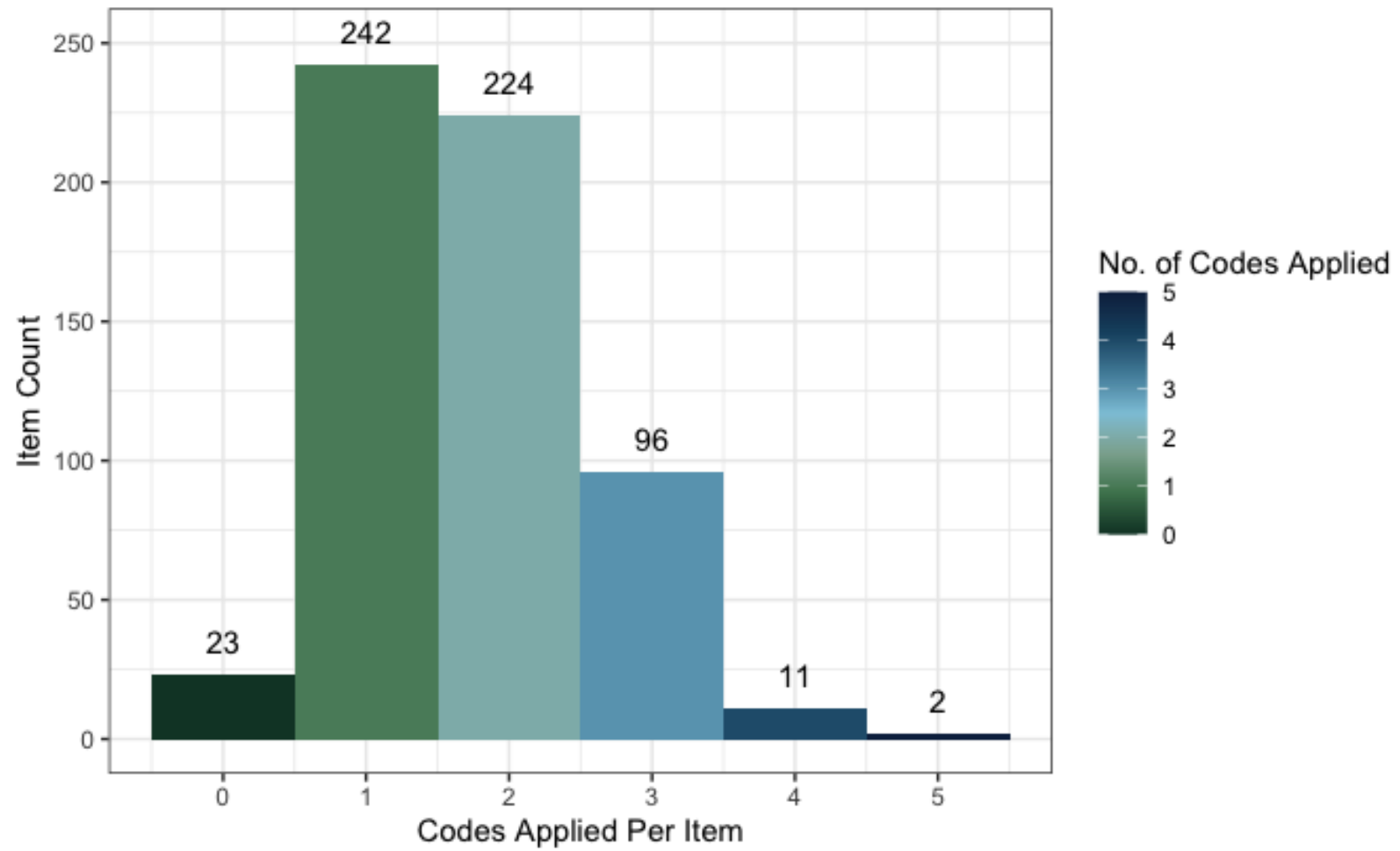
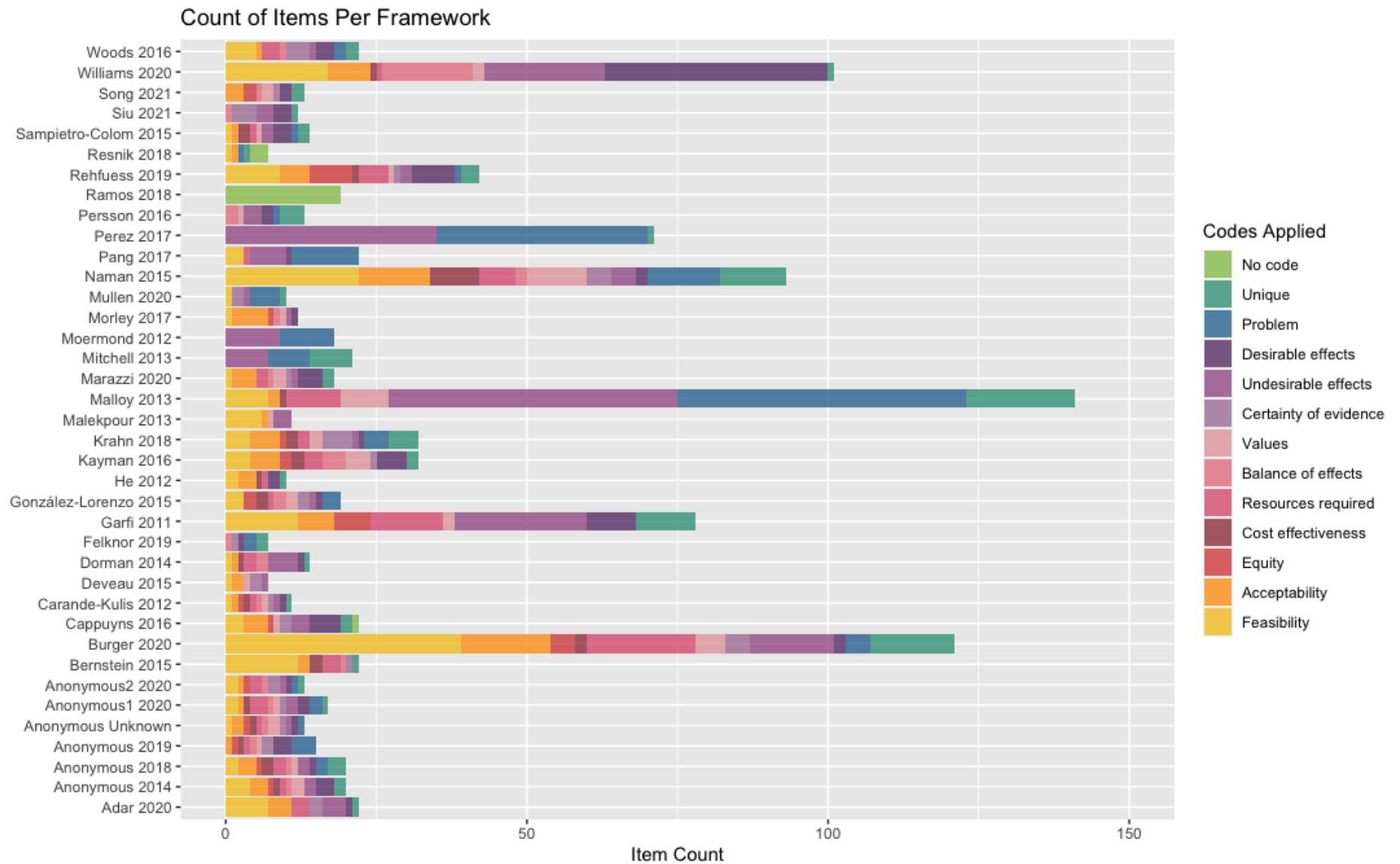


Figure 5. Count and proportion of codes applied to discovered EOH decision factors per framework



Proportion of Items Per Framework

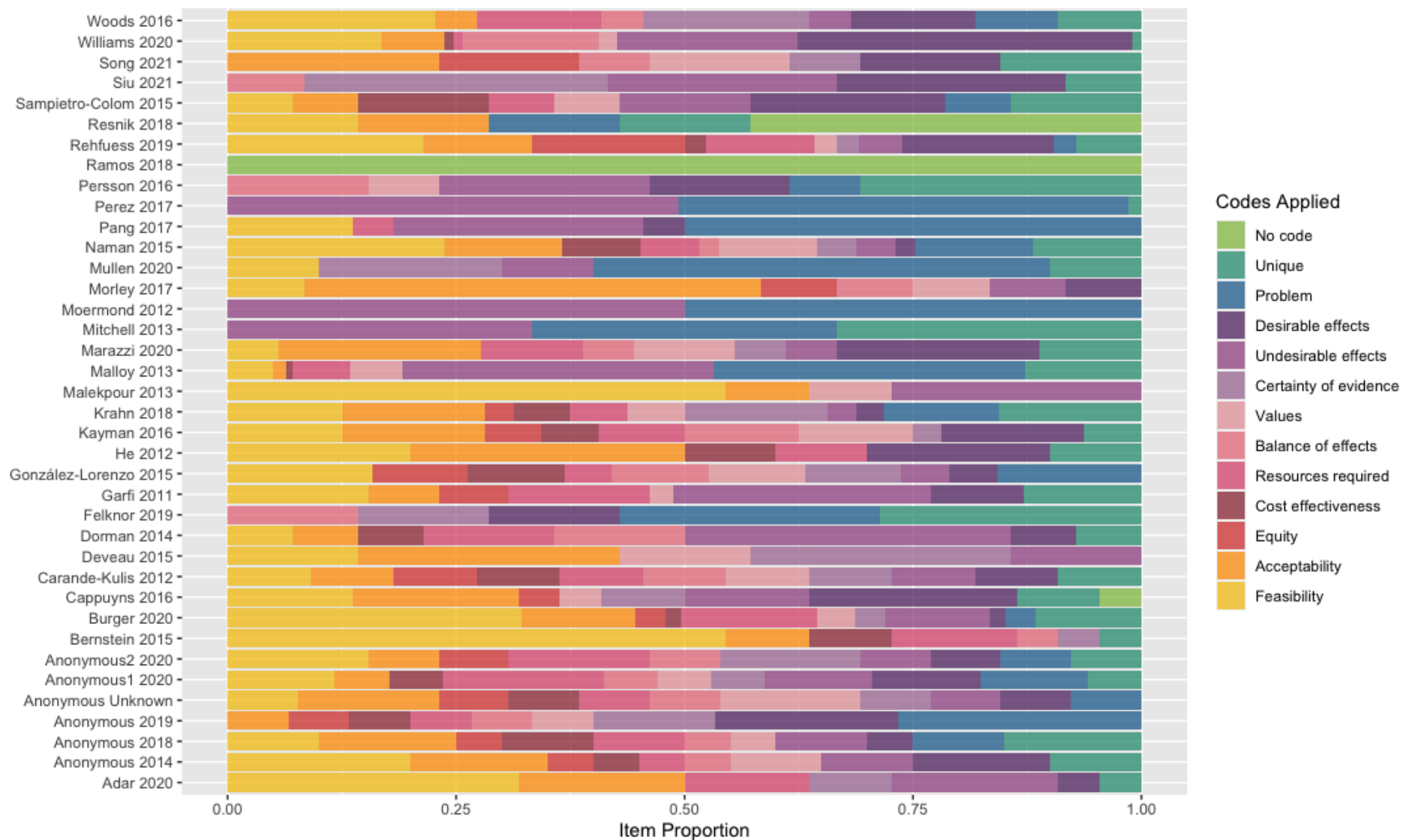


Figure 6. Count and proportion of codes applied to discovered EOH decision factors by type of organization that developed the framework

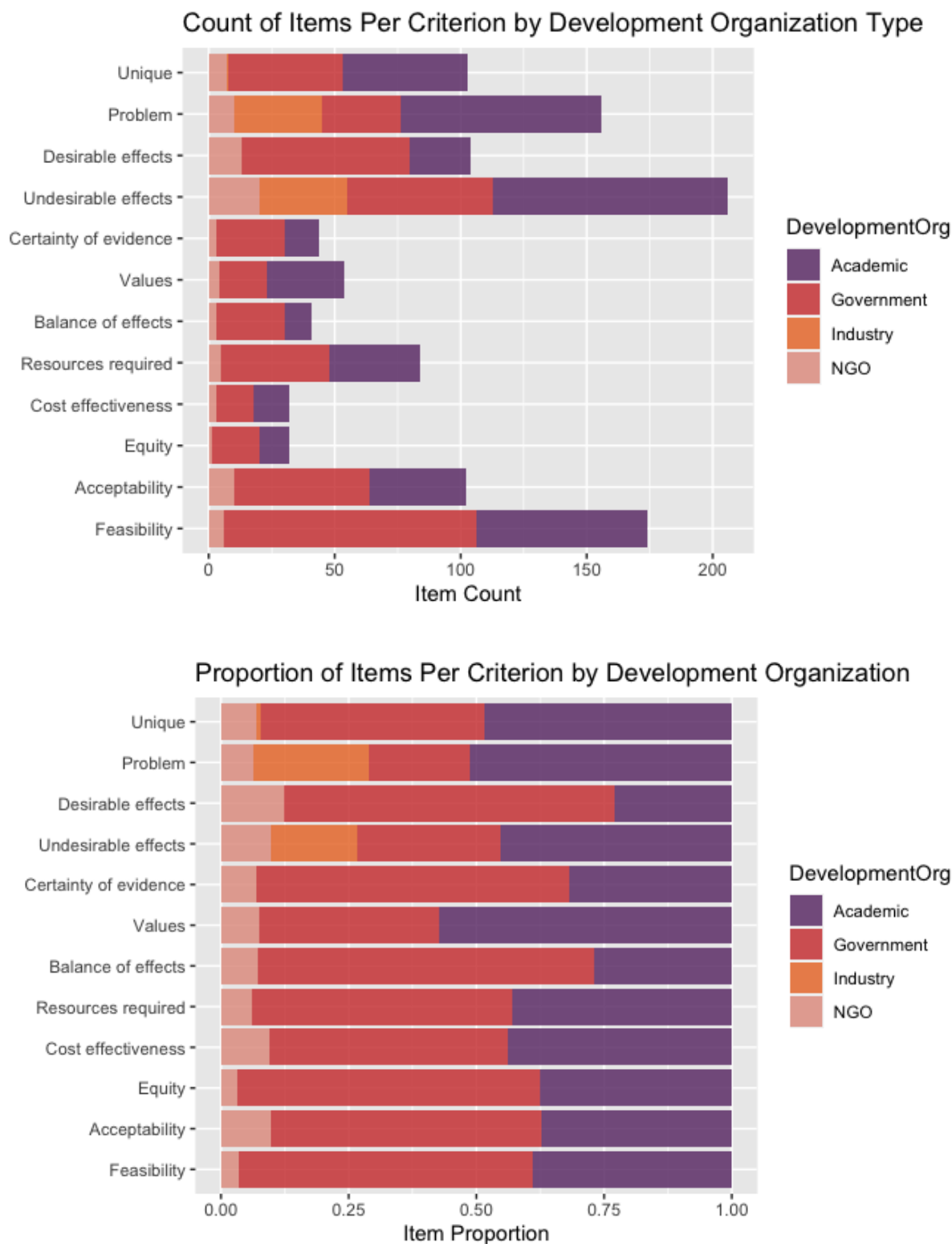


Figure 7. Count and proportion of codes applied to discovered EOH decision factors by framework topic

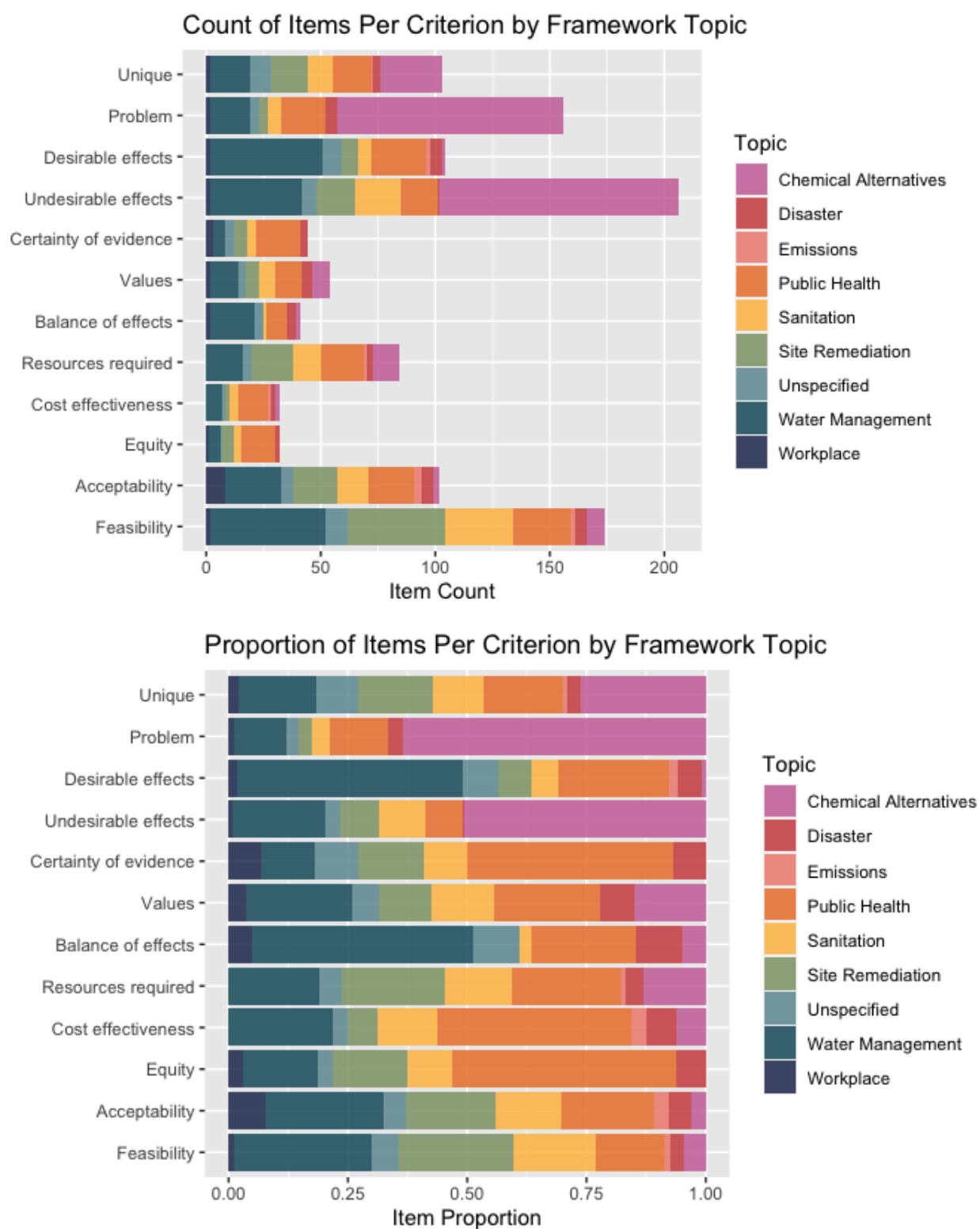


Figure 8. Participation in the Delphi process

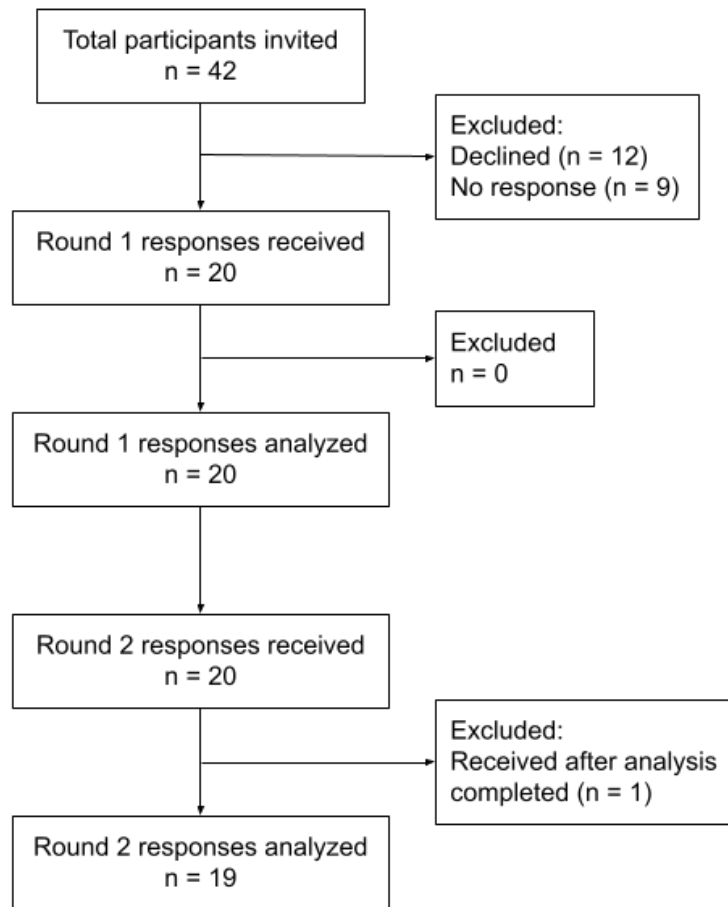


Figure 9. Disposition of items presented for rating

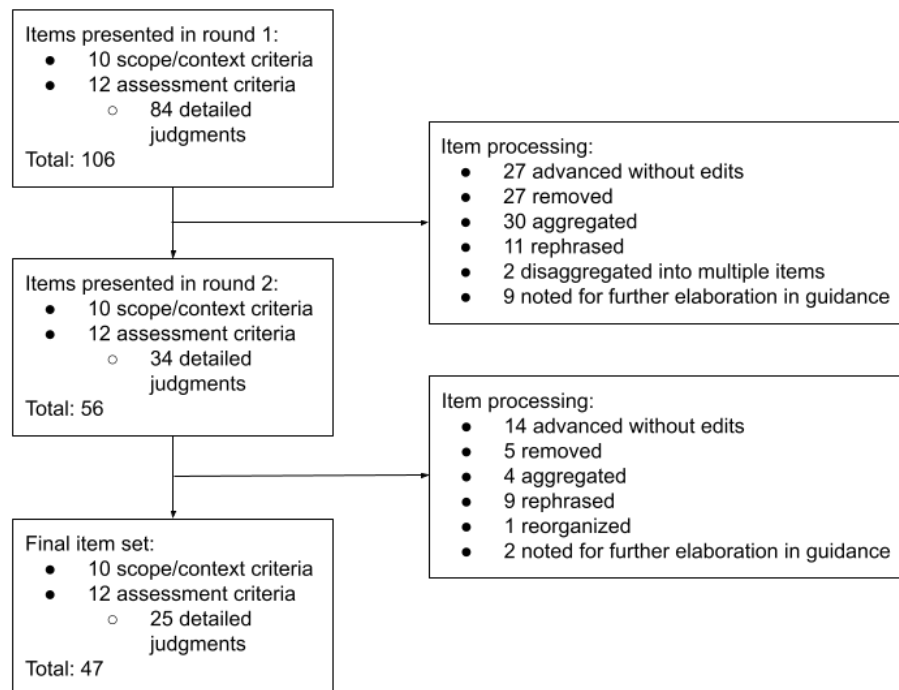


Table 6. Delphi panel demographic characteristics

Demographic Category	Round 1 (n = 20) n (%)	Round 2 (n = 19) n (%)
<i>Gender</i>		
Female	10 (50)	9 (47)
Male	10 (50)	10 (53)
<i>Geographical region</i>		
Africa	1 (5%)	1 (5%)
Asia	3 (15%)	2 (11%)
Australia	2 (10%)	2 (11%)
Europe	4 (20%)	4 (21%)
North America	9 (45%)	9 (47%)
South America	1 (5%)	1 (5%)
<i>Setting</i>		
Government or regulatory agency	10 (50%)	10 (53)
Academia or research	10 (50%)	9 (47)
<i>Area of expertise*</i>		
Cancer	1	1
Environmental health	10	10
Food safety or nutrition	1	1
Occupational health	5	4
Risk assessment or management	1	1
Other	4	4

**Multiple areas of expertise may be attributed to a single participant*

Table 7. Summary of results

ROUND 1		ROUND 2	
Content Removed (n = 27)	Content for Re-Rating (n = 56)	Content Removed (n = 5)	Proposed Framework (n = 47)
<p>Background questions or judgments (e.g., availability of data, mandate of the decision-maker)</p> <p>Redundant considerations (e.g., multiple criteria for judging the toxicity of an exposure)</p> <p>Implementation considerations (e.g., quality of communication plan)</p> <p>Material that was rated as unhelpful for decision-making because the phrasing was uninterpretable</p>	<p>Re-worded criteria and detailed judgments from the GRADE EtD for health system and public health decisions</p> <p>Certainty of cost-effectiveness</p> <p>Social justice considerations (e.g., issues of intergenerational equity)</p> <p>Acceptability and feasibility considerations related to laws and regulations (e.g., current laws and regulations applying to worker safety)</p>	<p>Community engagement in advocacy or organizing as an indicator of priority, as this factor may or may not be present regardless of priority</p> <p>Risk tolerance as a separate consideration from other values</p> <p>Laws and regulations as a consideration to inform judgments about the acceptability of an intervention</p> <p>Perception of feasibility as a consideration to inform judgments about feasibility</p>	<p>Problem: addition of irreversibility and precedent as considerations</p> <p>Desirable / Undesirable Effects: addition of time span to full effectiveness</p> <p>Resources Required / Certainty of Resources: simplified detailed judgments</p> <p>Cost Effectiveness: consolidated detailed judgments to certainty in analyses</p> <p>Equity: broadening considerations to include social and environmental justice in addition to health equity</p> <p>Acceptability: addition of certainty in estimates of acceptability</p> <p>Feasibility: addition of time span for sustainability and</p>

			tailoring of types of barriers/enablers to implementation
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Supplement to “Development of a framework to structure decision-making in environmental and occupational health: a systematic review and Delphi study”

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Supplement A. Database search strategy

Search date: September 26, 2021

Literature search performed by: Emily Senerth

Search Strategy:

Database: Ovid MEDLINE(R) ALL / PubMed(R) <1946 to Present>

1	exp *Occupational Health/	25331
2	exp *Occupational Exposure/	43236
3	exp *Occupational Diseases/	114368
4	exp *Occupational Medicine/	17832
5	exp *Environment/ and Public Health/	4901
6	exp *Environment, Controlled/	79973
7	exp *Environmental Exposure/	187600
8	exp *Environmental Health/	17029
9	exp *Environmental Pollutants/	261689
10	exp *Environmental Monitoring/	75753
11	1-10	627972
12	exp *Social Control, Formal/	427891
13	exp *Decision Making/	100339
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- 17 (decision* adj2 (determinant* or model* or analysis* or technique* or framework* or tool* or template*)).ti. 5573
- 18 (decisionmaking or decision-making).ti. 29672
- 19 (evidence-to-decision or evidence to decision).ti,ab. 2490
- 20 ((grade or grading) adj2 (evidence or recommendation*)).ti,ab. 8646
- 21 (strength of evidence or quality of evidence or strength of recommendation*).ti,ab. 22475
- 22 exp Review Literature as Topic/ 17771
- 23 exp *Policy Making/ 9685
- 24 12-23 628168
- 25 11 and 24 10304
- 26 limit 25 to english language 8805
- 27 limit 26 to yr="2011 - 2021" 3674

Database: SCOPUS Embase <1996 to Present>

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) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011)) AND (LIMIT-TO (LANGUAGE , "English"))

Database: Cochrane Library

[mh "Occupational Health"]

[mh "Occupational Exposure"]

[mh "Occupational Diseases"]

[mh "Occupational Medicine"]

[mh "Environment and Public Health"]

[mh "Environment, Controlled"]

[mh "Environmental Exposure"]

[mh "Environmental Health"]

[mh "Environmental Pollutants"]

[mh "Environmental Monitoring"]

[mh "Social Control, Formal"]

[mh "Decision Making"]

[mh "Decision Support Techniques"]

[mh "evidence based medicine"]

(evidence-based:ti,ab NEAR/2 (analys*:ti,ab OR assess*:ti,ab))

(decision*:ti NEAR/2 (determinant*:ti OR model*:ti OR analysis*:ti OR technique*:ti OR framework*:ti OR tool*:ti OR template*:ti))

(decisionmaking:ti OR decision-making:ti)

(evidence-to-decision:ti,ab OR "evidence to decision":ti,ab)

((grade:ti,ab OR grading:ti,ab) NEAR/2 (evidence:ti,ab OR recommendation*:ti,ab))

("strength of evidence":ti,ab OR "quality of evidence":ti,ab OR ("strength of recommendation"):ti,ab)

[mh "Review Literature as Topic"]

[mh "Policy Making"]

Supplement B. Grey literature search strategy

Date	Organization name & URL	Search strategy(s) / words searched	# of documents retrieved <i>All results retrieved in the search were reviewed for relevance by 1 reviewer</i>	# of documents included for extraction
1/3/22	Canadian Standards Association (CSA) https://www.csagroup.org/about-csa-group/	Searched decision [and] framework/model/tool/analysis, decision-making, recommendation(s), guideline(s), methodology	0 items screened	0
1/3/22	Chartered Institute of Environmental Health (CIEH) https://www.cieh.org	Searched decision [and] framework/model/tool/analysis, decision-making, recommendation(s), guideline(s), methodology	1 item screened	0
1/3/22	International Network of Agencies for Health Technology Assessment (INAHTA) https://www.inahta.org	Searched decision [and] framework/model/tool/analysis, decision-making, recommendation(s), guideline(s), methodology	3 items screened	1
1/3/22	Guidelines International Network https://g-i-n.net	Reviewed “resources” tab	0 items screened	0
1/3/22	International Federation of Environmental Health (IFEH) https://www.ifeh.org/index.html	Searched decision [and] framework/model/tool/analysis, decision-making, recommendation(s), guideline(s), methodology	5 items screened	0
1/3/22	Air & Waste Management Association (AWMA) https://www.awma.org	Searched decision [and] framework/model/tool/analysis, decision-making, recommendation(s), guideline(s), methodology	0 items screened	0
1/3/22	American Water Works Association https://www.awwa.org	Reviewed “publications” tab	0 items screened	0
1/3/22	Children’s Environmental Health Network (CEHN) https://cehn.org	Searched decision framework, guidelines	0 items screened	0
1/3/22	Environmental and Occupational Health Sciences Institute (EOHSI) https://eohsi.rutgers.edu	Searched decision [and] framework/model/tool/analysis, decision-	1 item screened	0

		making, recommendation(s), guideline(s), methodology		
1/3/22	Health Effects Institute (HEI) https://www.healtheffects.org	Searched decision [and] framework/tool, decision-making, guideline(s), methodology	1 item screened	0
1/3/22	US Climate and Health Alliance https://usclimateandhealthalliance.org	Searched decision [and] framework/tool, decision-making, guideline(s), methodology	2 items screened	0
1/3/22	Public Health Agency of Canada https://www.canada.ca/en/public-health.html	Reviewed mandate – unable to restrict search to public health agency website	0 items screened	0
1/3/22	Health Canada https://www.canada.ca/en/health-canada.html	Reviewed publications - guidelines	3 items screened	0
1/3/22	Environment Canada https://www.canada.ca/en/environment-climate-change.html	Reviewed publications	1 item screened	0
1/3/22	World Health Organization (WHO) https://www.who.int/publications/who-guidelines	Reviewed guidelines page; searched for guideline [and] methods/methodology	9 items screened	2
1/3/22	Canadian Agency for Drugs and Technologies in Health (CADTH) https://www.cadth.ca/about-cadth	Searched decision [and] framework/tool/criteria, decision-making, manual, methodology	59 items screened	1
1/3/22	Health Quality Ontario https://www.hqontario.ca	Reviewed “evidence to improve care” page	5 items screened	1
1/3/22	National Institute for Health and Care Excellence (NICE) https://www.nice.org.uk/about	Reviewed guidance – guidelines – guideline development process	1 item screened	0
1/3/22	British Columbia Ministry of Health https://www2.gov.bc.ca/gov/content/home	Reviewed guidelines – GPAC handbook	1 item screened	0
1/3/22	Scottish Intercollegiate Guidelines Network (SIGN) https://www.sign.ac.uk	Reviewed “what we do” - methodology	3 items screened	1
1/3/22	European Food Safety Authority (EFSA) https://www.efsa.europa.eu/en	Reviewed about – “how we work” and resources - methodology	7 items screened	0

1/4/22	ECRI https://www.ecri.org	Searched library for decision [and] framework/tool, decision-making, methodology	25 items screened	0
1/4/22	Centers for Disease Control and Prevention (CDC) https://www.cdc.gov/about/	Searched decision [and] framework/tool, decision-making, methodology	120 items screened	2
1/4/22	National Institute for Occupational Safety and Health (NIOSH) https://www.cdc.gov/NIOSH/	Searched decision [and] framework/tool, decision-making, methodology	40 items screened	2
1/4/22	Occupational Safety and Health Administration (OSHA) https://www.osha.gov	Searched decision [and] framework/tool, methodology	19 items screened	0
1/4/22	Environmental Protection Agency (EPA) https://www.epa.gov	Searched decision [and] framework/tool, decision-making [and] methodology	90 items screened	2
1/5/22	Science.gov https://www.science.gov	Searched decision framework and restricted results to topics "EPA" [or] "decision-making" from 2011 to 2022	134 items screened	1
1/5/22	Agency for Healthcare Research and Quality https://www.ahrq.gov	Searched decision [and] framework	24 items screened	1
1/6/22	NIH National Institute of Environmental Health Sciences https://www.niehs.nih.gov	Searched decision [and] framework/tool, decision-making	41 items screened	1
1/6/22	National Academies of Sciences, Engineering, Medicine https://www.nationalacademies.org	Searched decision [and] framework/tool	105 items screened	1
1/6/22	US Preventive Services Taskforce https://www.uspreventiveservices taskforce.org/uspstf/	Searched decision [and] framework	27 items screened	0
1/6/22	Federal Register https://www.federalregister.gov	Searched decision [and] framework, and restricted results to topics "environment" [or] "health & public welfare"	108 items screened	0
TOTAL			835 items screened	16 items moved to extraction

Supplement C. Abstraction instrument

1. Reviewer's initials *
2. Last name of primary author *
3. Publication year *
4. Journal title *
5. Document is in English *

Mark only one oval.

Yes No

Study characteristics

6. Study presents a decision-making framework *

Mark only one oval.

Yes No

7. Framework is used to formulate environmental or occupational health (EOH) threshold or acceptable exposure level *

Mark only one oval.

Yes No

8. Framework is used to come to an agreement on whether or not to recommend a public health/EOH intervention *

Mark only one oval.

Yes No

9. Framework is used for prioritization of public health/EOH interventions or hazards *

Mark only one oval.

Yes No

10. Framework is used to inform public health/EOH policy *

Mark only one oval.

Yes No

Study design

11. Study design *

Mark only one oval.

Case study

Systematic review of decision-making frameworks

Editorial/Commentary

Other:

The Framework (General Overview)

12. Title of the framework * (Or "no title")

13. Primary developer of the framework *

14. Primary user of the framework *

15. Please list all topics (e.g., air quality, noise, etc.) that the framework is being applied to *

16. Country in which the framework is being applied (List all). *

17. Country in which framework was developed (List all) *

18. Audience that the framework is intending to inform *

Check all that apply.

Polymakers

Stakeholders

Researchers

General population

Other:

The Framework (Specific Components)

19. How many domains does the framework have?

20. What is the name of the first domain

21. List all questions within the first domain

22. Framework has an additional domain

Mark only one oval.

Yes No

Second Domain

23. What is the name of the next domain

24. List all questions within the second domain

25. Framework has an additional domain

Mark only one oval.

Yes No

Third Domain

- 26. What is the name of the next domain
- 27. List all questions within the third domain
- 28. Framework has an additional domain

Mark only one oval.

Yes No

Fourth Domain

- 29. What is the name of the next domain
- 30. List all questions within the fourth domain
- 31. Framework has an additional domain

Mark only one oval.

Yes No

Fifth Domain

- 32. What is the name of the next domain
- 33. List all questions within the fifth domain
- 34. Framework has an additional domain

Mark only one oval.

Yes No

Sixth Domain

35. What is the name of the next domain

36. List all questions within the sixth domain

37. Framework has an additional domain

Mark only one oval.

Yes No

Seventh Domain

38. What is the name of the next domain

39. List all questions within the seventh domain

40. Framework has an additional domain

Mark only one oval.

Yes No

Remaining Domains

41. List all remaining domains and questions

Decision Criteria

42. Were criteria used to determine the overall decision about a recommendation, threshold, or policy?

Mark only one oval.

Yes No

43. Describe the criteria used to determine the overall decision.

Copy and paste from text

44. How were the criteria used to inform the overall decision?

Mark only one oval.

Weights

Judgment

Other:

Quality of the Framework

45. Does the framework advance research on the topic?

If yes, copy and paste from text. If not, answer "No" or "Not discussed"

46. Does the framework advance research on decision-making frameworks?

If yes, copy and paste from text. If not, answer "No" or "Not discussed"

47. Is there research supporting the overall decision of the framework?

If yes, copy and paste from text. If not, answer "No" or "Not discussed"

48. How will the overall decision be considered at the policy level?

If yes, copy and paste from text. If not, answer "No" or "Not discussed"

49. What is the weight that this decision/the research evidence carry at the national level?

If yes, copy and paste from text. If not, answer "No" or "Not discussed"

Context of the Framework

50. Does the framework take into consideration whether or not the issue is polarizing?

If yes, copy and paste from text. If not, answer "No" or "Not discussed"

51. Does the framework account for the fact that care options may vary in their salience to the patients and the public?

If yes, copy and paste from text. If not, answer "No" or "Not discussed"

52. Does the framework speak to whether the political systems are more or less amenable to the issue?

If yes, copy and paste from text. If not, answer "No" or "Not discussed"

Other Considerations

53. Funding sources disclosed in the study

54. Study limitations

55. Review references from the study. Are any relevant to this study and should be pulled for further review

Supplement D. Studies excluded at full text

Study	Title	Exclusion Reason
Anonymous 2021	Clinical Guidance to Optimize Work Participation After Injury or Illness: Using the Evidence to Guide Physical Therapist Practice.	No public health/EOH decision-framework
Tamers 2020	Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health.	No public health/EOH decision-framework
He 2021	A Risk and Decision Analysis Framework to Evaluate Future PM2.5 Risk: A Case Study in Los Angeles-Long Beach Metro Area.	No public health/EOH decision-framework
Tam 2020	Preparing for uncertainty during public health emergencies: What Canadian health leaders can do now to optimize future emergency response.	No public health/EOH decision-framework
Wolffe 2020	A Survey of Systematic Evidence Mapping Practice and the Case for Knowledge Graphs in Environmental Health and Toxicology.	No public health/EOH decision-framework
Declet-Barreto 2020	Hazardous air pollutant emissions implications under 2018 guidance on U.S. Clean Air Act requirements for major sources.	No public health/EOH decision-framework
Kassotis 2020	Endocrine-disrupting chemicals: economic, regulatory, and policy implications.	No public health/EOH decision-framework
Chughtai 2020	Policies on the use of respiratory protection for hospital health workers to protect from coronavirus disease (COVID-19).	No public health/EOH decision-framework
Thomas 2020	Ethical Pandemic Control Through the Public Health Code of Ethics.	No public health/EOH decision-

		framework
Watterson 2020	Lagging and Flagging: Air Pollution, Shale Gas Exploration and the Interaction of Policy, Science, Ethics and Environmental Justice in England.	No public health/EOH decision-framework
Makov 2020	Inconsistent allocations of harms versus benefits may exacerbate environmental inequality.	No public health/EOH decision-framework
Ozdemir 2020	Decision-making for the selection of different leachate treatment/management methods: the ANP and PROMETHEE approaches.	No public health/EOH decision-framework
Stokstad 2020	EPA expands controversial 'transparency' plan.	Full text unavailable
Rahimdel 2020	Prioritization of practical solutions for the vibrational health risk reduction of mining trucks using fuzzy decision making.	No public health/EOH decision-framework
Morgan 2019	A risk of bias instrument for non-randomized studies of exposures: A users' guide to its application in the context of GRADE.	Evidence appraisal framework
Gomez 2019	Literature Review of Policy Implications From Findings of the Center for Work, Health, and Well-being.	No public health/EOH decision-framework
Chang 2019	Policy changes for preventing and recognizing overwork-related cardiovascular diseases in Taiwan: An overview.	No public health/EOH decision-framework
Pieper 2019	Understanding lead in water and avoidance strategies: a United States perspective for informed decision-making.	No public health/EOH decision-framework
Ginsberg 2019	New Toxicology Tools and the Emerging Paradigm Shift in Environmental Health Decision-Making.	No public health/EOH decision-framework
Fojcikova 2019	ESTE-DECISION SUPPORT SYSTEM FOR NUCLEAR AND	No public health/EOH decision-

	RADIOLOGICAL ACCIDENTS.	framework
Caquilpan 2019	Advantages and challenges of the implementation of a low-cost particulate matter monitoring system as a decision-making tool.	No public health/EOH decision-framework
Nelms 2019	Evaluating potential refinements to existing Threshold of Toxicological Concern (TTC) values for environmentally-relevant compounds.	No public health/EOH decision-framework
Mederake 2019	Shaping EU Plastic Policies: The Role of Public Health vs. Environmental Arguments.	No public health/EOH decision-framework
Reis 2019	Decision-making under uncertainty in environmental health policy: new approaches.	No public health/EOH decision-framework
Allen 2019	Collaborative Workshops for Community Meaning-Making and Data Analyses: How Focus Groups Strengthen Data by Enhancing Understanding and Promoting Use.	No public health/EOH decision-framework
Schenk 2019	Industry Derived Occupational Exposure Limits: A Survey of Professionals on the Dutch System of Exposure Guidelines.	Hazard/risk identification framework
J 2019	A nuanced approach to the Environmental Noise Guidelines for the European Region related to traffic noise.	No public health/EOH decision-framework
Kiran 2019	The development of a globally acceptable national model for occupational hygiene in Turkey: a modified Delphi study.	No public health/EOH decision-framework
Iavicoli 2019	New avenues for prevention of occupational cancer: a global policy perspective.	No public health/EOH decision-framework
Pruvot 2019	Toward a quantification of risks at the nexus of conservation and health: The case of bushmeat markets in Lao PDR.	Hazard/risk identification framework

Genereux 2019	From Science to Policy and Practice: A Critical Assessment of Knowledge Management before, during, and after Environmental Public Health Disasters.	No public health/EOH decision-framework
Teyssere 2019	Identification and Prioritization of Environmental Reproductive Hazards: A First Step in Establishing Environmental Perinatal Care.	No public health/EOH decision-framework
Driver 2019	Utilization of the Maryland Environmental Justice Screening Tool: A Bladensburg, Maryland Case Study.	No public health/EOH decision-framework
Andersen 2019	Systematic literature review on the effects of occupational safety and health (OSH) interventions at the workplace.	Evidence appraisal framework
Mac 2019	Examining Agricultural Workplace Micro and Macroclimate Data Using Decision Tree Analysis to Determine Heat Illness Risk.	Hazard/risk identification framework
Ahlers 2019	Environmental hazard and risk assessment of thiochemicals. Application of integrated testing and intelligent assessment strategies (ITS) to fulfil the REACH requirements for aquatic toxicity.	Hazard/risk identification framework
Mohring 2019	Quantity based indicators fail to identify extreme pesticide risks.	Hazard/risk identification framework
Brown 2018	Evolution of the United States Energy System and Related Emissions under Varying Social and Technological Development Paradigms: Plausible Scenarios for Use in Robust Decision Making.	Hazard/risk identification framework
Greer 2018	Labour politics as public health: how the politics of industrial relations and workplace regulation affect health.	No public health/EOH decision-framework
Clark 2018	WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Quality of Life, Wellbeing and Mental Health.	No public health/EOH decision-framework

Msibi 2018	Using e-Delphi to formulate and appraise the guidelines for women's health concerns at a coal mine: A case study.	No public health/EOH decision-framework
McCarty 2018	The regulatory challenge of chemicals in the environment: Toxicity testing, risk assessment, and decision-making models.	No public health/EOH decision-framework
Colombo 2018	Decision-making in humanitarian crises: politics, and not only evidence, is the problem.	No public health/EOH decision-framework
Zhao 2018	A Novel Environmental Justice Indicator for Managing Local Air Pollution.	No public health/EOH decision-framework
Acir 2018	Endocrine-disrupting metabolites of alkylphenol ethoxylates - A critical review of analytical methods, environmental occurrences, toxicity, and regulation.	No public health/EOH decision-framework
Jiang 2018	Formal and informal environmental sensing data and integration potential: Perceptions of citizens and experts.	No public health/EOH decision-framework
Culin 2018	Brominated flame retardants: Recommendation for different listing under the Hong Kong Convention.	No public health/EOH decision-framework
Chen 2018	Decision-Making and Environmental Implications under Cap-and-Trade and Take-Back Regulations.	No public health/EOH decision-framework
Chari 2018	Expanding the Paradigm of Occupational Safety and Health: A New Framework for Worker Well-Being.	No public health/EOH decision-framework
Currie 2018	The application of system dynamics modelling to environmental health decision-making and policy - a scoping review.	No public health/EOH decision-framework
Wang 2018	What are the new challenges, goals, and tasks of occupational health in China's Thirteenth Five-Year Plan (13th FYP) period?.	No public health/EOH decision-framework

Chen 2018	Processing Technology Selection for Municipal Sewage Treatment Based on a Multi-Objective Decision Model under Uncertainty.	No public health/EOH decision-framework
Yu 2018	Investigation of a Brownfield Conflict Considering the Strength of Preferences.	No public health/EOH decision-framework
Kurth 2018	Decision making for independent municipal action.	No public health/EOH decision-framework
Morodi 2018	Environmental Decision Making on Acid Mine Drainage Issues in South Africa: An Argument for the Precautionary Principle.	No public health/EOH decision-framework
Horne 2018	Informing Environmental Water Management Decisions: Using Conditional Probability Networks to Address the Information Needs of Planning and Implementation Cycles.	No public health/EOH decision-framework
Stahl 2018	Applying theories to better understand socio-political challenges in implementing evidence-based work disability prevention strategies.	No public health/EOH decision-framework
Guski 2017	WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Annoyance.	No public health/EOH decision-framework
Post 2017	Key scientific issues in developing drinking water guidelines for perfluoroalkyl acids: Contaminants of emerging concern.	No public health/EOH decision-framework
Krimsky 2017	The unsteady state and inertia of chemical regulation under the US Toxic Substances Control Act.	No public health/EOH decision-framework
Gross 2017	Regulating toxic chemicals for public and environmental health.	No public health/EOH decision-framework
Koh 2017	Combining Lead Exposure Measurements and Experts' Judgment Through a Bayesian Framework.	No public health/EOH decision-framework

Howard 2017	Using systematic review in occupational safety and health.	Evidence appraisal framework
Zartarian 2017	Children's Lead Exposure: A Multimedia Modeling Analysis to Guide Public Health Decision-Making.	Hazard/risk identification framework
Samuels 2017	Pathways to Housing Policy: Translating Research to Policy to Achieve Impact on Well Being.	No public health/EOH decision-framework
Nielsen 2017	Evaluation of airborne sensory irritants for setting exposure limits or guidelines: A systematic approach.	Hazard/risk identification framework
Neira 2017	Environmental health policies for women's, children's and adolescents' health.	No public health/EOH decision-framework
Shaffer 2017	Developing the Regulatory Utility of the Exposome: Mapping Exposures for Risk Assessment through Lifestage Exposome Snapshots (LEnS).	No public health/EOH decision-framework
Gasparini 2017	Public Policy and the Next Generation of Farmers, Ranchers, Producers, and Agribusiness Leaders.	No public health/EOH decision-framework
Zolfagharipoor 2017	Effluent trading in river systems through stochastic decision-making process: a case study.	No public health/EOH decision-framework
Moretti 2017	Environmental, Human Health and Socio-Economic Effects of Cement Powders: The Multicriteria Analysis as Decisional Methodology.	No public health/EOH decision-framework
Malachowski 2017	The Sociopolitical Context of Canada's National Standard for Psychological Health and Safety in the Workplace: Navigating Policy Implementation.	No public health/EOH decision-framework
Gwinn 2017	Chemical Risk Assessment: Traditional vs Public Health Perspectives.	Hazard/risk identification framework

Agerstrand 2017	An academic researcher's guide to increased impact on regulatory assessment of chemicals.	No public health/EOH decision-framework
Booth 2017	Modeling aesthetics to support an ecosystem services approach for natural resource management decision making.	No public health/EOH decision-framework
Moridi 2017	Selection of optimized air pollutant filtration technologies for petrochemical industries through multiple-attribute decision-making.	No public health/EOH decision-framework
Ford 2017	A Critique of Risk Disclosure as the Solution for Minimizing Toxic Exposures in Pregnancy.	No public health/EOH decision-framework
Hall 2017	New approach to weight-of-evidence assessment of ecotoxicological effects in regulatory decision-making.	Hazard/risk identification framework
Gao 2017	Indicators' role: How do they influence Strategic Environmental Assessment and Sustainable Planning - The Chinese experience.	No public health/EOH decision-framework
Dellarco 2017	Using exposure bands for rapid decision making in the RISK21 tiered exposure assessment.	Hazard/risk identification framework
Tan 2017	Selecting Cooking Methods to Decrease Persistent Organic Pollutant Concentrations in Food of Animal Origin Using a Consensus Decision-Making Model.	No public health/EOH decision-framework
Yamauchi 2017	Overwork-related disorders in Japan: recent trends and development of a national policy to promote preventive measures.	No public health/EOH decision-framework
Lis 2017	How to Choose? Using the Delphi Method to Develop Consensus Triggers and Indicators for Disaster Response.	No public health/EOH decision-framework
Sweeney 2017	The Role of Healthcare Professionals in Environmental Health and Fertility Decision-Making.	No public health/EOH decision-framework

Holman 2017	Part I--Comparing Noncancer Chronic Human Health Reference Values: An Analysis of Science Policy Choices.	Hazard/risk identification framework
Holman 2017	Part II: Quantitative Evaluation of Choices Used in Setting Noncancer Chronic Human Health Reference Values Across Organizations.	No public health/EOH decision-framework
Bevan 2017	Setting evidence-based occupational exposure limits for manganese.	Hazard/risk identification framework
Xie 2017	Evaluating the Impact of the U.S. National Toxicology Program: A Case Study on Hexavalent Chromium.	No public health/EOH decision-framework
Moore 2017	Application of ecosystem services in natural resource management decision making.	No public health/EOH decision-framework
Samantra 2017	A risk-based decision support framework for selection of appropriate safety measure system for underground coal mines.	No public health/EOH decision-framework
Zolfagharipoor 2016	A decision-making framework for river water quality management under uncertainty: Application of social choice rules.	No public health/EOH decision-framework
Soderberg 2016	Complex governance structures and incoherent policies: Implementing the EU water framework directive in Sweden.	No public health/EOH decision-framework
Pirkle 2016	Managing mercury exposure in northern Canadian communities.	No public health/EOH decision-framework
Vandenberg 2016	A proposed framework for the systematic review and integrated assessment (SYRINA) of endocrine disrupting chemicals.	No public health/EOH decision-framework
Leech 2016	Inequitable Chronic Lead Exposure: A Dual Legacy of Social and Environmental Injustice.	No public health/EOH decision-framework

Kienzler 2016	Regulatory assessment of chemical mixtures: Requirements, current approaches and future perspectives.	No public health/EOH decision-framework
Trasande 2016	Burden of disease and costs of exposure to endocrine disrupting chemicals in the European Union: an updated analysis.	No public health/EOH decision-framework
Hristozov 2016	Demonstration of a modelling-based multi-criteria decision analysis procedure for prioritisation of occupational risks from manufactured nanomaterials.	No public health/EOH decision-framework
Reinikainen 2016	Promoting justified risk-based decisions in contaminated land management.	No public health/EOH decision-framework
Money 2016	Wishful Thinking? Inside the Black Box of Exposure Assessment.	No public health/EOH decision-framework
Teeguarden 2016	Completing the Link between Exposure Science and Toxicology for Improved Environmental Health Decision Making: The Aggregate Exposure Pathway Framework.	Hazard/risk identification framework
MacEachen 2016	Systematic review of qualitative literature on occupational health and safety legislation and regulatory enforcement planning and implementation.	No public health/EOH decision-framework
Syberg 2016	Environmental risk assessment of chemicals and nanomaterials--The best foundation for regulatory decision-making?.	Hazard/risk identification framework
Litow 2015	Occupational Interstitial Lung Diseases.	No public health/EOH decision-framework
Jolly 2015	Work-Related Asthma.	No public health/EOH decision-framework
Kelsall 2015	Don't ask, don't tell: Canadian policies on radon.	No public health/EOH decision-

		framework
Kaminsky 2015	Cultured construction: global evidence of the impact of national values on sanitation infrastructure choice.	No public health/EOH decision-framework
Garriga 2015	Improved monitoring framework for local planning in the water, sanitation and hygiene sector: From data to decision-making.	No public health/EOH decision-framework
Trasande 2015	Estimating burden and disease costs of exposure to endocrine-disrupting chemicals in the European union.	Economic/cost-benefit framework
Lu 2015	Optimization-based multicriteria decision analysis for identification of desired petroleum-contaminated groundwater remediation strategies.	No public health/EOH decision-framework
Linkov 2015	From "weight of evidence" to quantitative data integration using multicriteria decision analysis and Bayesian methods.	No public health/EOH decision-framework
Yasui 2015	250 mSv: temporary increase in the emergency exposure dose limit in response to the TEPCO Fukushima Daiichi NPP accident and its decision making process.	No public health/EOH decision-framework
Mahapatra 2014	The need for evidence-based public health response in disasters.	No public health/EOH decision-framework
Korfmacher 2014	Health impact assessment of urban waterway decisions.	No public health/EOH decision-framework
Bogen 2014	Unveiling variability and uncertainty for better science and decisions on cancer risks from environmental chemicals.	No public health/EOH decision-framework
Fenech 2014	Development of a decision-support tool for identifying the most suitable approach to achieve nitrate source determination.	No public health/EOH decision-framework

Banerjee 2014	Bayesian hierarchical framework for occupational hygiene decision making.	No public health/EOH decision-framework
Delpla 2014	A decision support system for drinking water production integrating health risks assessment.	Hazard/risk identification framework
Marinucci 2014	Building Resilience Against Climate Effects-a novel framework to facilitate climate readiness in public health agencies.	No public health/EOH decision-framework
London 2014	Ethics in occupational health: deliberations of an international workgroup addressing challenges in an African context.	No public health/EOH decision-framework
Bates 2014	The value of information for managing contaminated sediments.	No public health/EOH decision-framework
Sharma 2014	The legal framework to manage chemical pollution in India and the lesson from the Persistent Organic Pollutants (POPs).	No public health/EOH decision-framework
Rooney 2014	Systematic review and evidence integration for literature-based environmental health science assessments.	Evidence appraisal framework
Maier 2014	Derivation of an occupational exposure limit for inorganic borates using a weight of evidence approach.	No public health/EOH decision-framework
Morfeld 2014	Threshold value estimation for respirable quartz dust exposure and silicosis incidence among workers in the German porcelain industry.	No public health/EOH decision-framework
Messinger 2014	An approach for the delineation of a generic cut-off value for local respiratory tract irritation by irritating or corrosive substances as a pragmatic tool to fulfill REACH requirements.	Hazard/risk identification framework
Giubilato 2014	A risk-based methodology for ranking environmental chemical stressors at the regional scale.	No public health/EOH decision-framework

Scholten 2014	Strategic rehabilitation planning of piped water networks using multi-criteria decision analysis.	No public health/EOH decision-framework
Garcia-Alonso 2014	Protection goals in environmental risk assessment: a practical approach.	No public health/EOH decision-framework
Devos 2014	Towards a more open debate about values in decision-making on agricultural biotechnology.	No public health/EOH decision-framework
Chughtai 2013	Availability, consistency and evidence-base of policies and guidelines on the use of mask and respirator to protect hospital health care workers: a global analysis.	No public health/EOH decision-framework
Yuen 2013	Using health impact assessment to integrate environmental justice into federal environmental regulatory analysis.	No public health/EOH decision-framework
Pennell 2013	Bridging research and environmental regulatory processes: the role of knowledge brokers.	No public health/EOH decision-framework
Lieberman 2013	Structural approaches to health promotion: what do we need to know about policy and environmental change?.	No public health/EOH decision-framework
Akhtar 2013	GLIMPSE: a rapid decision framework for energy and environmental policy.	No public health/EOH decision-framework
Hegmann 2013	ACOEM practice guidelines: elbow disorders.	No public health/EOH decision-framework
Duhamel 2013	Creating a fall protection plan and a safer workplace.	No public health/EOH decision-framework
Taxell 2013	Methodology for national risk analysis and prioritization of toxic industrial chemicals.	Hazard/risk identification framework

Comber 2013	Development of a chemical source apportionment decision support framework for catchment management.	No public health/EOH decision-framework
Sutton 2013	Risk communication and decision tools for children's health protection.	No public health/EOH decision-framework
Liebman 2013	Occupational health policy and immigrant workers in the agriculture, forestry, and fishing sector.	No public health/EOH decision-framework
Macnaughton 2013	Bringing politics and evidence together: policy entrepreneurship and the conception of the At Home/Chez Soi Housing First Initiative for addressing homelessness and mental illness in Canada.	No public health/EOH decision-framework
Abdelzaher 2013	An alternative approach to water regulations for public health protection at bathing beaches.	No public health/EOH decision-framework
Brauer 2013	Just sustainability? Sustainability and social justice in professional codes of ethics for engineers.	No public health/EOH decision-framework
Morrice 2013	Coal mining, social injustice and health: a universal conflict of power and priorities.	No public health/EOH decision-framework
Wang 2013	Necessity and approach to integrated nanomaterial legislation and governance.	No public health/EOH decision-framework
Weinhold 2012	EPA proposes tighter particulate air pollution standards.	Hazard/risk identification framework
Bures 2012	A proposal for a computer-based framework of support for public health in the management of biological incidents: the Czech Republic experience.	No public health/EOH decision-framework
Carter 2012	Environmental planning and management in an age of uncertainty: the case of the Water Framework Directive.	No public health/EOH decision-framework

Henderson 2012	A data-driven approach to setting trigger temperatures for heat health emergencies.	No public health/EOH decision-framework
Gangwal 2012	Incorporating exposure information into the toxicological prioritization index decision support framework.	Hazard/risk identification framework
Alves 2012	U.S. EPA authority to use cumulative risk assessments in environmental decision-making.	No public health/EOH decision-framework
Milillo 2012	Use of geostatistics for remediation planning to transcend urban political boundaries.	No public health/EOH decision-framework
Zimmer 2012	Policy relevant results from an expert elicitation on the health risks of phthalates.	No public health/EOH decision-framework
Bartonova 2012	How can scientists bring research to use: the HENVINET experience.	No public health/EOH decision-framework
Liu 2012	Facilitating knowledge transfer: decision support tools in environment and health.	No public health/EOH decision-framework
Huang 2012	Cumulative environmental vulnerability and environmental justice in California's San Joaquin Valley.	Hazard/risk identification framework
Jennings 2012	Worldwide regulatory guidance values for surface soil exposure to carcinogenic or mutagenic polycyclic aromatic hydrocarbons.	No public health/EOH decision-framework
Blumensaat 2012	Water quality-based assessment of urban drainage impacts in Europe - where do we stand today?.	No public health/EOH decision-framework
Chen 2012	Optimizing decision making for late-phase recovery one year after the Fukushima nuclear accident.	No public health/EOH decision-framework

FoodandDrugAdministration 2012	International Conference on Harmonisation; final recommendation for the revision of the permitted daily exposure for the solvent cumene according to the maintenance procedures for the guidance Q3C Impurities: Residual Solvents; availability. Notice.	No public health/EOH decision-framework
Austin 2012	Policy, practice and decision making for zoonotic disease management: water and Cryptosporidium.	No public health/EOH decision-framework
Mohler 2012	RACER: dynamic use of environmental measurement data for decision making and communication.	No public health/EOH decision-framework
Sparrevik 2012	Use of stochastic multi-criteria decision analysis to support sustainable management of contaminated sediments.	Evidence appraisal framework
Saeed 2012	Environmental impact assessment (EIA): an overlooked instrument for sustainable development in Pakistan.	Hazard/risk identification framework
Carriger 2012	Influence diagrams as decision-making tools for pesticide risk management.	No public health/EOH decision-framework
Ronen 2012	Rationales behind irrationality of decision making in groundwater quality management.	No public health/EOH decision-framework
Ellickson 2011	Cumulative risk assessment and environmental equity in air permitting: interpretation, methods, community participation and implementation of a unique statute.	Hazard/risk identification framework
Hovell 2011	Smokefree community policies promote home smoking bans. Unknown mechanisms and opportunities for preventive medicine.	No public health/EOH decision-framework
Furlong 2011	Governance and sustainability at a municipal scale: the challenge of water conservation.	No public health/EOH decision-framework

Davila 2011	Definition and insertion of the GSPC in the political context of Mexico.	No public health/EOH decision-framework
Nweke 2011	Symposium on integrating the science of environmental justice into decision-making at the Environmental Protection Agency: an overview.	No public health/EOH decision-framework
Dainiak 2011	Literature review and global consensus on management of acute radiation syndrome affecting nonhematopoietic organ systems.	No public health/EOH decision-framework
Dainiak 2011	First global consensus for evidence-based management of the hematopoietic syndrome resulting from exposure to ionizing radiation.	No public health/EOH decision-framework
Loring 2011	Managing environmental risks: the benefits of a place-based approach.	No public health/EOH decision-framework
Brown 2011	Science versus policy in establishing equitable Agent Orange disability compensation policy.	No public health/EOH decision-framework
Hodge 2011	Building evidence for legal decision making in real time: legal triage in public health emergencies.	No public health/EOH decision-framework
Ding 2011	Occupational exposure limits in Europe and Asia--continued divergence or global harmonization?.	No public health/EOH decision-framework
Collins 2011	Risk-based targeting: identifying disproportionalities in the sources and effects of industrial pollution.	No public health/EOH decision-framework
Couch 2011	Community stress, psychosocial hazards, and EPA decision-making in communities impacted by chronic technological disasters.	No public health/EOH decision-framework
Kreger 2011	Creating an environmental justice framework for policy change in childhood asthma: a grassroots to treetops approach.	No public health/EOH decision-framework

Liu 2011	Guided adaptive optimal decision making approach for uncertainty based watershed scale load reduction.	No public health/EOH decision-framework
Nweke 2011	A framework for integrating environmental justice in regulatory analysis.	No public health/EOH decision-framework
Zabeo 2011	Regional risk assessment for contaminated sites part 1: vulnerability assessment by multicriteria decision analysis.	Hazard/risk identification framework
Gibson 2011	A burden of disease approach to prioritizing environmental policy initiatives: a case study in the Middle East.	No public health/EOH decision-framework
Pizzol 2011	Regional risk assessment for contaminated sites part 2: ranking of potentially contaminated sites.	No public health/EOH decision-framework
WorldHealthOrganization 2011	Evaluation of certain contaminants in food.	No public health/EOH decision-framework
Fann 2011	Maximizing health benefits and minimizing inequality: incorporating local-scale data in the design and evaluation of air quality policies.	No public health/EOH decision-framework
Woodruff 2011	The need for better public health decisions on chemicals released into our environment.	Hazard/risk identification framework
Landrigan 2011	Children's vulnerability to toxic chemicals: a challenge and opportunity to strengthen health and environmental policy.	No public health/EOH decision-framework
Hengpraprom 2011	Developing tools for health impact assessment in environmental impact assessment in Thailand.	Hazard/risk identification framework
vanBroekhuizen 2011	Dealing with uncertainties in the nanotech workplace practice: making the precautionary approach operational.	No public health/EOH decision-framework

Sizirici 2011	Knowledge based ranking algorithm for comparative assessment of post-closure care needs of closed landfills.	No public health/EOH decision-framework
Iavicoli 2011	Occupational health and safety policy and psychosocial risks in Europe: the role of stakeholders' perceptions.	No public health/EOH decision-framework
Simon 2011	Just who is at risk? The ethics of environmental regulation.	No public health/EOH decision-framework
Scheepers 2011	Application of biological monitoring for exposure assessment following chemical incidents: a procedure for decision making.	No public health/EOH decision-framework
Saldavar-Tanaka 2021	Should the precautionary principle be implemented in Europe with regard to nanomaterials? Expert interviews	No public health/EOH decision-framework
Britton 2021	Accelerating sustainable ocean policy: The dynamics of multiple stakeholder priorities and actions for oceans and human health	No public health/EOH decision-framework
Choi 2021	Mainstreaming of health equity in infectious disease control policy during the covid-19 pandemic era	No public health/EOH decision-framework
Lopez-Alonso 2020	Management of occupational risk prevention of nanomaterials manufactured in construction sites in the eu	Hazard/risk identification framework
Ingram 2020	Health Disparities, Transportation Equity and Complete Streets: a Case Study of a Policy Development Process through the Lens of Critical Race Theory	No public health/EOH decision-framework
UmstattdMeyer 2020	Physical activity Space Methodology for Assessment and Prioritization (PASMAP): Combining systematic observations with community perceptions to identify community physical activity resource priorities	No public health/EOH decision-framework

Ho 2020	Comparison of freshwater monitoring approaches: strengths, opportunities, and recommendations	No public health/EOH decision-framework
Schoch-Spana 2020	Vector control in Zika-affected communities: Local views on community engagement and public health ethics during outbreaks	No public health/EOH decision-framework
Cherednichenko 2020	Formal Modeling of Decision-Making Processes Under Transboundary Emergency Conditions	No public health/EOH decision-framework
Atwood 2019	New perspectives for cancer hazard evaluation by the report on carcinogens: A case study using read-across methods in the evaluation of haloacetic acids found as water disinfection by-products	Hazard/risk identification framework
Terracini 2019	Contextualising the policy decision to ban asbestos	No public health/EOH decision-framework
Ceccato 2018	Data and tools to integrate climate and environmental information into public health	No public health/EOH decision-framework
Elwell 2018	Using people's perceptions of ecosystem services to guide modeling and management efforts	No public health/EOH decision-framework
Bennett 2018	Drumming-associated anthrax incidents: Exposures to low levels of indoor environmental contamination	No public health/EOH decision-framework
Xiao 2018	A novel multi-criteria decision making method for assessing health-care waste treatment technologies based on D numbers	No public health/EOH decision-framework
Ganesh 2018	Climate Change, Public Health, and Policy: A California Case Study	No public health/EOH decision-framework
Costa-Souza 2018	A socio-historical approach to policy analysis: The case of the Brazilian workers, " food policy	No public health/EOH decision-framework

Hinchcliff 2017	The enhanced knowledge translation and exchange framework for road safety: A brief report on its development and potential impacts	No public health/EOH decision-framework
Browne 2017	The case for „Äenvironment in all policies,Ä: Lessons from the „Ähealth in all policies,Ä approach in public health	No public health/EOH decision-framework
Stolk 2017	Decision intelligence in public health „Ä Dione	No public health/EOH decision-framework
Hall 2017	Supporting the eu response to environmental emergencies: European multiple environmental threats emergency network	Hazard/risk identification framework
Palmer Fry 2017	Monitoring local well-being in environmental interventions: A consideration of practical trade-offs	No public health/EOH decision-framework
Aliani 2016	Determining an appropriate method for the purpose of land allocation for ecotourism development (case study: Taleghan County, Iran)	No public health/EOH decision-framework
Bell 2016	Bread and roses: A gender perspective on environmental justice and public health	No public health/EOH decision-framework
Friesen 2016	Combining Decision Rules from Classification Tree Models and Expert Assessment to Estimate Occupational Exposure to Diesel Exhaust for a Case-Control Study	Evidence appraisal framework
Shen 2016	Vulnerability assessment of urban ecosystems driven by water resources, human health and atmospheric environment	No public health/EOH decision-framework
Pizzol 2015	Risk-based prioritization methodology for the classification of groundwater pollution sources	No public health/EOH decision-framework
Hoyos 2015	Incorporating environmental attitudes in discrete choice models: An exploration of the utility of the awareness of consequences scale	No public health/EOH decision-framework

Mera 2015	A Public health decision support system model using reasoning methods	No public health/EOH decision-framework
Pottage 2014	Responding to biological incidents - What are the current issues in remediation of the contaminated environment?	No public health/EOH decision-framework
Bas 2014	A framework for child safety and health management by analogy to occupational safety and health management	No public health/EOH decision-framework
Birnbaum 2012	Consortium-based science: The NIEHS's multipronged, collaborative approach to assessing the health effects of Bisphenol A	No public health/EOH decision-framework
Bartonova 2012	How can scientists bring research to use: The HENVINET experience	No public health/EOH decision-framework
Yabar 2012	Comparative assessment of the co-evolution of environmental indicator systems in Japan and China	No public health/EOH decision-framework
Hopkins 2011	Risk-management and rule-compliance: Decision-making in hazardous industries	No public health/EOH decision-framework
Gordon 2011	Structuring expert input for a knowledge-based approach to watershed condition assessment for the Northwest Forest Plan, USA	No public health/EOH decision-framework

Supplement E. GRADE Evidence to Decision (EtD) framework for health system and public health decisions

Criteria	Main questions	Detailed judgements
<i>Problem</i>	Is the problem a priority?	<ul style="list-style-type: none"> • Are the consequences of the problem serious (i.e. severe or important in terms of the potential benefits or savings)? • Is the problem urgent? [not relevant for coverage decisions] • Is it a recognized priority (e.g. based on a political or policy decision)? [Not relevant when an individual patient perspective is taken]
<i>Desirable effects</i>	How substantial are the desirable anticipated effects?	Judgments for each outcome for which there is a desirable effect
<i>Undesirable effects</i>	How substantial are the undesirable anticipated effects?	Judgments for each outcome for which there is an undesirable effect
<i>Certainty of evidence</i>	What is the overall certainty of the evidence of effects?	See GRADE guidance regarding detailed judgments about the quality of evidence or certainty in estimates of effects
<i>Values</i>	Is there important uncertainty about or variability in how much people value the main outcomes?	<ul style="list-style-type: none"> • Is there important uncertainty about how much people value each of the main outcomes? • Is there important variability in how much people value each of the main outcomes? [not relevant for coverage decisions]

Criteria	Main questions	Detailed judgements
<i>Balance of effects</i>	Does the balance between desirable and undesirable effects favor the intervention or the comparison?	<ul style="list-style-type: none"> • Judgments regarding each of the four preceding criteria • To what extent do the following considerations influence the balance between the desirable and undesirable effects: <ul style="list-style-type: none"> - How much less people value outcomes that are in the future compared to outcomes that occur now (their discount rates) - People's attitudes towards undesirable effects (how risk averse they are) - People's attitudes towards desirable effects (how risk seeking they are)
<i>Resources required</i>	How large are the resource requirements (costs)?	<ul style="list-style-type: none"> • How large is the difference in each item of resource use for which fewer resources are required? • How large is the difference in each item of resource use for which more resources are required?
<i>Certainty of evidence of required resources</i>	What is the certainty of the evidence of resource requirements?	<ul style="list-style-type: none"> • Have all-important items of resource use that may differ between the options being considered been identified? • How certain is the evidence of differences in resource use between the options being considered? (see GRADE guidance regarding detailed judgments about the quality of evidence or certainty in estimates) • How certain is the cost of the items of resource use that differ between the options being considered? • Is there important variability in the cost of the items of resource use that differ between the options being considered?

Criteria	Main questions	Detailed judgements
<i>Cost effectiveness</i>	Does the cost effectiveness of the intervention favor the intervention or the comparison?	<ul style="list-style-type: none"> • Judgments regarding each of the six preceding criteria • Is the cost-effectiveness ratio sensitive to one-way sensitivity analyses? • Is the cost-effectiveness ratio sensitive to multi-variable sensitivity analyses? • Is the economic evaluation on which the cost-effectiveness estimate is based reliable? • Is the economic evaluation on which the cost-effectiveness estimate is based applicable to the setting(s) of interest?
<i>Equity</i>	What would be the impact on health equity?	<ul style="list-style-type: none"> • Are there groups or settings that might be disadvantaged in relation to the problem or options that are considered? • Are there plausible reasons for anticipating differences in the relative effectiveness of the option for disadvantaged groups or settings? • Are there different baseline conditions across groups or settings that affect the absolute effectiveness of the intervention or the importance of the problem for disadvantaged groups or settings? • Are there important considerations that should be made when implementing the intervention in order to ensure that inequities are reduced, if possible, and that they are not increased?
<i>Acceptability</i>	Is the intervention acceptable to key stakeholders?	<ul style="list-style-type: none"> • Are there key stakeholders that would not accept the distribution of the benefits, harms and costs? • Are there key stakeholders that would not accept the costs or undesirable effects in the short term for desirable effects (benefits) in the future? • Are there key stakeholders that would not agree with the values attached to

Criteria	Main questions	Detailed judgements
		<p>the desirable or undesirable effects (because of how they might be affected personally or because of their perceptions of the relative importance of the effects for others)?</p> <ul style="list-style-type: none"> • Would the intervention adversely affect people's autonomy? • Are there key stakeholders that would disapprove of the intervention morally, for reasons other than its effects on people's autonomy (e.g. in relation to ethical principles such as no maleficence, beneficence or justice)?
<i>Feasibility</i>	Is the intervention feasible to implement?	<p>For decisions other than coverage decisions:</p> <ul style="list-style-type: none"> • Is the intervention or option sustainable? • Are there important barriers that are likely to limit the feasibility of implementing the intervention (option) or require consideration when implementing it? <p>For coverage decisions:</p> <ul style="list-style-type: none"> • Is coverage of the intervention sustainable? • Is it feasible to ensure appropriate use for approved indications? • Is inappropriate use (indications that are not approved) an important concern? • Is there capacity to meet increased demand if covered? • Are there important legal or bureaucratic or ethical constraints that make it difficult or impossible to cover the intervention?

Supplement E. Unique EOH decision factors organized by related GRADE EtD assessment criteria

GRADE EtD Criteria	Discovered EOH Decision Considerations
<i>Problem</i>	<ul style="list-style-type: none"> ◇ The decision might lead to irreversible and severe consequences and the values at stake are also irreplaceable ◇ Is the problem urgent? ◇ Does the problem constitute an extraordinary event? ◇ Is it a recognized priority (e.g., based on a political or policy decision)? ◇ Local priorities: extent to which funding for intervention is a city or county priority compared with other rivaling priorities ◇ Decisions by other jurisdictions: what have other jurisdictions (provinces, countries) done with respect to the technology, device, or intervention being considered? ◇ Requires a coordinated international response ◇ Magnitude of need (availability of an effective, comparable alternative) ◇ Origin of/reason for request: Who requested the review? What was their rationale? What is their responsibility/mandate? ◇ Availability of data: extent to which potential health risk factors are monitored ◇ Availability of data: hazard inventory and information on severity of hazards ◇ Availability of data: whether contamination of water and soil is known to be present in the community ◇ Community involvement: extent to which the unserved community has organized and advocated for an intervention ◇ Decisions can be enforced by means of laws or regulations ◇ How regulated is the intervention: are there penalties for failure? ◇ Unique toxicological considerations (i.e., developmental, epigenetic) ◇ Unique exposure considerations (i.e., persistence, bioaccumulation) ◇ Chemical properties: ADME (Absorption, Distribution, Metabolism, and Elimination)
<i>Desirable effects</i>	<ul style="list-style-type: none"> ◇ Time span for the alternative policies and measures to reach their full effectiveness ◇ It is more important to avoid false negatives than false positives ◇ Does early intervention of this exposure improve outcomes compared to later intervention?

GRADE EtD Criteria	Discovered EOH Decision Considerations
	<ul style="list-style-type: none"> ◇ Timing is at least as important as being right ◇ Most proportional response, if compulsion or coercion is needed
<i>Undesirable effects</i>	<ul style="list-style-type: none"> ◇ It is more important to avoid false negatives than false positives ◇ Timing is at least as important as being right
<i>Certainty of evidence</i>	None
<i>Values</i>	<ul style="list-style-type: none"> ◇ Stakeholders: types and distribution of types, identification of new groups of stakeholders ◇ Values that tend to be systematically downplayed by traditional decision methods ◇ Social justice and equality: How is social justice and/or equality addressed? What is the duration of the intervention and are there issues of intergenerational equity? Are the impacts/benefits unreasonably disproportionate to particular groups? Is spirit of 'polluter pays principle' upheld with regard to distribution of impacts/benefits? ◇ Expected societal values: broadly shared values in society that bear on the appropriate use of the intervention ◇ Interactions with different branches and levels of government, as well as the citizens that they represent ◇ Community engagement
<i>Balance of effects</i>	<ul style="list-style-type: none"> ◇ People's attitudes towards desirable effects (how risk seeking they are). ◇ People's attitudes towards undesirable effects (how risk averse they are).
<i>Resources required</i>	None
<i>Certainty of evidence of required resources</i>	None
<i>Cost effectiveness</i>	<ul style="list-style-type: none"> ◇ Cost-effectiveness with a societal perspective and using average costs ◇ Differential cost analysis process, budget impact analysis, cost-effectiveness using hospital perspective (i.e. actual costs for hospital)

GRADE EtD Criteria	Discovered EOH Decision Considerations
	<ul style="list-style-type: none"> ◇ Economic evaluation: a measure of the net cost or efficiency of the intervention compared to other alternatives; the uncertainty of results should be considered ◇ Costs, benefits and impacts of potential actions ◇ Adequacy: appropriateness of cost and outcome measures, comprehensiveness of cost and outcome valuation/aggregation
<i>Equity</i>	<ul style="list-style-type: none"> ◇ The minimal infringement of moral considerations should have priority among other effective policies. ◇ Expected ethical values: the potential ethical issues inherent in using or not using the technology; relevant ethical issues should be listed ◇ Accordance with universal human rights standards. ◇ The probable public health benefits should outweigh the infringed moral considerations. ◇ Examining the health outcomes and legal and ethical considerations
<i>Acceptability</i>	<ul style="list-style-type: none"> ◇ Would the intervention (option) adversely affect people's autonomy? ◇ Are there key stakeholders that would disapprove of the intervention (option) morally, for reasons other than its effects on people's autonomy (i.e., in relationship to ethical principles such as non-maleficence, beneficence or justice)? ◇ Most proportional response, if compulsion or coercion is needed ◇ Accordance with universal human rights standards. ◇ Protect human rights and individual autonomy ◇ Congressional mandate: are congressional views or mandates going to change? ◇ Awareness of health risks: extent to which decision-makers are aware of health risks associated with the exposure ◇ Communication: quality of communication plan ◇ Decisions can be enforced by means of laws or regulations ◇ Examining the health outcomes and legal and ethical considerations
<i>Feasibility</i>	<ul style="list-style-type: none"> ◇ Federal laws and regulations now enable alternative uses for the exposure or intervention ◇ Regulatory framework: Current laws and regulations applying to worker and public health and safety ◇ Congressional mandate: are congressional views or mandates going to change?

